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„A dual-task intervention combined with response-related feedback to reduce anxiety and boost cognition and functional fitness in elderly"

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Declaration

I declare that I (Marion Bittner) have written this thesis independently and have used only the resources indicated. This thesis has been submitted solely as a final thesis related to the European Master in Health and Physical Activity (University of Vienna, University of Rome "Foro Italico") and has not been submitted in any other course or by any other person (e.g., work by other people from the internet).

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Abstract (English)

Nowadays, generalized anxiety disorders appear to be highly prevalent and correlate with dysfunctions in several brain networks such as the prefrontal cortex. This brain area contributes to a variety of executive functions, which are responsible for fundamental skills managing daily life activities. Noteworthy, the executive functions decrease disproportional during aging. Specifically, anxiety absorbs the resources which would be needed for attentional control, limiting the overall cognitive resources and resulting in performance deficits. Hence, few studies have suggested dual-task training as a new approach to stimulate EFs, and further, to improve the activity in the prefrontal cortex and the performance outcome. Considering the psychological perspective, the "response-related feedback" is a proofed mental technique to enhance performance, allowing an external focus and leading to an automatic control process. However, the role of dual-task training and feedback in that setting is yet to research. A healthy and a high anxious older adult participated in the pilot study. Both were compared with a representative control group of younger healthy participants (15). The anxiety level, the cognitive skills, as well as the functional fitness were assessed before and after the intervention, including seven sessions with dual-task training with feedback. Additionally, the ERP data of the brain activity during a discriminative response task was recorded. Further, the prefrontal negativity before the external stimuli were observed and compared between the two timepoints. The results indicate that, dual task training might improve the trait anxiety level (pre 46, post 25) and the cognitive status (pre 18, post 25) of high anxious people. In both participants, the behavioural data and the fitness status improved. Also, the prefrontal negativity and the Bereitschaftspotential were greater after the intervention. The intervention showed to be an effective tool to improve the functional fitness, the anxiety level and the cognitive status of anxious and healthy older people. Further, health relevant issues, such as risk of falling, poor social behaviour, or poor daily life performance might be positively affected by the training.

Abstract (German)

Generalisierte Angststörungen sind heutzutage weit verbreitet und gehen mit Funktionsstörungen in verschiedenen Gehirnarealen, wie dem präfrontalen Cortex, einher. Um grundlegende Aktivitäten im Alltag bewältigen und steuern zu können, sind vor allem die exekutiven Fähigkeiten essentiell. Diese entspringen aus dem präfrontalen Cortex und werden vom Alterungsprozess negativ beeinflusst. Studien belegen, dass Angst auch die Aufmerksamkeit und exekutive Funktionen beeinträchtigt, indem die allgemeinen Ressourcen dadurch beansprucht werden. Dies führt in weiterer Folge zu beeinträchtigten Leistungen im Alltag. Dem entgegenwirkend, wurde das Dual-Task Training als neuer Ansatz zur Stimulierung von exekutiven Fähigkeiten und des präfrontalen Cortex hervorgebracht. Aus psychologischer Perspektive stellt das sogenannte „response related feedback“ eine bewährte Technik dar, um Leistungen allgemein zu verbessern. Dabei wird der Fokus bei einer Bewegung extern gelenkt, was zu einem besseren automatischen Kontrollprozess führt. Erwähnenswert ist, dass die Rolle des Dual-Task Trainings und des Feedbacks in dem Setting noch nicht näher erforscht wurde. Zwei TeilnehmerInnen (beide >65 Jahre, hoch ängstlich/nicht ängstlich) wurden für die Pilotenstudie rekrutiert und mit einer repräsentativen Kontrollgruppe von 15 jungen gesunden TeilnehmerInnen verglichen. Das Level der Angststörung, die kognitiven Fähigkeiten, sowie die funktionelle Fitness wurden vor und nach der Intervention überprüft und analysiert. Außerdem wurden Gehirnaktivitäten als ereigniskorrelierte Potentiale während Reaktionstests am Computer aufgenommen. Speziell wurde die präfrontale Negativität, welche vor einer externen Stimulation sichtbar wird, beobachtet und zwischen den Zeitpunkten verglichen. Die Ergebnisse deuten darauf hin, dass Dual-Task Training kognitive Fähigkeiten (vor und nach der Intervention nach MoCA Fragebogen: 18,25), sowie die Angststörungen bei hoch ängstlichen älteren Menschen verbessern können (vor und nach der Intervention nach STAI Fragebogen: 46, 25). Beide TeilnehmerInnen verbesserten sich bei den Reaktionstests, sowie bei den Fitness Tests. Auch die präfrontale Negativität und das Bereitschaftspotential zeigten nach der Intervention einen erhöhten Anstieg. Demzufolge bewies sich die Intervention als eine effektive Methode, um die Fitness von Senioren zu verbessern und, speziell, um die kognitiven Fähigkeiten bei hoch ängstlichen älteren Personen zu steigern und das Level der Angststörung zu verringern. Gesundheitsrelevante Probleme, wie ein erhöhtes Sturzrisiko, ein geringes soziales Verhalten und den daraus resultierenden Schwierigkeiten bei der Alltagsbewältigung könnten von dem Training positiv beeinflusst werden und gesundheitsmindernden Faktoren entgegenwirken.

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3. Experimental Part 30

Abbreviations

GAD	General Anxiety Disorder
EF	Executive Functions
PFC	Prefrontal Cortex
SMA	Pre-motor Cortex
pN	Prefrontal negativity
BP	Bereitschaftspotential
ERP	Event related potential
OE	Omission errors
CE	Comission errors
ICV	Intra-individual co-efficient of variation
RT	Response Time
MoCa	Montreal Cognitive Test
STAI-Y	State Trait Anxiety Inventory

1. Introduction

The aging process becomes a major issue in the public health sector, as the old population is continuing to grow rapidly. Various disorders, altered social behaviours as well as diseases are at higher risk in older people, which leads to a poor quality of life and to an enormous impact of the health care costs (Maron & Nutt, 2017). Hence, to live and perform independently in our community is determined by various social, physical, emotional, as well as cognitive factors. Research has presented, that cognition shows the greatest predictor of performing daily life in older people successfully (McAlister & Schmitter-Edgecombe, 2016). Moreover, our overall life expectancy is increasing from year to year. Hence, the major issue is to not only extend the life years but also to improve the quality-of-life years. An universal goal of current scientific research is to fill the gap of life expectancy and the expectancy of years free of disability (Montero-Odasso et al., 2012).

One of the common cognitive disorders, which appears in older ages, is defined as the so-called generalized anxiety disorder (GAD). The disorder is mainly associated with persisted worry and fear about everyday situations. Further, people affected by anxiety show poor task performance, especially when it comes to cognitive-motor tasks, such as walking while talking (Feldman et al., 2019; Tyrer & Baldwin, 2006). However, anxiety is used to be treated with drugs or expensive psychotherapies, which are not fitting to individuals. Moreover, the disorder mostly does not get detected or mixed up with other disorders, as for example depression, which leads to wrong or any treatment. Hence, those factors are highlighting the poor knowledge about the GAD in individuals (Hidalgo & Sheehan, 2012).

From a neural point of view, increased anxiety is associated with a dysfunction of the fronto-parietral network and especially in the prefrontal cortex (PFC), which includes the function of top-down attentional process. Therefore, people with GAD switch their attentional resources to task-irrelevant thoughts, which results in a poor performance. Accompanying, an additional effect has been shown when it comes to the aging process. Especially, the executive functions, which origins in the PFC are disproportional decreasing by the aging process. For instance, working memory, or attentional control show poor function when it comes to perform different tasks (Falbo et al., 2016; McAlister & Schmitter-Edgecombe, 2016)

To focus on the improvement of general health among older people with GAD means to aim to decrease anxiety, while increasing cognitive function and a general physical fitness. Cognitive-physical dual-tasks presents an attentional demanding task, where the target group shows a poor performance. Therefore, future interventions should focus to train dual-task to boost executive function performances and further to normalize the PFC activity in anxious but also in healthy older people (Kimura & Matsuura, 2021).

Considerations from a cognitive neuroscience and a physical exercise science showed also great effects adding feedback to a performed task. This directs the attention from the performer to the effect of the movement instead to the movement itself. Various literature proofed that this method leads to a better automatic control process, which would therefore boost the task-irrelevant attention of anxious people positively (McNevin et al., 2003).

In order to improve GAD, but also the cognitive and physical function of older people the experimental study has the main purpose to detect the activity level of the PFC while performing cognitive tasks utilizing state of the art electroencephalographic methods. Next, based on the results of anxiety-related brain activity, an intervention containing physical-cognitive tasks combined with additional response-related feedback will be accomplished. This aims to normalize the PFC activity and improve cognitive and physical fitness in anxious older people. Further, suggestions based on the interventions will be made for performing a training, which is suitable for real-life conditions for elderly people who suffers from GAD.

For this aim, the experimental study will be constructed by a team of researchers, who are experts in cognitive neuroscience and in the science of physical exercise using both laboratory experiments and innovative physical-cognitive exercise training to be applied in the gym and even at home. Noteworthy, preliminary data of the effect of feedback mechanism on anxious younger people will be considered to get the confidence for the experimental study with older participants.

The multidisciplinary project will be developed to provide a physical-cognitive dual-task training linked with response-related feedback to older people with and without anxiety. Further, the study should address the relevance of improving cognitive and physical fitness to reduce health care costs and ensure a better quality of life in older ages.

2. Theoretical Part

2.1. Anxiety

2.1.1 Definition and Symptoms

Generalized anxiety disorder (GAD) counts as a serious psychiatric condition and belongs to the most prevalent mental disorders. GAD is specified as a great excess of worry and less control to manage the worries in individuals. Moreover, affected people anticipate a disaster and are overly concerned about various things, as for example about money, health, or family. Feeling of restlessness, sleep disturbance and tension are common in people with the disorder. GAD belongs to a specific category of psychiatric disorders and is defined as a chronic illness. Therefore, compared to the state and trait anxiety, the disorder is defined as a high level of anxiety and will be diagnosed when having the symptoms for at least 6 months (Feldman et al., 2019; Tyrer & Baldwin, 2006).
Considering the symptoms of GAD, affected people often report palpitations, dry mouth and sweating. They feel mostly threat, tension, restlessness and have sleep problems. Additionally, motor skills, such as gait and balance are influenced negatively by the anxiety. Likewise, various literature mentioned, that GAD leads further to poorer functioning in general (Feldman et al., 2019; Tyrer & Baldwin, 2006).

2.1.2 Epidemiology

According to accumulated literature, the percentage of the population affected by anxiety disorder during lifetime varies between 5% to 33% (Bandelow & Michaelis, 2015; Hidalgo & Sheehan, 2012; Maron & Nutt, 2017b). Over the past decades, the diagnostic criteria for GAD have been changed, which declares the great spread of the prevalence rates. Moreover, the rates may differ between countries, considering different language or instruments (Hidalgo & Sheehan, 2012). Bandelow & Michaelis (2015) highlights that the heterogeneity of the rates occurs from methodologies differences. Interestingly, the prevalence of the disorder may not have been changed over years. The impression may be deceived, justified by the increased treatment of anxiety disorders. Furthermore, females tend to have a greater prevalence of anxiety disorders compared to males (Bandelow & Michaelis, 2015; Tyrer & Baldwin, 2006). However, the COVID-19 pandemic disease is recently increasing the GAD prevalence especially among older people (Shanafelt et al., 2020).

2.1.3 Health Care

Maron and Nutt (2017) reported in their study that, GAD is highly associated with health care costs, meaning that, affected people are reliant on the primary care resources, which leads to a great impact on the health care system. Moreover, to treat the disorder, two aspects need to be considered. First to decrease the acute symptoms but also to focus on the long-term prevention. However, due to a more efficient and early diagnosis, the health care costs could be more economized (Hidalgo & Sheehan, 2012). Additionally, GAD proves to be a risk factor for cognitive impairments or depression, which leads to a double amount cost of treatment compared to a single diagnosis of GAD (Beloe & Derakshan, 2020; Tyrer & Baldwin, 2006). To summarize, the high prevalence, the enhanced health care costs, as well as the impairment of GAD are remarkable implications which should get more attention in the public health sector.

2.1.4 Genetic Background

Bandelow & Michaelis (2015) reported that there is an anxiety disorder heritability of 30% to 50%, which highlights the hypothesis, testifying that anxiety prevalence is not increasing by the time.

Considering the genetic factors of the disorder, there is currently only view research available. Hidalgo & Sheehan (2012) highlights the poor investigations regarding the genetic factors. Considering family and twin studies, it may occur that depression and anxiety disorder have same genetic risk factors. This could cause from a shared genetic basis, while the environment plays an important role regarding their manifestation (Tyrer & Baldwin, 2006). Also, neuroticism may genetically correlate with GAD. However, currently, there is still no evidence for any definitive specific gene, which could be linked to GAD (Maron & Nutt, 2017b).

2.1.5 Treatment

The treatment of GAD consists mainly of psychological therapies and pharmacological supply. Specifically, cognitive behavioural therapies are applied for patients (Tyrer & Baldwin, 2006). According to the pharmacological treatment, guidelines have recommended over many years the selective serotonin or noradrenaline reuptake inhibitors, which have a great safety profile but leads often to treatment discontinuation and poor therapeutic outcome. So far, other alternatives have been proofed as not successful (Maron & Nutt, 2017b).

However, Bandelow & Michaelis (2015) outlined that there is still an under recognition and further undertreatment of the disorder. Moreover, affected people mostly don't get inpatient treatment. The World Health Organization (WHO) demonstrated that only 50% of the cases have been detected, while only 30% get a treatment. Additionally, it has been shown that people with the disorder get diagnosed after 2 years in average it last years without recognizing the disorder. This can be explained by the absence of the individual to the health care service, or through an incorrectly diagnosis. However, psychological and pharmacological treatments do exist, it is more questionable whether and which diagnosis is given to the patient. Especially depression is overlapped with GAD by the medicals, which leads to a wrong treatment. Maron & Nutt (2017) showed meaningful differences between depression and GAD in the biology. It is more known about depression and its treatment, which could be the explanation why it is still mixed up. Hence, it is essential to investigate in a better way to distinguish GAD from other mental disorders. New biological insights of the disorder should be focused on to have a greater knowledge of the pathogenesis. Hidalgo & Sheehan (2012) is in line with the above described treatment issues and mentioned, that the late diagnosis and treatment leads definitely to the high cost burden of the health care system. Moreover, the researchers are questioning the current situation regarding the responsible people for the diagnosis, as pharmaceutical companies might have the power to determine the treatment, without having the medical knowledge.

2.1.6 Comorbidities

In line with the above-mentioned issue to distinguish GAD with depression, research has presented, that anxiety disorders often correlate to other disorders. Specifically, Hidalgo et al. (Hidalgo & Sheehan, 2012) reported, that 89% of affected people suffer from at least one other disorder. Especially with other mental disorders, such as the well-known depression (Bandelow & Michaelis, 2015). Moreover, Tyrer & Baldwin (2006) state that 3 of 5 affected people show a comorbidity with depression. In addition, more comorbid cases can be observed in clinical settings. The so-called Berkson´s paradox justified the greater proportion compared to the general population by the bigger burden and need for treatment, when suffering from two or more disorders (Bandelow & Michaelis, 2015). Leading to a worse prognosis, more disability and further poor response to the treatment (Hidalgo & Sheehan, 2012).

2.1.7 Brain Structure

Various literature has been found according to anatomical differences in the brain comparing people with GAD and without. Most of the neurocognitive models of anxiety agree with a main hypothesis, saying that there is a greater activation and increased grey matter in the region of amygdala, while there is a poor activation in the fronto-parietal network, especially in the PFC in people with GAD. Hence, GAD is associated with an altered function and connectivity between amygdala and PFC (Bishop, 2009). Also, the function of the serotonergic system is well-discussed in that research area. However, there is no significant abnormality in the system in people with GAD.

Nevertheless, considering the neurobiology aspects in GAD people, it has not been well researched yet, causing by the wrong prognosis mixing up with other mental disorders (Hidalgo & Sheehan, 2012).

2.2 The Aging Process

2.2.1 Brain aging process

Giving an overview of the neuroscience perspective in older adults, it is well known, that age-related changes in the human brain affect cognitive and motor performance. During the aging process, individuals undergo neuroanatomical changes, such as a decrease of brain tissue, synthesis, serotonin, acetylcholine, binding of dopamine, as well as a worse connection of white matter can be measured (Schättin et al., 2016). In addition, the grey matter, especially in the PFC is atrophying, beginning already to decrease after 20 years (Di Russo et al., 2017; Harada et al., 2013). Thus, research has been proofed that the general brain weight is decreasing. Zanto & Gazzaley reported a 11-16% less weight by the age of 90 compared to the peak achieved weight in the adulthood (Zanto & Gazzaley, 2019). Moreover, the activity in the central serotonergic system declines with aging, which leads to a greater risk for depression, or anxiety (Gokdemir et al., 2020). At a functional level, greater activation in various brain areas could be observed in older compared to younger people. Additionally, an over-activation in the brain might be caused due to an expression of poor neural specialization and non-selective recruitment, which is also called “de-differentiation”. Another theory state that an over-activation is a result of a compensation to result an accurate performance (Di Russo et al., 2017).

Considering the metabolic factors, the changes during aging involve a loss of mitochondrial function and neuronal activity pattern. Most of all, the prefrontal lobe is affected by the age-related changes, which is influencing the cognitive and motor functions negatively (Schättin et al., 2016).

According to the cognitive decline, the so-called crystallized intelligence, which refers to skills and knowledges, which is practiced and familiar remain stable over the years. In contrast to the crystallized intelligence, the fluid intelligence is declining by the aging process. Such as EF, processing speed, memory or reasoning about less familiar stuff is categorized into fluid intelligence. The reduction of processing skills has been well researched in a laboratory environment. Although, transferable results in everyday life is still not 100% clarified (Di Russo et al., 2017). The most common skill which is affected by the aging process shows the memory of individuals. The chances might cause by the declined processing speed, or the reduced ability to ignore irrelevant information. Also, visual constructions skills, such as putting together individual parts to make a coherent whole is affected by the aging process (Harada et al., 2013). Moreover, the ability to concentrate and focus on various specific stimuli is altering a lot. The attentional system of older people is even worse when providing a complex attention task. Especially, the so-called EF are declining through the lifespan. This includes a broad range of cognitive abilities such as the ability to self-monitor, plan, organize, reason, or be mentally flexible (Falbo et al., 2016). However, those above mentioned cognitive abilities peak in the third decade (Harada et al., 2013).

Furthermore, there is a relationship between cognitive and gait dysfunction in healthy elderly. Hypothesizing that altered EF are causing to the dysfunction, as EF are essential cognitive resource required for walking. Moreover, the risk of falling is associated with poor EF (Montero-Odasso et al., 2012).

In general, regular physical activity is proven to counteract to the aging process, while enhancing the angiogenesis and neurogenesis, as well as the synaptic plasticity in the brain. Knowing that, those mentioned processes are decreasing by aging (Gokdemir et al., 2020). Hence, those altered abilities, should follow the model “use it or lose it”. Since various literature certified, that the brain and its functions are plastic and able to be modified through the life span, cognitive function could be improved even in older ages (Zanto & Gazzaley, 2019).

However, Harada et al. (2013) stated that research in the normal cognitive aging area seems poor comparing to pathologic diseases. Hence, a better understanding of the normal brain aging process might give us a better overview on the abnormality in brain aging.

2.2.2 Motoric aging process

Studies in the past decades have reported that the aging process is altering the central and peripheral nervous systems as well as the neuromuscular system. Hence, this leads to a poor motor performance, such as coordination skills, postural stability, gait or variability in the movement (Seidler et al., 2010). Especially, balance and gait present a main issue according to various literature since the risk of falling is increasing by an altered gait or balance performance.

Furthermore, according to a great body of research, the gait patterns of individuals are relevant factors which need to be assessed to define the functional fitness while aging. Moreover, walking ability belongs to the main function to manage the daily life. Hence, parameters of the gait, such as speed, variability or stride length are important to assess the functional status of individuals. There is great evidence, that gait is related with cognition, especially in older people. In daily life, slow gait presents a great indicator of an altered functioning (Feldman et al., 2019; Montero-Odasso et al., 2012). Additionally, poor cognitive ability can also reduce postural stability. An increased postural sway while standing, as well as a poor control of displacements of the center of mass and pressure in relative to the stability limit can be reported in older people (Seidler et al., 2010). However, these effects occur due to the reduced attentional resource allocation, which will be processed in detail in the next chapter (Feldman et al., 2019; Montero-Odasso et al., 2012). Thus, older people show a greater coordination deficit while doing a multi-task movement, such as walking while talking, independently if temporal of spatial coordination (Seidler et al., 2010).

Combining the knowledge of EF with physical performance, Schättin et al. (2016) reported that reduced executive function impacts the gait performance and therefore amplifies the risk of falling as well. Montero-Odasso et al. (Montero-Odasso et al., 2012) underlined the effect of EF on gait patterns and mentioned that there is an association between early decline in cognitive processes, such as EF, slower gait and gait instability.

Gait impairments are mainly related to decreased muscle strength, combined with poor balance it leads to an increased risk of falling. This remains a main problem in the public health sector, as 20-30% of older individuals who experienced a fall suffer injuries and poor mobility (Seidler et al., 2010). Hence, findings from a large body of literature indicate that neurobiological and pathological processes in the brain are related to the pathogenesis of falls (Lord & Close, 2018). Summarizing that, various factors during aging impacts the risk of falling, which lead to a more inactive life and further to a poorer quality of life (Seidler et al., 2010).

2.3 Relevant brain structures and functions

2.3.1 Prefrontal Cortex

The prefrontal cortex (PFC) belongs to the cerebral cortex and covers the front part of the frontal lobe. It reaches about 30% of the total cortical area. Scientists are about a high interest to explore the functions and abilities of this area due to its extraordinary functional attributes. Although, most aspects remain still not clear and unresolved. A great body of knowledge regard to the function or structure of the PFC has arisen through non-human studies, as for example with rats (Carlén, 2017; Falbo et al., 2016; Teffer & Semendeferi, 2012). However, Carén (2017) mentioned that transferring results and knowledge to the human brain remain critical, causing by the diversified evolution of the species.
The PFC consists of various subregions, which still have not been uniformly categorized. Considering the Brodmann classification of the areas, there are 52 parts, which are numbered sequentially and accorded to cytoarchitectural organization. Hence, as showing in the figure 1, the PFC contains Brodmann area's 8, 9, 10, 11, 12, 13, 14, 24, 25, 32, 44, 45, 46, and 47. Whereas Teffer & Semendeferi (2012) categorize for example 9, 10 and 46 as the dorsolateral area with mostly executive functions. The language (44, 45), emotional processing and sociality (47, 10, 11, 13) are placed in the so-called orbitofrontal cortex. However, there are various different categorizations for subareas in the PFC.

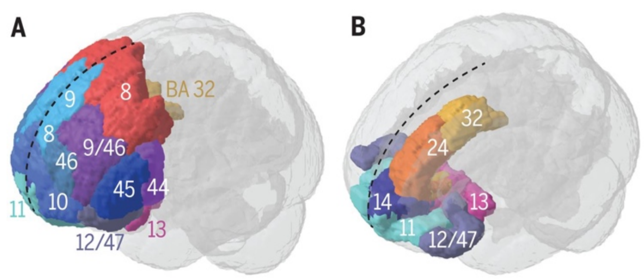

Figure 1: *PFC Area with a frontal-side perspective (Bandelow & Michaelis, 2015)*

Considering the functional abilities of the PFC, a great body of literature has demonstrated that the PFC present a main role in cognition. Hence, it implicates for example planning, decision making, personality expression, or moderating social behavior. The mentioned functions are defined as the so-called executive functions (EF) (Carlén, 2017; Falbo et al., 2016).

Great evidence reported that PFC anatomy as well as physiology decline with age, leading to multiple cognitive deficits (Zanto & Gazzaley, 2019). Moreover, the frontal areas are disproportionately affected by the aging process (McAlister & Schmitter-Edgecombe, 2016). Schättin et al. (2016) is in line with the frontal hypothesis and reported that both cross-sectional and longitudinal studies proof that the PFC is highly vulnerable to the aging process. Hence, cognitive functions, such as EF are also affected negatively by the aging process. Further, previous results show a correlation of the decreased PFC volume and a decreased gait speed, may justified by an altered process of information (Schättin et al., 2016).

According to the systematic review written by Pelicioni et al. (2019), the PFC activation is increased when performing a complex task while walking, independently of age or sex. The cognitive task is demanding the attention and executive function, which leads to a greater activation.

Likewise, the pharmacological study of George et al. (2019) reported that there is a greater PFC activation, seeing in the increased oxygen haemoglobin level, while performing dual-tasks, which is also defined as an attention demanding task. Next, anxiety has been reported in the past years as another factor, which is affecting the PFC negatively. It has been presented that anxiety leads to poor PFC activity (Balconi & Ferrari, 2013).

2.3.2 Executive functions

As mentioned above, the so-called executive functions (EF) origin in the PFC. In previous literature, the EF are defined as group of control processes, which regulate goal-directed actions and thoughts. Specifically, the EF are needed during a new or unusual situation, sequencing complex tasks goals or initiating goal-directed behaviour (McAlister & Schmitter-Edgecombe, 2016). Schättin et al. (2016) define the EF as so-called higher level cognitive abilities, which control the lower level ones. Likewise, EF include fundamental skills, such as planning, self-monitoring, self-control, working memory, time management, organization, and adaptable thinking. To perform tasks, such as walking, more EF components are required and cooperate with each other. For example, inhibition, attention and working memory will be activated for a successful gait performance.

Therefore, those functions are needed to manage daily life activities independently (Falbo et al., 2016). Moreover, it appears as a predictor of day-to-day functioning in elderly (McAlister & Schmitter-Edgecombe, 2016).

Based on evidence, those functions are amongst an essential cognitive resource, which is highly negative affected by the aging process (Falbo et al., 2016; Montero-Odasso et al., 2012). Moreover, it seems like the EF decreases disproportional during aging. A decline of

EF is associated with a poor postural stability, as well as a greater risk of falls. Furthermore, those degradation impact the daily life performance negatively and lead to worse quality of life. In line with the aging theory, Schättin et al. (2016) reported that the thickness and volume of the PFC relate with the EF.
Those automatically processes, such as inhibition, are not only affected by the aging process, but also by anxiety. Particularly, people with GAD show a remarkable deterioration in automatic processing (Balconi & Ferrari, 2013). Considering the great body of literature addressing altered executive function, anxiety is also impoverishing the working memory, which counts as an executive function. Baldestron et. al (2017) stated, that there are two hypotheses regarding an altered working memory in anxiety affected people. Poor working memory may result from a poor cognitive control system or from the inability to use control mechanism to screen out task-irrelevant processing and focus on the task. Moreover, results in their study showed a poor PFC activity (especially in the dorsolateral), as well as a poorer working memory performance in anxious people.

2.3.3 Attention and Attentional Control Theory

According to several studies, the anxiety has been linked to an altered performance and cognitive results in individuals (Eysenck et al., 2007). Anxious people need attentional resources to manage and reduce their worry about threat to a current situation or goal. Apparently, this correlates with the adverse cognitive performance effects. There is an abundant evidence that cognitive performance is affected by anxiety. Additionally, various studies have been proofed that hypothesis, during an attentional demanding task (Derakshan & Eysenck, 2009).
The attentional control theory (ACT) represents the current theoretical framework to explore the relation and effect of anxiety regarding the attentional control (Beloe & Derakshan, 2020). The theory is drawn on the beforehand Working Memory Model and the Processing Control Theory, which both have been shown many limitations over the past (Derakshan & Eysenck, 2009; Shi et al., 2019). Hence, ACT presents a development stated theory, taking advantage in its strengths, and creating solutions from the limitations (Eysenck et al., 2007).
According to the ACT, anxiety absorbs the resources which would be needed for the attentional control depending on the current situation. Hence, it is limiting the overall cognitive resources. This results in performance deficits, especially in executive demanded tasks, such as dual-task exercises (Coombes et al., 2011; Hausdorff et al., 2008). Or from another perspective, increasing the anxiety by threatened situation leads to a decreasing attentional control (Coombes et al., 2011; Shi et al., 2019).

Taking the article of Beloe & Derakshan (2020) into account, there is also evidence for a common genetic aetiology for the anxiety and attentional control. Meaning that, less attentional control could be a phenotypic and genetic risk factor for the disorder. Other scientists (Shi et al., 2019) agree with that hypothesis, saying that anxiety and poor attentional control could be bidirectional influenced. However, they highlight the variation of the impact of attentional resources depending on processing. The effect of anxiety on the attentional resources has been too simplified in the past literature. The attentional bias or orientation may better be seen as a multiple process instead as a single one.

2.3.3.1 Top-down and bottom-up subsystems

Further, the ACT can be split into the top-down and bottom-up subsystems. Whereas first mentioned one is influenced by the goals and expectations of the individual. The so-called goal directed system is placed in the prefrontal cortex. Secondly, the stimulus driven system, defined as bottom-up driven process includes the temporal-parietal and ventral frontal cortex and is influenced by the salient stimuli. It has been shown that both systems interact frequently with each other in their functioning (Beloe & Derakshan, 2020; Derakshan & Eysenck, 2009; Eysenck et al., 2007). Considering that the ACT implied that higher level of anxiety relates to a decreased attentional control, the interaction of the above-mentioned subsystems can be disrupted. Specifically, the goal-directed system decreases, while the stimulus-driven system increases by the processing of threat related stimuli, which is task-irrelevant (Derakshan & Eysenck, 2009; Shi et al., 2019). Hence, the imbalance of the two subsystems results in a poorer performance on cognitive tasks. Although, Coombes (2011) mentioned that the consequences, especially during goal-directed motor tasks has yet to be researched.

2.3.3.2 Brain function

Moreover, evidence has been accumulated that anxiety correlates with a greater activation in the amygdala and a poor activation in the PFC area, where the top-down regulation of attention is placed in. Hence, anxiety is affecting the attentional control, which represents the function of central executive component of the working memory (Derakshan & Eysenck, 2009). According to the central executive functions, various but slightly simultaneous approaches for categorizing the functions have been published. Three main functions can be filtered into shifting, inhibition and updating. Inhibition is the ability to suppress a disruptive and task-irrelevant stimulus, defined as negative attentional control (Coombes et al., 2011). Using the attentional control in a positive way to shift the attention flexibly to assure to remain the focus on the task-relevant stimuli, is called Shifting. Third, the updating function is representing the ability to update and monitor working memory representations utilising short-term memory and capacity. As the function does not involve much attention, it is not directly influenced by anxiety. However, it is affecting the efficiency of the shifting and inhibition function (Derakshan & Eysenck, 2009; Eysenck et al., 2007)

2.4 Cognitive Training

Considering the decline of cognitive functions during the aging process, an intervention or a program, which hinders that altering process, seems to be highly relevant (Schättin et al., 2016). Since it is well-known, that cognitive plasticity remains through the whole lifespan, interventions to improve cognition are proofed to be effective. Hence, a major health goal is to ensure a safer life in their environment of individuals and further, a stable quality of life. Accumulated research exists in regard to cognitive training to improve a better cognitive performance of older adults (Verghese et al., 2016). Specifically, studies presented successful cognitive training interventions to improve attentional control. Cognitive training in all the variations presents a high potential method for the future and has attracted attention, since the methods getting more accurate and valid. Moreover, to perform cognitive tasks, no risk needs to be taken and no additional equipment need to be required. Meaning that for instance, people don't feel physical fatigue during cognitive task (Kimura & Matsuura, 2021).

Since it is already known, that people affected by anxiety show difficulty to concentrate and task-irrelevant thoughts, which therefore impacts the working memory, an intervention addressing on that functioning seems to be effective (Balderston et al., 2017). Hence, an accumulated body of studies have been investigated to address working memory to improve cognitive control. In the study presented by Beloe & Derakshan (2020) they focused on the working memory and attentional control deficits arising by anxiety and depression. So, a training via dual n-back working memory training was tested with anxiety affected non-clinical older adults to reduce anxiety and depression. Significant results were presented as sustainable in a follow-up. Highlighting that working memory can induce cognitive plasticity, since the cognitive system is needed to perform out of routine, or out of the comfort zone. Specifically, the dual n-back training increases the level step by step according to the individual's performance. Progressive higher levels of performance can be achieved and further the working memory can increase (Beloe & Derakshan, 2020). Likewise, in another study (Sari et al., 2016), they reported that working memory training improve the attentional control mechanisms and decrease the inhibition-control deficits, which are commonly shown in people affected by anxiety. Before and after a 3-week dual n-back training, a Flanker task that included a stress induction, an emotional Antisaccade task and an EEG were used. Results could be shown under conditions where a maximal observed anxiety effect is given. Hence, they highlighted that there is a causal association between the attentional control and the anxiety disorder. However, a big sample size as well as a follow-up intervention remain resource extensive, but although, it should be more focused on in future to ensure accurate results.

2.4.1 Dual-Task Training

A growing body of research has been investigating in dual-task interventions, since beneficial effects in cognitive performance could be observed in the past. However, the optimal type of exercise is yet to be identified. Specifically, dual-task performance is defined to perform two tasks simultaneously, such as two physical, or two cognitive tasks, but also a physical combined with a cognitive task (Falbo et al., 2016).
According to evidence-based literature, an association of EF and a performance of complex human behaviours, such as dual-task performance, was found. Moreover, the EF is required to manage a dual-task performance successfully (Kimura & Matsuura, 2021). In previous literature it was reported that such a combination needs extra attention. Hence, it requires attentional resources from the individual, which is depending on the EF (George et al., 2019). Currently, scientists describe the attention as a system, which has limited resources. Therefore, when doing more tasks simultaneously, they compete for the same limited brain cortical resources. For example, when people walk while they talk, they perform an attention-demanding task. As a result, a slowing down of the gait, or in general a worse performance can be observed (Falbo et al., 2016; Montero-Odasso et al., 2012). Holtzer et al. (2019) called it a neuronal inefficiency, which occurs when there is a great brain activation but at the same time a bad performance.
Those findings are in agreement with the so-called “posture first” hypothesis. It indicates that people in older age prioritize physical performance, such as walking, over cognitive task performance under dual-task conditions. However, there are various meanings regard to that hypothesis and the influencing factors are still not 100% clarified (Holtzer et al., 2019).
Furthermore, dual-task performance can be defined as a so-called internally driven process. This process is mainly associated with a brain activation of the PFC and relates to executive functions, such as attention and working memory. In contrast, an externally driven process can be observed for example while negotiation obstacles in the area of the supplementary motor cortex. (Mirelman et al., 2017).

In the past decade, various studies observing dual-task interventions have been found. In the study by Kimura & Matsuura (Kimura & Matsuura, 2021) a physical-cognitive dual-task training were tested in healthy younger people. As a result, they reported that the dorso-lateral prefrontal cortex (DLPFC) is activated during a dual-task performance. Moreover, the activity in that brain area seems to affect the performance. Likewise, in the study by Mirelman et al. (2017), it was mentioned that there was a greater activation in the PFC when doing physical-cognitive dual-task in contrast to single task walking. Additionally, greater effects were shown in healthy older adults compared to younger adults. This could be explained by a greater reliance on cognitive compensation in older people. Falbo et al. (2016) were also focusing on a physical-cognitive dual-task intervention of older adults and presented similar results. The age-related inhibitory performance deficit could be improved compared to the control group, which trained single task. Additionally, in both groups physical performance, such as gait could be increased. However, according to a recent study, a dual-task repetition over a time period is needed to improve the long-term dual-task performance (Kimura & Matsuura, 2021).
Additionally, whether and how to transfer the dual-tasks from laboratory conditions into real life dual-tasking is not well known yet. Although, Schättin et al. (2016) suggested in their review to include exergaming (visual and acoustic) as a potential training strategy. Hence, the training could contain cognitive - motor parts including an interactive video game-based physical exercise. Moreover, they reported, that exergame training is influencing the EF and gait performance in a positively. In addition, they highlighted, that exergaming could be an auspiciously training strategy in the future to address the PFC activity, the EF, as well as the gait performance in aging humans. Further, to have a better benefit, a visual and acoustic stimulus should be targeted on specific EF, which are more affected by the aging process. Similarly, Lord et al. (2018) mentioned this training method as a potential strategy for the future as well. This could lead to a better entertaining factor and further to a better adherence. Also, they highlighted, that improved cognitive function and dual-tasking may lead to a decreased risk of falling. Hence, in future considerations, new applications and modern technologies may be of high interest.

2.4.1.2 Health Benefit

In order to ensure the best health benefit in older people with and without GAD, accumulating literature is trying to research for a model to integrate and combinate physical with cognitive demanding training. It has been reported various times, that this combination has a great benefit for the motor and cognitive capability (Falbo et al., 2016). Especially, recent studies suggest dual-task training as a new approach for preventing fall risk, as it also improves the executive function (Lord et al., 2018). Moreover, combining physical with cognitive tasks, compared to either physical or cognitive dual-task, shows a higher health benefit. Hence, both cognitive functions and also physical functions can be improved. Specifically, greater physical performance, such as gait speed, stride length, stability, and more can be presented (Falbo et al., 2016).

As mentioned above, in the aging sector, a major goal is to reduce fall risks and enhance the ability to perform the daily life independently. Therefore, considerations in future should mainly focus on improving both functions to ensure people a safe and independent life as long as possible and to decrease the enormous health care costs. However, in the study of Falbo et al. (2016), they stated that it is more sufficient for older people if the experience is coupled with the ability to walk in those conditions which is representing the everyday life. Moreover, they highlighted the potency of group training sessions, to enhance motivation and further better results.

2.5 Response Generated Feedback

In the past decades, many mental techniques have been developed to improve performance in individuals by modifying cognitive processes. An evidence-proofed and effective approach is based on given feedback, defined as the so-called response related feedback technique (RRF). Specifically, people receive an information as a result of a task execution. The feedback can be given from an instructor, or from the system and can be distinguished by verbal, visual, or a combination of both.

Moreover, the kind of feedback presents a major variable in terms of adherence since it may affect the adherence of individuals to the exercise. Specifically, negative versus positive feedback needs to be considered in order to ensure the most effective outcome. Hence, various literature has presented, that a mix of positive and negative feedback shows an effective method to continue the participation of exercise (Shin & Lee, 2018).

2.5.1 Constrained Action Hypothesis

Hence, considering the psychological perspective, the “response-related feedback” (RRF) is a well-known mental technique to enhance performance. With respect to the so-called “constrained action hypothesis”, RRF allow external focus during task execution and support individuals to a better performance, as it directs the person to the effect of the movement instead to the movement itself. Moreover, the external focus leads to an automatic control process avoiding interferences with the natural movement and improving performance stimulated learning. Whereas internal focus constrains the neuromuscular system and disrupt the automatic movement control. In line with that, research has shown that manipulated focus directing the attention externally impacts kinetics, kinematics, the variability of movement, as well as the general performance outcome (McNevin et al., 2003; Vidal et al., 2018) Hence, evidence based, the feedback, which directs the performer to an external focus, leads to a better performance. Moreover, the distance between the action and its effect is another factor, which should be considered. McNevin et al. (2003) mentioned, that increased distance of the movement effect may lead to a better automatic control process and improves the learning effect even more.

In addition, it has been proofed that such outcomes are not only temporarily during the performance, but also occur afterwards. Specifically, in the study presented by (Wulf et al., 2002), it was mentioned, that after 1 week retention under no-feedback conditions, there could be still a learning effect seen. Hence, the attentional focus, which is affected by the feedback, contains a learning effect. These outcomes occur in both beginners and experienced performers, independently of the environment.

However, in accordance with the altered brain activity of anxious older people, receiving feedback, no literature could be found and is yet to be identified. But, based on the literature mentioned above, it is expected, that the poor activity in the PFC and the great processing of threat related stimuli can be normalized, switching the attention with directing the individual to an external focus (Shi et al., 2019).

2.6 Brain activity assessment

2.6.1 Electroencephalogram

The mentioned cognitive resources can be assessed by measuring the brain activity. Moreover, to evaluate the activity in specific parts of the cortex, different measurement instruments are used to be utilized. One of the most common technique is the so-called electroencephalogram (EEG), which allow recordings and interpretation of the electrical activity in the brain(Mirelman et al., 2017).

Specifically, brain neurons generate electrical impulses that fluctuate rhythmically in distinct patterns and can be recorded at scalp level. This recording, produced by such an instrument, is defined as an electroencephalogram, commonly abbreviated EEG. Further, to assess the electrical activity of the brain, a number (up to 256) of electrodes are attached to the scalp. Each electrode transmits a signal to one of several recording channels of the electroencephalograph. This signal consists of the difference in the voltage between the electrode and another reference electrode. The rhythmic fluctuation of this potential difference is shown as peaks and troughs on a line graph by the recording channel. For example, the EEG of a healthy adult in a fully conscious but relaxed state is made

up of regularly recurring oscillating waves known as alpha waves. In contrast, when a person is excited or startled, the alpha waves are replaced by low-voltage rapid irregular waves. Further, as seen in the figure 2, during sleep, or in case of being in a coma, the brain waves become extremely slow. Other abnormal conditions are associated with particular EEG patterns. For example, irregular slow waves known as delta waves arise from the vicinity of a localized area of brain damage (Di Russo et al., 2019; Mirelman et al., 2017).
Specifically, an EEG signal detects synaptic currents, flowing within the dendrites, when the brain cells are activated. Hence, a magnetic field is generated which can be seen on the EEG system (Sanei & Chambers, 2013).

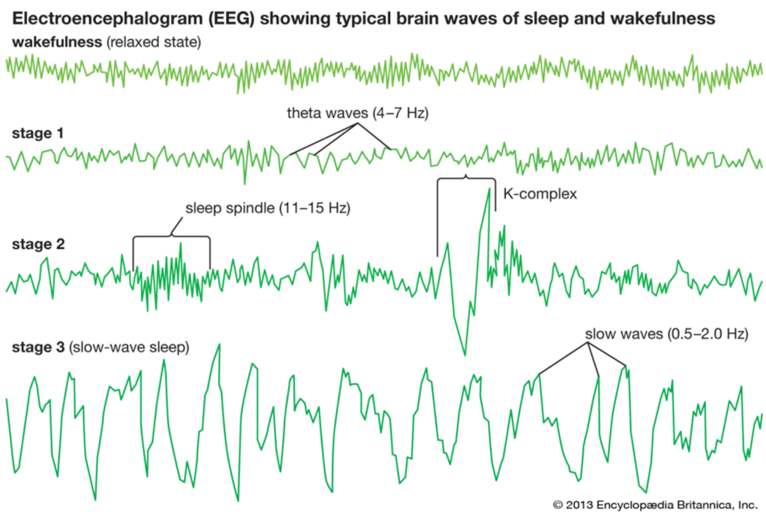

Figure 2: *Electroencephalogram (EEG) with typical brain waves of sleep and wakefulness (Encyclopædia Britannica, Inc. 2021)*

However, the EEGs are in high interest for scientist in order to diagnose functional and brain abnormalities. Since EEG measurement provides an effective but also affordable method, it satisfies the rising global demand for more modest and economical services in the healthcare sector. Hence, to ensure a diagnosis in an early state of different diseases, the detection of physiological and functional changes in the brain presents an essential method. Noteworthy, an appropriate interpretation as well as the knowledge of signal processing techniques are required to analyse the EEG signals successfully. While EEG allows to detect general brain states it is unable to record specific brain responses the determined events (Sanei & Chambers, 2013).

2.6.2 Event related Potential

A useful diagnostic method of an EEG is defined as the Event-Related Potential (ERP), where the electrical response in the human cortex to any event will be measured directly. It represents a central method in the research field of cognitive neuroscience remained since around 60 years. Specifically, the ERP method is capturing and segregating complex dynamics of the neural process. A high temporal resolution ensures a valid method to measure the brain electrical activity. Hence, a sum of action potentials, which are locked by the time to a sensory, motor of cognitive event can be detected. Specifically, the signals can be distinguished by the amplitudes, source locations, latencies aswell as the frequency (Di Russo et al., 2019; Sanei & Chambers, 2013).
According to recent scientific research, prefrontal ERP components that are associated to cognitive processing could be found. Specifically, those ERPs were shown while performing tasks requiring motor responses to visual stimuli. Therefore, this leads to a high interest of scientific workers, as measured ERPs could be transferred to challenging cognitive processing in real life conditions of individuals. Tasks related to that cognitive processing, seeing in ERP, are for example Go - No go conditions, which are also called discriminative response tasks (DRT). This can be seen in laboratory conditions, but also in the daily life, such as preparing and selecting action to the colour of the traffic lights. Moreover, this process of Go/No-go paradigm is related to the goal-directed behaviour, which represents the top-down attention of people. However, although there is a quite interesting transfer seeing between both conditions, in an experimental environment, the event is repeated many times to collect the average electrical response (Di Russo et al., 2019).

2.6.2.1 Prefrontal Negativity (pN)

Furthermore, during such conditions, research have recently found a slow wave, which occur before the stimulus onset. Likewise, just few literatures have focused on the anticipatory phase compared to
the great contributions on post-stimulus ERPs. However, this negative anticipatory wave can be detected over the prefrontal scalp area and is defined as the prefrontal negativity (pN). It can be seen as the first activity starting from around -800ms before the stimulus on bilateral prefrontal electrodes. The activity peaks just before the stimulus onset. Specifically, this preparatory brain wave can be compared to the well-known Bereitschaftspotential (BP), since both precedes and prepares response emission of the upcoming action. But, while the BP is originating in the premotor cortex and presents the index of the preparation of the motor aspects, the pN presents the index of action cognitive preparation in

the PFC (Di Russo et al., 2017, 2019). The difference between the pN and the BP are in the figure 3 shown below.

Preliminary data has indicated, that the pN1 shows a poorer rise before a visual stimulus in anxious compared to healthy people. This is in line with the above-mentioned fact, that the top-down process is limited due to the limited attentional resources (Shi et al., 2019).

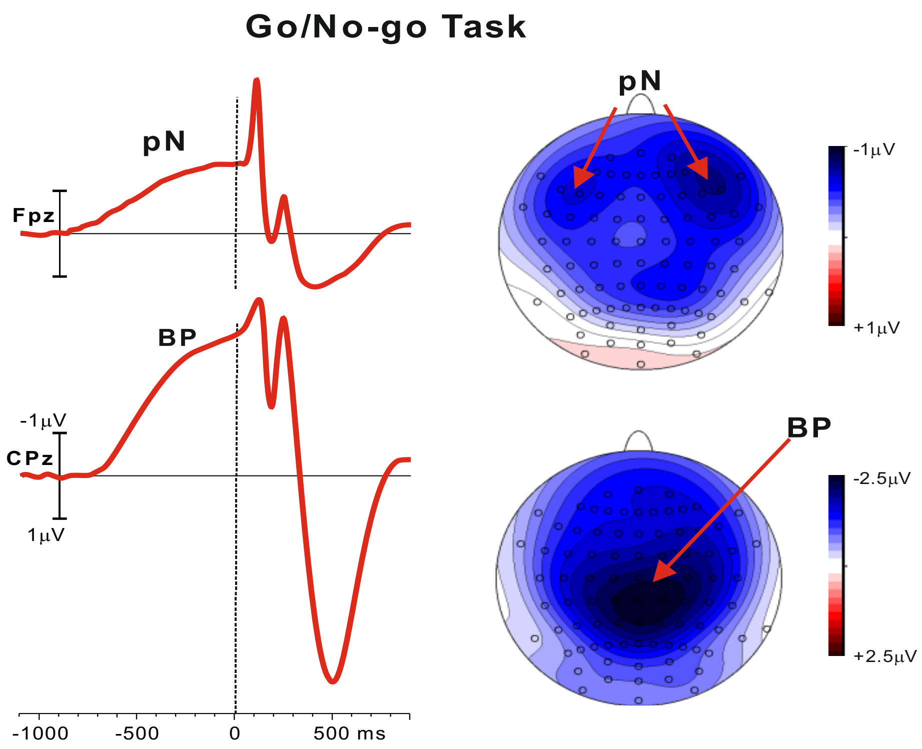

Figure 3 a: *pN waveform with the scalp topography;* ***b:*** *BP waveform with the scalp topography (Di Russo et al., 2019)*

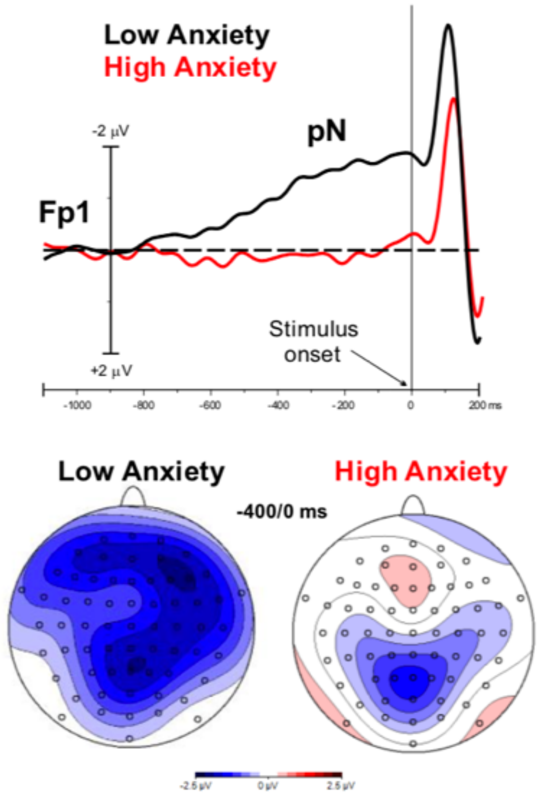

Figure 4: *ERP at left prefrontal channel (Fp1) showing reduced pN activity in an anxious participant (Di Russo et al., 2019)*

3. Experimental Part

According to the above-described topic and the current state of the art, hypotheses were planned to implement and led through an experimental study. For the aim of this thesis, two studies are presented in the following chapter, while the data of the first study was already recorded aiming to give an evidence-based baseline for the main study. Noteworthy, the COVID-19 situation prevented a proper process of an experimental study with older participants. Therefore, the main experimental study, which was planned to take place in spring 2021, was postponed to autumn 2021. Hence, preliminary data were recorded aiming to detect tendencies of expected outcomes and to ensure an effective test protocol in autumn. Further considerations and adaptions will be based on the following study. Additionally, data from a preliminary study were used to present evidence-based results with young participants giving motivation to run a study with older participants. Noteworthy, those data were recorded at the beginning of this year prior to my research stay in Italy at the Foro Italico University. However, the outcomes of this study aimed to introduce into the main study.

3.1 Preliminary study on young people

3.1.1 Introduction

To verify that the PFC activity represented by the pN is modulated by anxiety and that the response-related feedback can normalize the hypofunctional PFC activity in anxious people, young people (university students) were recruited for a preliminary study and divided into high and low anxious (AH and LA) people. Both groups performed a discriminative response task (DRT) to compare the pN in the conditions.
In that study it was expected to find low pN in the HA group in the standard DRT (with no feedbacks) and a pN normalization in the DRT with feedbacks. A confirmation of that hypothesis would give the confidence to the proposed intervention for the main study with older people.

3.1.2 Methods

3.1.2.1 Participants

For the determination of the sample size, a G*Power 3.1.9.2 Software was used (Faul et al., 2007). To detect a medium effect size (0.25), with power (1– β) set at 90 and α=0.05, the recommended minimum sample size comprised 30 participants (15 per group). Accordingly, thirty-two volunteers (16 females; mean age 22.1 years, SD=2.2) were recruited in the study. All volunteers were students at the "Foro Italico" University and received an extra credit for their participation.
Participants were divided according to their trait anxiety scores, measured by the Italian version of "State Trait Anxiety Inventory" (STAI-Y2) (Spielberger et al., 1983). Noteworthy, the participants were previously selected from a larger sample of 143 students, excluding those with normal anxiety levels. Specifically, participants who scored 44 and higher out of 80 points on the trait anxiety score were classified as high anxious (HA), whereas people who scored less than 34 were classified as low anxious (LA)(Ansari & Derakshan, 2011a, 2011b). Participants who scored between the groups were not considered. The two groups were also selected to be age- and sex-matched.
Additionally, inclusion criteria contained that all participants need to have a normal or corrected-to-normal vision. Hence, to avoid excessive eye blinking only glasses but not contact lenses were allowed. Also, participants reported no past or present neurological or anxiety disorders and were right-handed (Oldfield, 1971). Before the experiment, they were informed about the procedure and provided written informed consent. The study was approved by the Ethical Committee of the Santa Lucia Foundation (Rome, Italy).

3.1.2.2 Study Design

The participants performed a discriminative response task (DRT) with or without feedback. In both tasks, participants had to discriminate between three Go stimuli and three No-Go stimuli. The two sessions were counterbalanced among participants. The students were performing in a quiet and dimly lit room in front of a computer monitor at 114 cm distance. A response panel was fixed on the right armchair. A yellow circle (subtending 0.15 × 0.15° visual angle) served as fixation point and was displayed on the screen. Specifically, as pictured in the figure 5 below, the stimuli consisted of six (three targets and three non-targets) squared configurations (subtending 4×4° and made of vertical, horizontal or both vertical and horizontal lines) presented centrally on a dark grey background. The stimuli were randomly presented for 250 ms with equal probability.

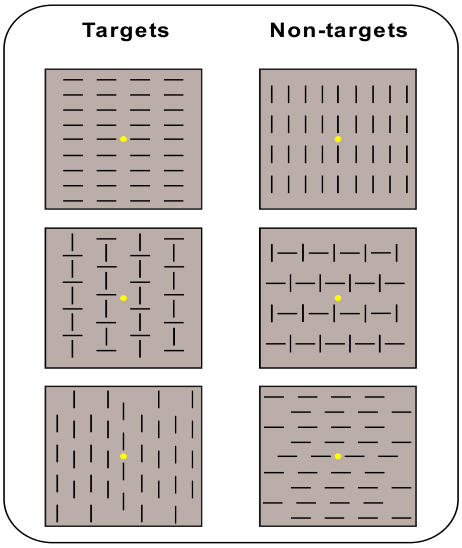

Figure 5: *Schematic representation of the 6 different stimuli used in the experiment (3 Go, 3 No-go)*

During the feedback session, a buzz sound of 250 ms (binaural at 60 dB) was emitted 600 ms after the target onset, in the case of a lack of response to targets, whereas in the case of an unwanted response to non-targets the same sound was emitted concomitantly to the button press. No sounds followed correct responses. The sounds were emitted by two loudspeakers which were placed symmetrically on each side of the computer screen. Noteworthy, the stimulus onset ranged asynchrony from 1.5 to 2.5 s in order to avoid time prediction effects on the RT and to reduce brain activity overlap.

The students were asked to fixate the central circle for all the run duration avoiding eye blinking and to press a button with the right index finger when target stimuli appeared, withholding the response if non-target stimuli appeared. Additionally, the participants were required to be as accurate and fast as possible.
After receiving the task instructions, participants familiarized with the task performing a block of 30 trials. The entire experiment consisted of two sessions (Feedback and Standard) of ten runs, containing 84 trials each (participants performed a total of 840 trials: 420 targets and 420 non-targets stimuli per session). Each run lasted around 3.5 min with a short rest in between the blocks. The total duration of the experiment depended on the participants' rest time and was about 40-50 min per session.

3.1.2.3 Electrophysiological Recording & Data Analysis

The EEG signal was recorded using three BrainAmp™ amplifiers (BrainProducts GmbH, Munich, Germany) with 64 scalp electrodes mounted by following the 10–10 International system. All electrodes were initially referenced to the M1, and then re-referenced to M1/M2 average. Horizontal and vertical electrooculograms (EOG) were recorded using additional bipolar montages with electrodes placed, respectively, at external canthi (HEOG) and below and above the left eye (VEOG). Electrode impedances were kept below 5 KΩ. The EEG was digitized at 250 Hz, amplified and stored for offline averaging.
The EEG was processed using the software Analyzer 2.1 (BrainProducts GmbH, Munich, Germany). The EEG was low-pass filtered at 30 Hz (slope 24 dB/octave) and segmented using 2000 ms epochs lasting from 1100 ms before to 900 ms after the stimulus, with stimulus onset at 0 time. To study the pre-stimulus ERP, target and non-target trials were averaged together and the first 200 ms of the segment (−1100/−900 ms) was selected as baseline. The correction of eye-movement artifacts was carried out by using the ocular correction with the independent component analysis tool (ICA) available in the Analyzer software. This method, introduced by Jung et al. (2000), produced better results compared with other ocular correction methods. Next, epochs still contaminated by artifacts or other signals exceeding the amplitude threshold of ±60 μV were discarded. In the final average, about 7% of trials were rejected.
To select the intervals and electrodes to be included in statistical analysis, the "collapsed localizer" method was used (Luck & Gaspelin, 2017), in which a localizer ERP is obtained collapsing (averaging) all experimental conditions. To identify the interval of analysis, the global field power (GFP) was calculated. The GFP describes the ERP spatial variability at each time point considering all scalp electrodes simultaneously, resulting in a reference-independent descriptor of the potential field. The pre-stimulus interval in which the GPF

was larger than 70% of its maximum value was used for further analysis. The GFP approach selected the pre-stimulus interval from -320 ms to 0 ms, in which the mean amplitude was calculated for statistical purposes. The electrodes with amplitude larger than 70% of the maximum value in the intervals selected by the collapsed localizer were jointed in spatial pools and considered for statistical analysis. Two foci of activity were clearly present, a bilateral prefrontal activity of the pN, and a medial centro-parietal activity of the BP. The pN was then represented by a pool containing Fp1, Fpz, Fp2, AF7, AF3, AFz, AF4, AF8 electrodes (prefrontal pool). The amplitudes were submitted to a 2x2 ANOVA with Task (Standard vs. Feedback) and Anxiety (Low vs. High) as factors.

All statistical analyses were performed using the SPSS version 13.0 (SPSS Inc., Chicago, IL, USA). To evaluate the effect-size of the results, the partial eta squared ($p\eta 2$) were also reported to reduce the likelihood of Type 1 errors in the ANOVAs. Additionally, Post-doc comparisons were performed by the Bonferroni correction to the p value. Results were considered as significant with the alpha level of 0.05. For the ANOVAs, the Mauchly's test of Sphericity was adopted showing non-significant results ($p>0.5$) for all considered comparisons indicating that the assumption of sphericity has not been violated.

3.1.3 Results

In the figure shown below, the pN waveforms at the prefrontal pool are pictured. A different rising of the pN wave can be seen according the groups and with and without feedback. The ANOVA on the pN amplitude showed non-significant effects of the Group ($F(1,30)=1.87$, $p=.171$) and Task ($F(1,30)=2.33$, $p=.139$). However, the interaction between Group and Task was significant ($F(1,30)=9.13$, $p=.005$, $\eta p2=.217$). Post-doc comparisons indicated that the pN of the HA group in the Standard task was smaller ($p<.021$) than all other conditions, which did not differ each other.

As seen in the Figure 6 below, the pN initiated at about -800 ms and were maximal at the stimulus onset.

Moreover, the Figure 7 shows the scalp topography of the groups and tasks in the intervals from -320 to 0 ms. Hence, the pN presented the typical bilateral prefrontal radial distribution, which is more prominent over the right hemisphere (For normative data on the pN and BP please see Di Russo et al. 2019).

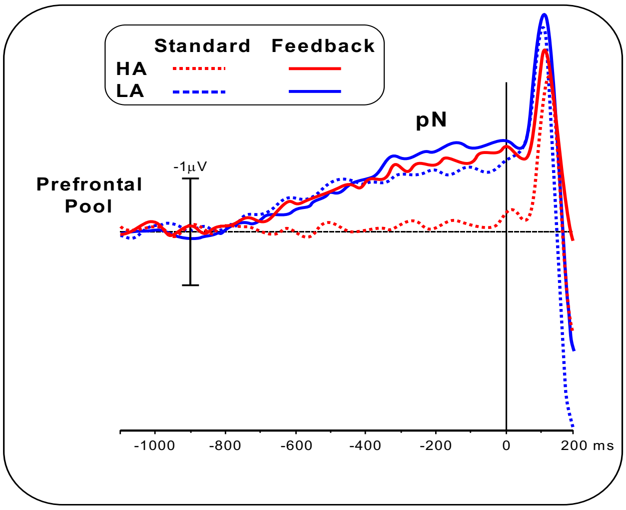

Figure 6: *Pre-stimulus ERP waveform at the prefrontal pool of electrodes representing the pN in both conditions (Feedback and Standard) and in both groups (HA=high anxious; LA=low anxious)*

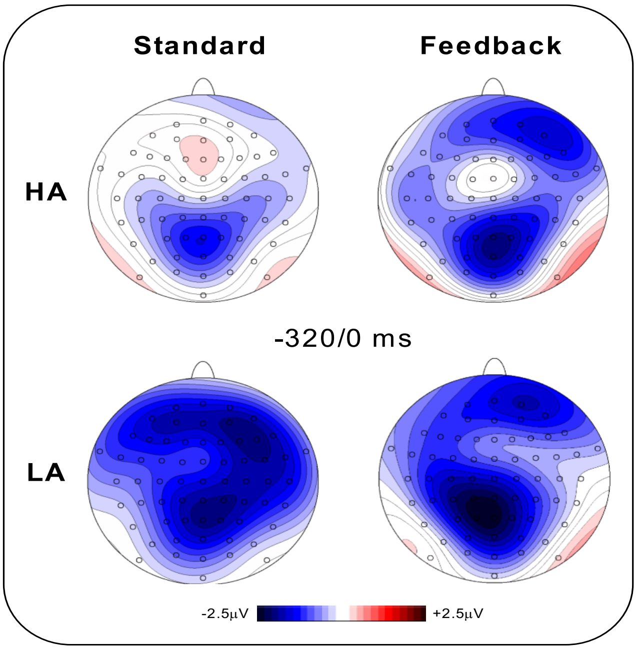

Figure 7: *Scalp topographies of both tasks and groups (top-flat view), showing the pN component in the last 320 ms before the stimulus onset.*

3.1.4 Discussion

To sum up, this preliminary data has indicated, that the pN shows a poorer rise before a visual stimulus in anxious compared to healthy people. In addition the response-related feedback seems to be able to normalize the pN wave. This is in line with the above-mentioned fact, that the top-down process is limited due to the limited attentional resources (Shi et al., 2019).

3.2 Experimental Study on old people

3.2.1 Introduction

Based on the preliminary study, a case study, including older people with and without anxiety were conducted. Hence, the below described intervention study included two old participants in order to compare and to proof the hypothesis also in elderly. Moreover, the results will be considered for the main experimental study in the next months. The selected methods running the study are similar to the preliminary study. Before the intervention, each participant was informed about all procedures and was asked to sign an informed consent. Moreover, the project was following the Declaration of Helsinki-Guidelines and was submitted to the committee for the authorization of the research (CAR) at the University of Rome "Foro Italico" to obtain the approval of ethical aspects.

Similar results as in the preliminary study were expected with older anxious people. Hence, a positive outcome of the analysed factors, such as the fitness, the cognitive and the ERP data after the intervention with feedback were expected. Due to the small number of participants (n=2), no significant results can be presented. However, qualitative interpretation of the results is possible to give tendencies and motivation for the future. Specifically, based on the above-described current knowledge in regard to the thesis topic, following outcomes were expected:

Pre-Tests:

- The ERP data of the anxious older participant during DRT testing will show a hypoactivation in the pN compared to healthy peers.
- The anxious participant will show poor DRT behavioral data compared to healthy peers.

Post-Tests:

- Both, the anxious and healthy participant will show an increase of cognitive and physical fitness, as well as DRT behavioral data after the intervention.
- The anxious participant will show a significant increase of the preparatory negativity after the intervention.
- The healthy participant will show a normalization of the preparatory negativity after the intervention.

3.2.2 Methods

3.2.2.1 Participants

Two participants aged 65 and 87 years, whereas one person showed high anxiety (HA) and the other person no anxiety at all (NA), based on the STAI-Y2 questionary, were assigned for this study. Both participants performed the physical-cognitive DT training with feedback. The participants were living in the close community center and remained independently in their all-daily life. Noteworthy, both were free of any treatments. The recruitment of the participants took place between May and June 2021.
After the enrolment, participants showed no exclusion criteria, so the study could start without any doubts.

3.2.2.2 Study Design

The study is defined as a pre-liminary case study. Due to the Coronavirus situation, only oneperson per time was allowed to enter the laboratory. Hence, less people could participate in the study. The results will be considered for the future experimental study, which is planned for autumn 2021. However, the study contained an intervention, which lasted over 1 month, including 7 training sessions and a pre- and post-screening test. The participants were asked to come to the laboratory at the Foro Italico University twice a week to perform the training.
The schedule was individually managed with the participants twice a week. Additionally, each person participated for the screening tests before, and after the intervention to detect the ERP data, as well as the cognitive and functional fitness.

3.2.2.3 Screening

At the screening sessions, the cognitive and functional fitness of the participants were tested. Also, the anxiety level of the participants was conducted. Additionally, the ERP data during a discriminative task on the computer were measured.
The specified details are shown below:

3.2.2.3.1 Body screening

Table 1 shows the typology of baseline physical data of the participants recorded before the intervention.

Table 1: *Body Screening of both participants*

Body Screening	
Age	years
Sex	f/m
Circumference	cm
Height	cm
Weight	kg
BMI	kg/m^2

3.2.2.3.2 State Trait Anxiety Inventory

To detect the anxiety level of the participants, the so-called “State Trait Anxiety Inventory” (STAI) were used. The STAI-Y version contains 40 self-reported items which aims to assess the trait anxiety as a stable character, as well as the state anxiety about a specific event. The selected assessment remains sensitive to the level of anxiety over many years. Moreover, the inventory has been utilized over 14.000 times, which highlights the enormous relevance.
Hence, the participants were asked to fill out the questionary, which lasted around 5 minutes to complete. Further, the STAI were scored using the norms of the Italian version, whereas the higher scores define the higher level of anxiety. As mentioned in the study

above, the levels of anxiety can be categorized in four categories, whereas a score above 44 is defined as high anxiety (Spielberger et al., 1983).

3.2.2.3.3 Montreal Cognitive Assessment

Next, to screen the cognitive status of the individuals, the “Montreal Cognitive Assessment (MoCA)” was utilized. Noteworthy, the method presents a cognitive screening instrument, which was commonly developed to detect cognitive impairment. This assessment contains cognitive tasks which requires visuospatial, memory, attention, concentration, language, abstraction, as well as orientation skills. The process lasted around 10min.
Moreover, the assessment has been proofed to be sensitive and specific, detecting cognitive impairments, such as Alzheimer’s disease and has been validated for older people ranging between 55 and 85 years. Also, executive functions, higher-level language abilities, and complex visuospatial processing can be mildly impaired in participants with mild cognitive impairments, which are detected by the MoCA (Larner, 2016).

3.2.2.3.4 Functional Fitness Battery

According to the physical fitness assessment, tasks were selected which are suited for elderly people to detect the functional fitness. Noteworthy, positive results ensure all inclusion criteria for a safe participation at the intervention. Moreover, the tasks were scored to detect any difference between the pre- and postintervention. Specifical, the “Four Square Test”, the “Functional Reach Test”, the “Time up and go Test” and basic balance tasks were performed. Those tools are valid and effective methods to measure static and dynamic stability, as well as balance. According to the literature, those factors are associated with detecting the risk of falling. Following test - details are described below:

- Four Square Step Test

  As pictures in figure 8, the participants were asked to step as fast as possible in clockwise and counterclockwise directions on four 1m squares, which are drawn on the floor. The time was taken two times. This test aimed to assess the dynamic stability including four directions. Literature has stated that the assessment presents a reliable and valid clinical test, which is easy to score and to also to administer. Moreover, it shows a high sensitivity and specificity to identify differences between groups of older adults compared to other mobility and balance tests (Dite & Temple, 2002).

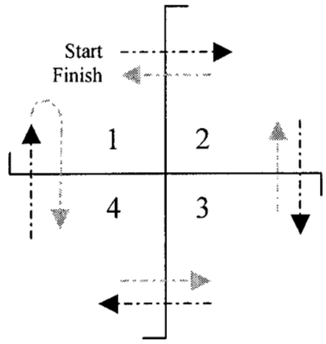

Figure 8: *Representation of the Four Square Step Test (Dite & Temple, 2002)*

- Functional Reach Test

  As seen in the figure 9, the participants were trying to reach the hand horizontal along the wall as far as possible while staying in a fixed feed position. The distance between the stretched arm in normal position and in the maximal movement position were measured two times. According to the literature, the assessment detects the postural control of individuals precisely, inexpensive, but is also age sensitive. Moreover, the functional reach test has been proofed to be clinical accessible (Duncan et al., 1990).

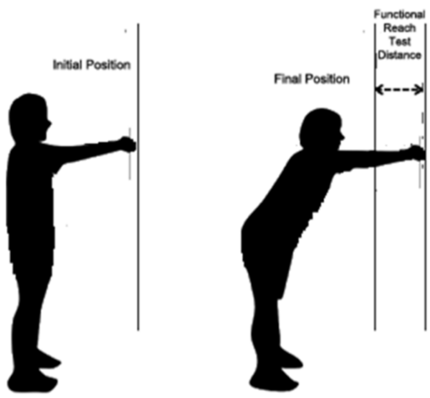

Figure 9: *Representation of the Functional Reach Test (Pires et al., 2020)*

- Time up and Go Test

  The participants were asked to stand up from a chair without support, walk 3 meters forward, turn around an obstacle, walk back and sit down again. The time was taken for two trails. Hence, the purpose was to perform the task as fast as possible. Additionally, another two trails were performed including a cognitive part. Specifically, the participants needed to list the alphabet in alternate version while performing the test. The time was measured, starting and ending in the sitting position in all trails (figure 10).

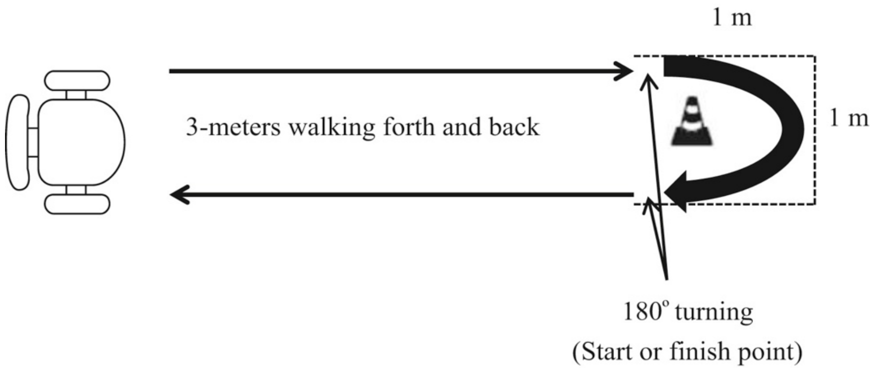

Figure 10: *Representation of the Time up and Go Test (Chan et al., 2017)*

- Static Balance Test

  The balance test included tasks such as standing with both feet, one foot and in the tandem position during different conditions. Hence, each task was performed first with opened eyes and second with closed eyes. The time was measured until the participants could not remain the position without any support. If the individuals reached in any task more than 30 seconds, the tasks could be stopped, and the participants got the highest score.

  Specifically, in the tandem position the participants must stand with one foot in front of the other, while the heel was touching the toe. The task in that position was assessed with the dominant leg in the back. Noteworthy, the balance test on one leg was measured twice for each leg and the best trail was counted.

3.2.2.3.5 Discriminative Response Task

Next, to measure the activity in the PFC during the discriminative response task (DRT), the Electroencephalographic (EEG) were utilized with high temporal resolution using the event-related potential (ERP) as described above. Therefore, a high-density EEG including scalp electrodes were used. The size EEG cap varies according to the size of the participant's head.

Specifically, the cognitive and sensorial preparation phase before the stimuli onset were considered. Accumulated literature has proofed, that the DRT test provides a valid method to record brain correlates of top-down PFC cognitive functions in the visuo-motor tasks using the ERP method. This PFC activity precedes both, stimulus perception and response emission allowing for cognitive anticipation and preparation (pN). The pN presents a preparatory brain wave that precedes and prepares response emission. Also, the pN is the index of the cognitive preparation of action, including attention and inhibition. To highlight, the ERP analysis were focused on the preparatory brain wave labelled as "prefrontal negativity (pN) which is a top-down activity originating from the PFC (Di Russo et al., 2017, 2019).

According to the test procedure, the figure 11 shows the stimuli which consisted of 2 targets plus 2 non-targets in squared configurations. Hence, in contrast to the preliminary study, only 4 different target stimuli were selected, fitting to the cognitive level of the participants. Target and non-target stimuli were randomly presented for 250 ms with equal probability. Likewise, the stimulus onset asynchrony (SOA) ranged from 1.5 to 2.5 s. The participants were asked to press a button with the right index finger when a target stimulus appeared, withholding the response for non-target (go/no-go task). Hence, the response time (RT) as well as the accuracy were measured. Meanwhile, the brain activity were recorded (Di Russo et al., 2017, 2019). The test was repeated 10 times, without any pre-trial. The participants were tested in a pre-set room after preparing the EEG cap. Likewise, the visual stimuli were presented on a 24" screen, sitting in front of the computer. At the center of the screen, a fixation point was always seen. So, they were asked to press the button with the right hand as soon as possible after seeing one of the two Go-patterns. The specific test procedure is similar to the preliminary stud, which is described in the chapter above.

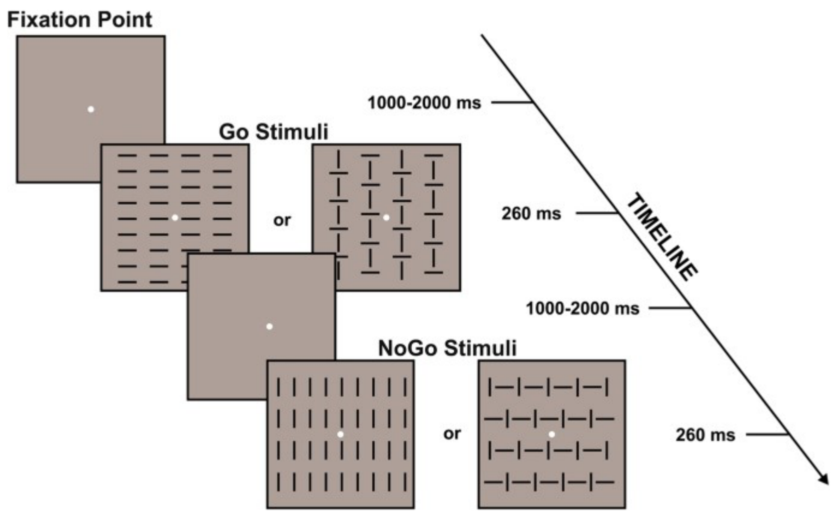

Figure 11: *Schematic representation of the DRT Go/No-go Tasks stimuli (2 Go, 2 No-go) (Di Russo et al., 2019).*

3.2.2.4 Intervention

After the screening day, instructors ensured that the participants provide all inclusion criteria for further participation. Each intervention session lasted around 30 min and took place twice a week in the laboratory of Foro Italico University. In sum, 7 sessions were performed in a month, following the same physical-cognitive dual-task training with feedback.
The concurrent performance of physical and cognitive exercises required inhibitory control of attention, as the attention allocation to both physical and cognitive tasks involve inhibition of prepotent and distracting behavior. Based on previous literature, it is expected that both participants will improve functional fitness and cognitive performance. Additionally, the PFC activity in the pN phase will be normalized, meaning that in anxiety older individuals the activity will decrease, while in health older individuals the activity will increase. Hence, both will benefit from the training with feedbacks and reduce normalize anxiety level (Falbo et al., 2016).

3.2.2.4.1 Training Content

The purpose of the training intervention is to improve the functional abilities as well as the cognitive functions. Hence, this should lead to a better PFC activation and in a further perspective to an improved and independently daily life function. Noteworthy, the program was initially developed in the laboratory of Foro Italico University designed for older people.
It contained tasks which included exercises for the lower and upper body performed either while sitting on a gymnastic ball, standing or while walking. In addition, the training consisted of various stimulus-response cognitive tasks, linking different types of upper or lower limbs exercises with different visual stimuli. So, the tasks were arranged in short routines to concurrently stimulate muscle power, static and dynamic balance and different cognitive functions in a coordinated manner. Likewise, promoting inhibition of habitual responses and challenge working memory, participants performed task sequences reversing or “scattering” the learned order. Also, they were asked to learn different stimulus-response associations and further, to switch between them based on changing external cues.
To perform those tasks, the “Witty SEM” system (Microgate S.r.l, Bolzano, Italy) were utilized (figure 12). Specifically, that training system presents a cognitive reactive training method. It is made up of photocells, which are able to project numbers, letters, arrows and colors. Moreover, those led matrices provide a built-in proximity sensor, which allows an interaction with the performer. Hence, the portable training system provides visuo-auditory

cues to enhance different types of cognitively demanding tasks. So, the cognitive functions of the participants are stimulated while training physical and functional abilities.
These devices can be placed on individual or multiple standing support scattered in the room or placed in front of the sitting or standing participant who will be asked to associate the emitted signals with different physical tasks. So, the devices can be used flexible, in a laboratory or at home and can be self-controlled or controlled at distance by an operator using a smartphone app.

Figure 12: *Witty-Sem Devices by Microgate S.r.l.*

Considering the transfer of the Witty-Sem System to the real-life intervention with older people, the procedure was selected wisely to ensure a safe and effective training method. The stimulus categories were coded by distinct colors and symbols, while the participants were asked to brush as quickly and accurately as possible the sensors with the target color/symbol.
Specifically, the physical-cognitive dual-task training was composed of the following tasks mentioned below. Noteworthy, the difficulty was calibrated in the preliminary testing suited to the participants. However, the level of difficulty was increased individually during the intervention.

1. Direction Change Test:

The participants were asked to move fast to the left or to the right side of the devices to reach two different target positions according to an appearing arrow, starting from a standing position. The arrow was presented on the smart device embedded in a stream of letters (only arrows preceded by and A letter were the starting signal). In the congruent condition the movement were following the arrow direction (right arrow move to the right). In the incongruent condition the movement were opposed (left arrow move to the right). A more difficult level was to include arm movements varying depending on the color (figure 13).

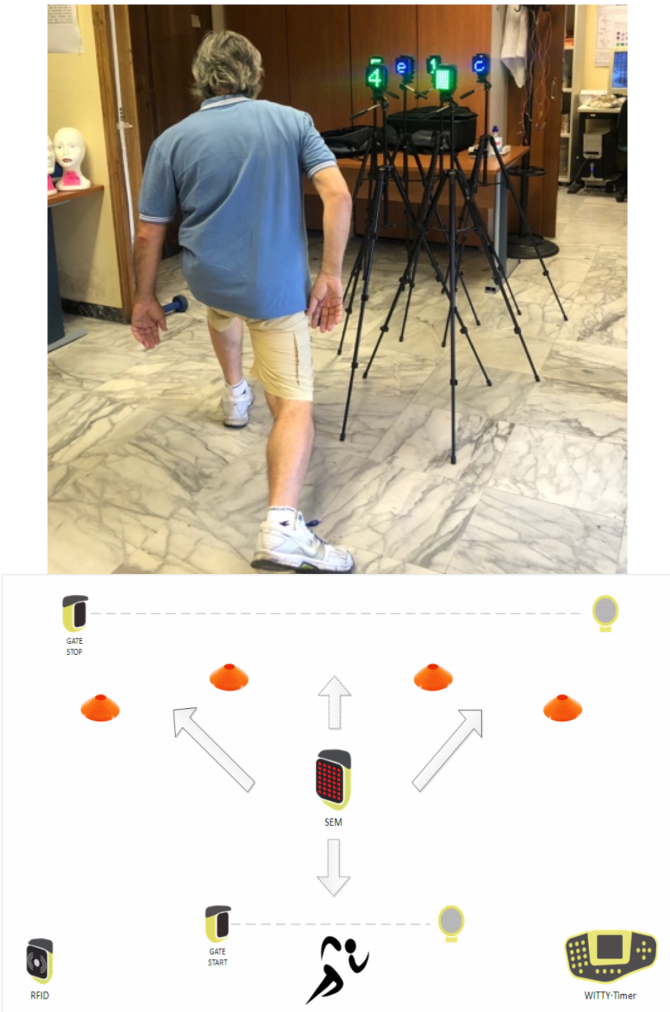

Figure 13: *Representation of the direction change test (Microgate S.r.l, 2019)*

2. Standing DRT – Hawk Eye:

The participants stood in front of up to 6 smart devices placed in a frontal line 1m before the person. The distance to the device were reachable making a big step towards them. The user brushed the selected device flashing with the target symbol/colour combination and stepped back afterwards. Therefore, the easiest level of the program was selected to start. In particular, 5 devices showed a green symbol, while one was showing a red symbol. Depending on the distance of the device the subject had to perform in the direction of the red fish stretching the arm in that direction or making a step forward. The test was challenging especially the peripheral vision and visual precision. Individually, the time of flashing lights were decreased after few sessions to increase the difficulty. Also, participants had to stand on one leg, or walk back and forth meanwhile (figure 14).


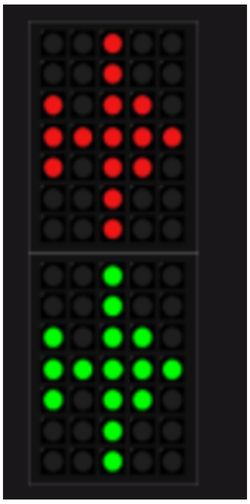

Figure 14: *Representation of the Hawk eye test (Microgate S.r.l, 2019)*

3. Walking Trail Making Test – Juggle Factor:

At the trail making test, consecutive numbers from 1 to 4 appeared in the right order on different devices and disappeared afterwards. Therefore, 6 devices were scattered in a frontal line. Hence, participants were asked to walk as fast as possible without running towards the standing devices indicating the numbers in an ascending order and in the correct position of the presentation after the numbers disappeared. Then, the participant needed to step back to the beginner position. Noteworthy, the first level of this task was selected at the beginning. Individually, the difficulty of the test could increase, asking the participant to step for and back or to move a ball around the body while watching the numbers appearing. Also, a hard level contained the numbers appeared in the opponent order. These tasks were especially challenging the working memory since the user needed to remember the right order and handle them. Hence, also the swift decision making is required.

Figure 15: ***Representation of the Juggle factor test***

4. Eye for detail Test:

   For the so-called “eye for detail” test the users were asked to identifiy two identical symbols out of three. So, they needed to memorize them and brush the selected ones. Therefore, the devices were placed in front of the participant with 1m distance showing three symbols one at a time on different screens. In another trial, the same test was performed in a sitting position on a gymnastic ball. The devices were placed in a half circle shape around the participant. So, the user needed to require more peripheral focus. To increase the difficulty, two out of four symbols were similar and had to be selected. Also, the time of the flashing symbols could be decreased. The test aimed to improve the visual processing, as well as the visual memory (figure 16).

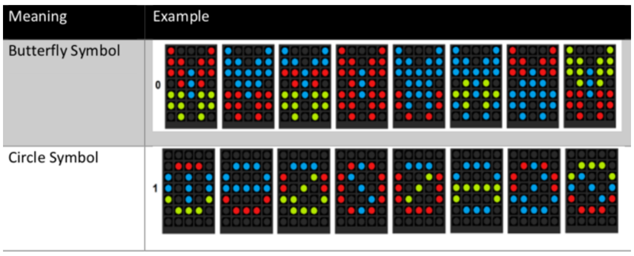

Figure 16: *Representation of the Eye for detail test (Microgate S.r.l, 2019)*

Additionally, the participants received immediate feedback on hits, miss, commission errors and the reaction time by combinations of lights and sounds emitted by the sensors. If there was a mistake, the process was stopped, and a new task was following. Also, a sound rang out and the missed target was presented. Moreover, an assistant provided continuous and immediate verbal and non-verbal feedbacks about the physical performance.

3.2.2.5 Analysis

Since only two participants were participating in the study, a statistical analysis was not applicable. Hence descriptive data were analysed to show single results and to present possible tendencies for future studies. Therefore, the Microsoft Excel program were mainly used to analyze the data and to create figures. The results were compared within the participants before and after the intervention calculating the change in percentage of the initial value. Additionally, data were compared with preliminary data of young participants.

3.2.3 Results

3.2.3.1Basic Screening

The HA participant is female and 78 years old, the NA participant is male and 65 years old. According to the BMI classification for elderly of the World Health Organization, both showed a normal BMI (table 2).

Table 2: *Body Screening of both participants*

	NA (not anxious)	*HA (high anxious)*
Age	65	78
Sex	male	female
Height	1.69m	1.55m
Weight	85.2	61.2
Circumference	107cm	99cm
BMI	29.8	25.5

3.2.3.2 Montreal Cognitive Test

As pictured in figure 17, at the Montreal Cognitive test, the NA participant reached a score of 27 points before and 26 points after the intervention. Hence, he showed a normal cognitive ability in both tests (Larner, 2016). In contrast, the HA could improve the cognitive ability after the intervention. She reached a score of 18 point at the pre-test, which is categorized as a cognitive impairment. After the intervention, she could reach 25 points, which presents an improvement of 39%.

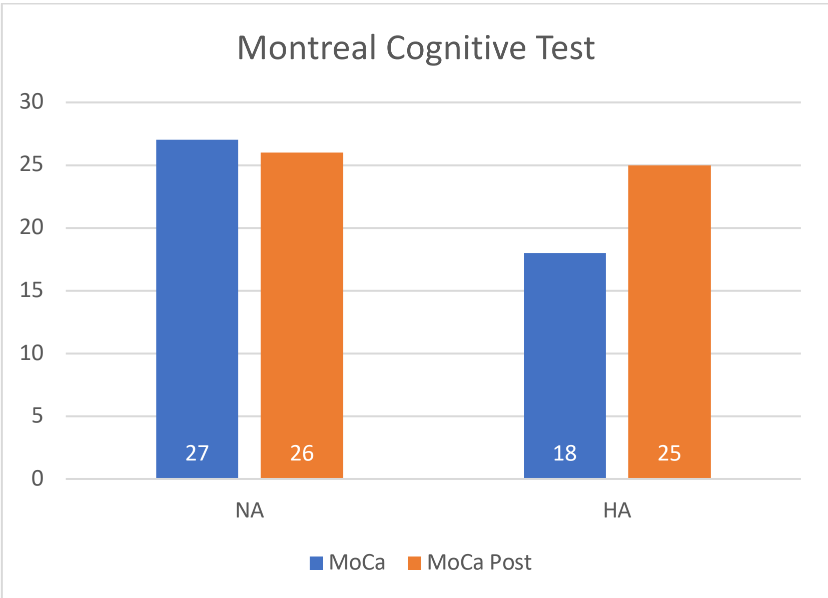

Figure 17: *MoCa score of both participants before and after the intervention*

3.2.3.3 State Trait Anxiety Inventory

The NA participant showed no anxiety level at all at the pre-test. He did not show a great difference of both, the trait and the state anxiety level after the intervention. According to Ansari & Derakshan (2011a, 2011b), with 25 and 23 points on the anxiety questionary he stood on the lowest level.

The HA participant showed a high trait anxiety (46 points) and a low state anxiety before the intervention (32 points). Noteworthy, a high anxiety level are classified with more than 44 points. Showing in the table 3 below, the anxiety level of the HA participant could decrease after the intervention. The participant reached the lowest trait anxiety level (25 points), while the state anxiety level stayed stable (31 points). Hence, the trait anxiety level decreased about 46% from the initial value.

Table 3: *STAI Scores of both participants before and after the intervention*

	NA		*HA*	
	Pre	Post	Pre	Post
Trait Anxiety	24	25	46	25
State Anxiety	21	23	32	31

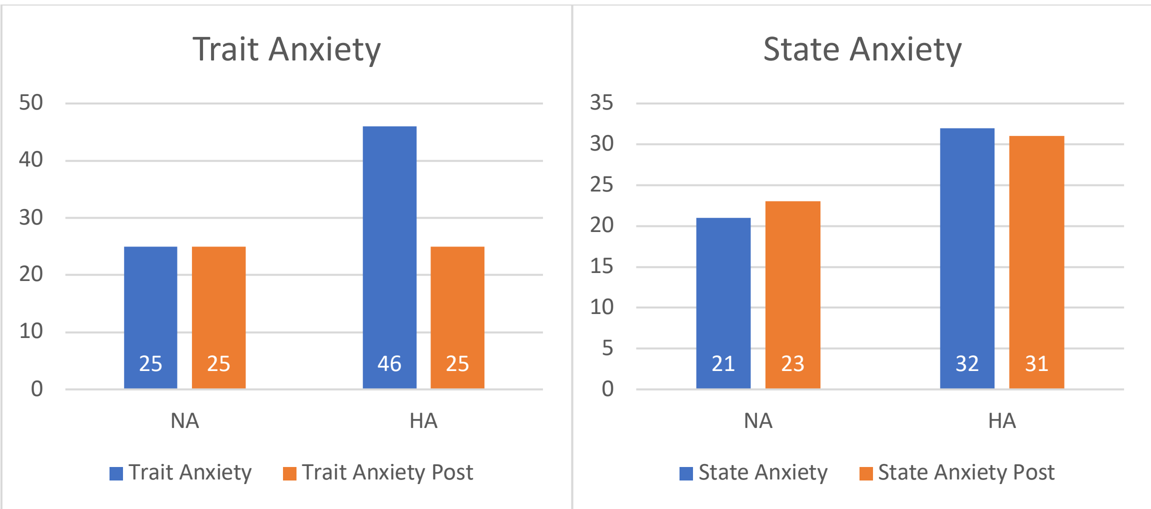

Figure 18: a) *Trait Anxiety Score of both participants;* ***b)*** *State Anxiety score of both participants before and after the intervention*

3.2.3.4 Fitness Assessment

According to the fitness screening before and after the intervention, the participants could try every task once before the trial was recorded. All balance tests were assessed only once, while the 4 square test, the time up and go test and the functional reach test were recorded twice and the mean value of both were calculated.
All results in details from the Pre- and Post – tests are listed in the table 4 and illustrated in the figure below:

Table 4: *Fitness Tests of both participants before and after the intervention, (OE = open eyes, CE=closed eyes, 30s= max reached; -= not attempted)*

	NA		*HA*	
	Pre	Post	Pre	Pos
Standing OE	30s	30s	30s	30s
Standing CE	30s	30s	30s	30s
Tandem dominant OE	30s	30s	30s	30s
Tandem dominant CE	3.75s	30s	-	4.99s
Tandem nondominant OE	30s	15.91	-	3.03s
Tandem nondominant CE	24s	30s	-	2.03s
One Leg dominant OE	22.66s	18.22s	2.37s	9.13s
One Leg dominant CE	1.72s	4.06s	-	3.66s
One Leg nondominant OE	0.89s	30s	-	1.66s
One Leg nondominant CE	5.87s	4.43s	-	2.91s
Functional Reach Test (mean)	37.5cm	36.5cm	24cm	28cm
4 Square Test (mean)	8.86s	7.35s	13.06s	8.19s
Time up and go Test (mean)	7.86s	4.56s	12.36s	6.38s
Time up and go Test cogni-tive (mean)	9.95s	5.41s	21.38	12.02

All, standing with opened eyes, closed eyes, and the tandem position with the dominant leg wit opened eyes could be performed for more than 30s by both participants.
Considering the results of the NA participant, various improvements can be seen. Especially, the time during the functional fitness tests could be increased, while the balance

tests only partly improved. The mean time of the 4 square test decreased from 8.86s to 7.35s, the mean time up and go test from 7.86s to 4.56s and the same test with cognitive task added from 9.95s to 5.41s.

The HA improved the performance in every task. While the participant was too anxious and not able to perform the most balance tasks before the intervention, she could perform all of them after the intervention. Additionally, the mean distance at the functional and reach test improved from 24cm to 28cm, which presents a 17% increase. Likewise, to the NA participant, she performed the functional tests faster. She improved the time about 37% at the 4 square test from 13.06s to 8.19s. Remarkable, the mean time at the time up and go test decreased almost about the half (49%) from 12.36s to 6.36s. Likewise, she performed the cognitive time up and go test within 21.38s before and 12.02s after the intervention, which presents a 44% improvement from the initial value. The results of both participants are pictured in the figure 19 below:

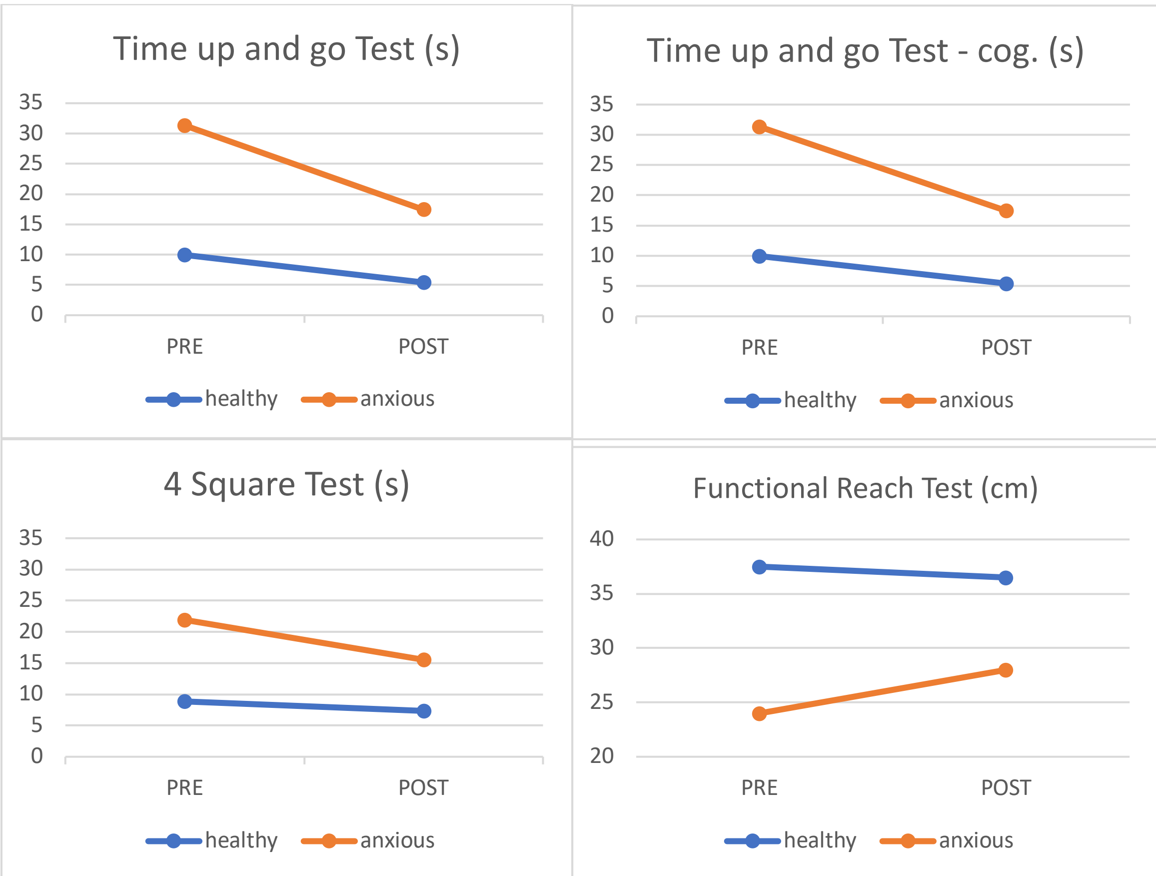

Figure 17:* *a)* *Time up and go Test (s),* *b)* *Time up and go Test – cognitive (s),* *c)* *4Square Test,* *d)* *Functional Reach Test (cm) of all participants before and after the intervention.

3.2.3.5 Discriminative Response Task

The behavioural data of the discriminative response task were compared to the representative group of the preliminary study described above. Generally, the response speed, the response consistency, the accuracy and the commission errors were evaluated.
The mean response time and the standard deviation were needed to calculate the intra-individual co-efficient of variation (ICV). The omission errors (OE – missing responses to the targets) as well as the commission errors (CE – responses to No go trials) were used to evaluate the accuracy.

As shown in the table 5 and illustrated in the figure 20, the healthy young participants showed better results in every behavioural DRT factor. The response time to the stimuli were improved of the HA participant about 41% (962–560 ms), while the response time of the NA participant were increased about 5% (520–550 ms). Likewise, the accuracy of the NA participant enhanced, decreasing the responses to No-go trials from 35% to 19% and the missing responses to targets from 9% to 4%. Also, the HA participant could improve the omission errors from 40% to 26%, but the responses to No-go increased from 23% to 26%.

Table 5: *Behavioural Data of the older participants before and after the intervention and the young participants of the preliminary study*

	NA		*HA*		*NA young*
	Pre	Post	Pre	Post	-
Response time	520ms	550ms	964ms	560ms	450ms
Commission errors	25%	19%	23%	26%	19%
Omission errors	9%	4%	40%	26%	3%
ICV	0.312	0.235	0.303	0.245	0.220

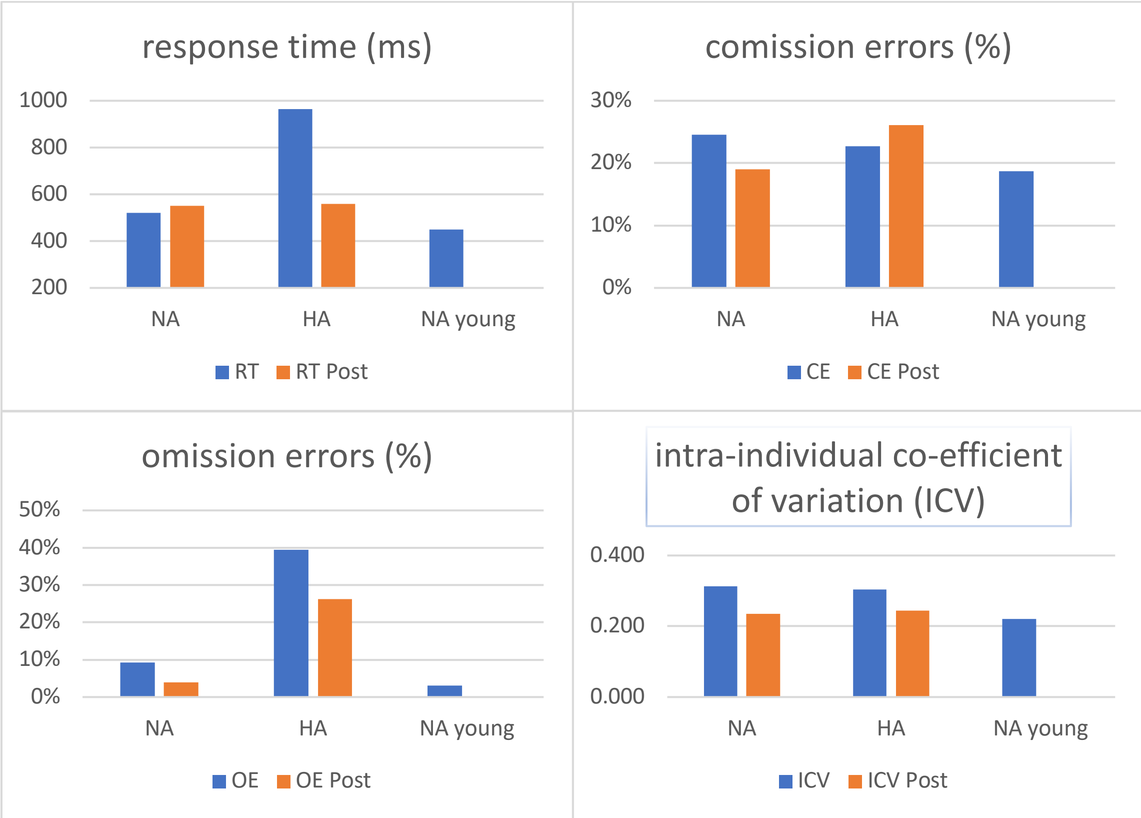

Figure 18: *Behavioural data of the older participants before and after the intervention and the young participants of the preliminary study*

3.2.3.6 ERP Data

Figure 21 shows the pN waveforms developing before at the medial prefrontal electrode Fpz representing the activity of the prefrontal cortex. The BP is also displayed at the medial central electrode CPz representing the activity of the premotor cortex.

A different amplitude of the pN wave can be seen according to the groups and the test before and after the intervention. The pN initiated at about -800 ms and was maximal at stimulus onset. Additionally, data of the group of 15 healthy young participants were added to the figure. Whereas the pN activity of the HA participant was almost flat before the intervention, after the intervention the pN became larger as the young group. In the NA participant the pN was large (greater than young group and the HA participants) in the pre-test and became slightly larger in the post-test.

Additionally, the BP during the DRT test were analysed. Likewise, to the pN improvements, both old participants increased the BP activity. After the intervention, both showed a BP amplitude comparable to that of the young group. However, the HA participant had a lower BP activity in the pre-test and, hence, a bigger improvement. The slope of rising is also different in the HA participant, seeing a flatter curve before the stimulus onset. Looking at the figure below, the BP activity onset is slightly later than the pN component in all participants. The BP initiated at about -700 ms. Noteworthy, the smooth green waveforms of the young group are less noisy than the individual data caused by the average of 15 individuals.

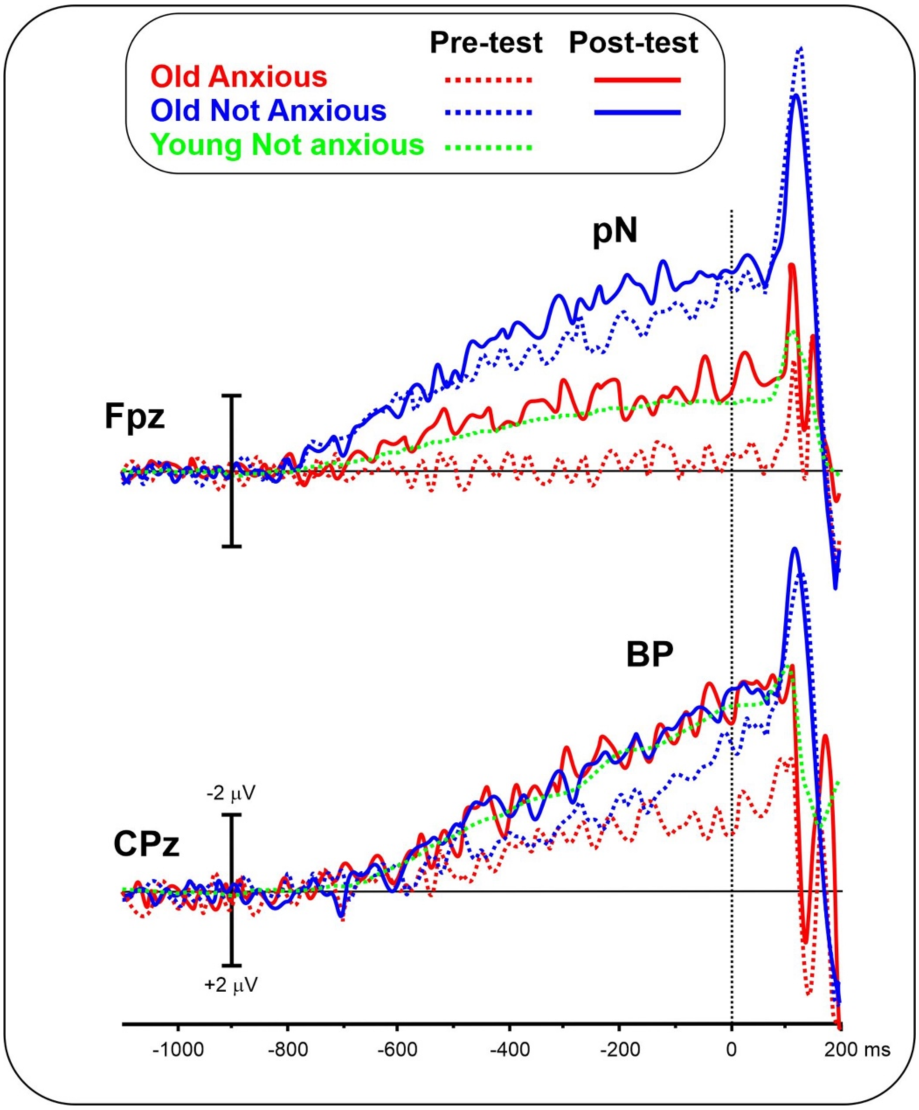

Figure 19: *pN and BP ERP waveforms of the older participants before and after the intervention and of the young participants of the preliminary study.*

Furthermore, the scalp topography of the participants shows the activity distribution before and after the intervention in the intervals from -400ms to 0ms. As showed in the figure 22 there is a great increase of activity at prefrontal and central areas in both participants. While the HA participant did not show any activity at prefrontal and only little in central at the pre-test, there was more activity in both areas at the post-test, detecting almost -5 μV at CPz. The NA participant showed more activity in the right prefrontal area, increasing that activity after the intervention. The topographical distribution was similar in all the reported cases.

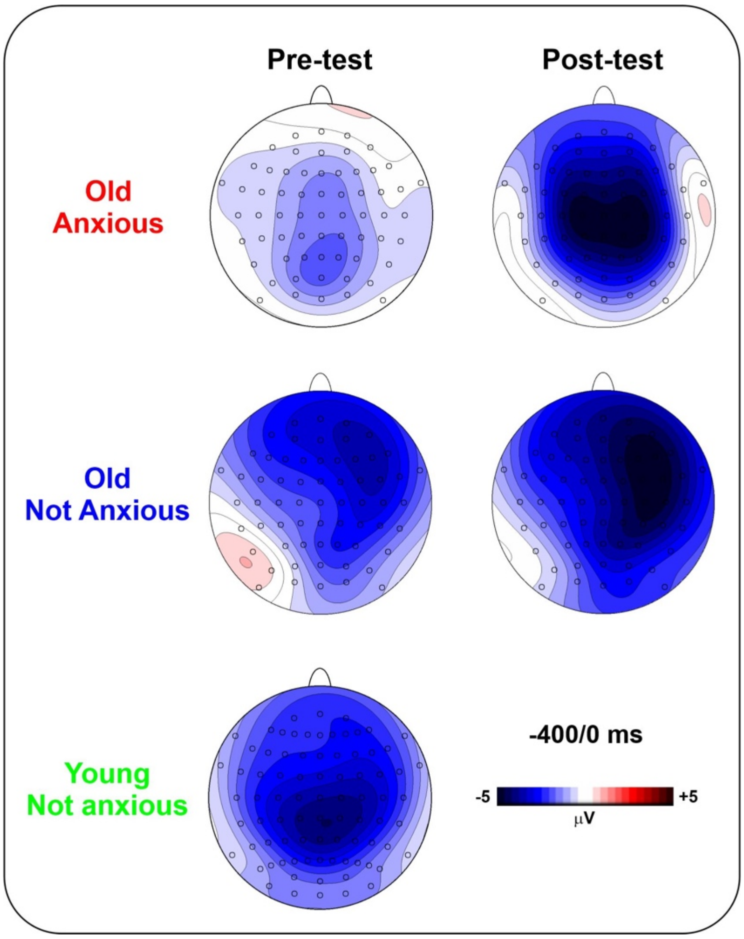

Figure 20: *topographical brain activity distribution at -400/0 ms before the stimuli onset of the older participants before and after the intervention and the young participants of the preliminary study*

3.2.4 Discussion

In the present study, two participants were recruited to perform the intervention with the purpose to provide preliminary data, showing the effectiveness of dual-task training on PFC activity, cognitive function, fitness function and anxiety level. Therefore, pre- and post- screenings were performed, using a high-density EEG with ERP analysis during DRT tasks. Hence, the pN preparatory activities in PFC areas as well as in the premotor BP were analysed comparing the data with normative data from group of young participants. Additionally, functional and cognitive fitness were assessed, and differences were analysed.

3.2.4.1 Anxiety

According to the STAI-Y questionary detecting the anxiety level of the participants, great results after the intervention could be presented. While the NA participant did not show much difference after the intervention and stood on the lowest level, the HA participant improved a lot in terms of the trait anxiety. Hence, she showed a high trait anxiety level before (46 points) but reached 25 points after the intervention. So, the trait anxiety level decreased about 46% from the initial value. Those results are confirming the expected outcomes and are motivating for future research. The fact, that only one month of dual-task training might be required to alleviate a disorder in that extent is great and appeals for further considerations. Moreover, subjectively, the participant felt more secure and told the instructors that she manages the daily life much better in terms of, for example, not holding on a bar while walking the stairs, and more.

In line with the great anxiety results are the functional and cognitive results, confirming a correlation between those factors. Moreover, the improved anxiety level of the HA participant could correlate with the improved behavioural data of the DRT test and the increased pN activity. Hence, the attentional control and processing efficiency might be improved and the distraction by task-irrelevant stimuli could be decreased. Thus, the results are in agreement with the relevant literature, association anxiety with task performance and poor PFC activity (Park & Moghaddam, 2017; Sari et al., 2016). So, stimulating the EFs with dual-task training is in line with few other studies (Falbo et al., 2016; Lord & Close, 2018). Not to forget that additional feedback to the task performance can boost the positive effect leading the internal focus to the effect of the movement (McNevin et al., 2003).

The STAI score and the statement of the HA participant is in agreement with the knowledge of GAD and quality of life. Literature has reported that older anxious people show a decreased quality of life. Since it is known, that GAD correlates with a poor mental health, social functioning and vitality, the improvement of the anxiety level is in great interest for researchers (Hidalgo & Sheehan, 2012).

3.2.4.2 Cognitive performance

When it comes to the cognitive skills after the intervention, the HA participant could improve the score of the MoCa Test about 39% and reached 25 points out of 30 while the results of the NA participant stood quiet stable (27, 26). Research has reported that a score of 18-25 points presents a mild cognitive impairment (*MoCA – Cognitive Assessment*, 2021). Hence, the HA participant almost improved her cognitive skills from a mild cognitive impairment to no cognitive impairment at all. This result is enormous and confirms the expectation. Moreover, it shed lights for a promising and effective intervention method to improve the cognitive status in anxious older people. It has been reported multiple times, that GAD is affecting the cognitive performance negatively, due to worrying and trying to use strategies to achieve the goal (Derakshan & Eysenck, 2009).

Additionally, an early detection of impairment could lead to an effective search for the root cause. It is in great interest to improve the time of the diagnosis since it is evidence-based that this correlates to the quality of life of the affected people. Specifically, the cognitive performance is highly related to the gait performance, meaning that gait impairments and further falls are more prevalent in people with poor cognitive performance. Moreover, this correlation shows stronger effects in older people (Montero-Odasso et al., 2012). Worth to state out, the plasticity of the brain even in older ages allows individuals to improve and prevent degenerative processes, highlighting the importance of the early assessment of cognitive function.

3.2.4.3 Fitness Tests

Considering the functional fitness data after the intervention, various improvements can be reported.

Looking at the balance tests, so it can be seen that the HA participant did not even try various tasks. She was too anxious and/or not able to stand on the nondominant leg and with closed eyes. After the intervention, she could perform every task, which is already a great improvement and worth to report. Noteworthy, the participant is with 5 s at tandem closed eyes task still below the normative data from the study of Vereeck et al. (2008) with age matching dwelling elderly (13.20 s). Also, the task, standing on one leg, could improve about 3 times from 2.37 s to 9.13 s, which is still less than the normative group (21.43 s). Standing with closed eyes, which was not possible before the intervention, she could reach 3.66 s afterwards (representative data: 4.87 s).

However, the NA participant could improve a lot as well. Besides the task of standing with the dominant leg OE, standing with the nondominant leg CE and the nondominant tandem task with OE, the time of the other tasks could increase. After the intervention he could reach the maximal time in both dominant leg tandem task, where he is above the mean time of the normative data. Although, the time of the task, standing with one leg OE and CE, is less than the normative data (27.72 s, 8.93 s).
However, a proper comparisons was not possible, as the participants only had one pre trail and one test trail, while the normative study collected the mean time out of three trails. Those limitation should be considered for the experimental study.
According to the functional reach test it is a clinical assessment to measure dynamic balance aiming to explain the risk of falling, especially in elderly. The distance was assessed two times and the mean were calculated afterwards. Reaching more than 25 cm only low risk to fall can be interpreted (Duncan et al., 1990). Hence, the NA participant did not show any risk, even the distance decreased a bit after the intervention, reaching 37.5 cm and 36.5 cm.
The HA participant only reached 24 cm at the pre-screening, which correlates with a 2x greater risk of falling than normal (Duncan et al., 1990). After the intervention the distance could be improved to 28 cm. Thus, she could decrease her risk of falling. That improved performance at this test could cause from a better movement strategy trained by the dual-task intervention.The 4square step test aimed to assess the ability to step over little obstacles, forward, sideway, or backward. Those movements were also included in various performance tasks in the intervention training expecting better outcomes afterwards. Compared to the representative group of geriatric older people, both participants showed good results. Literature has reported that poor performance in that test correlates also with risk of falling. Specifically, older people reaching more than 15 s are about that higher risk (Moore & Barker, 2017). However, the HA participant could improve the mean performance (test measured two times and mean time were calculated afterwards) about 37% (13.06 s, 8.19 s). Also, the time of the NA participant decreased about 17% from 8.86 to 7.35 s. Hence, the expected outcomes to achieve better results due to the intervention program could be confirmed.
Considering the time up and go test and in addition the cognitive part, great improvements could be observed as well. This test is designed for the elderly population to measure the progress of balance, walking and sitting considering the relation to the risk of falling. Noteworthy, it is recommended that the test including the cognitive part, should not be interpreted solely, due to only moderate accuracy. Remarkable, the HA participant could improve the mean time about the half (49%) from 12.36 to 6.36 s. The literature's cut off point to have a greater risk of falling in older adults are more than 12 s at the test

(Shumway-Cook et al., 2000). Similar results could be shown in the test with cognitive tasks. There she performed the test within 21.38 s before and 12.02 s after the intervention, which presents a 44% improvement from the initial value.
Also, the NA participant could decrease the time almost about the half from 7.86 to 4.56 s and 9.95 to 5.41 s. Hence, no risk of falls would be correlated before or after the intervention. However, better results highlight the effectivity of the program also in healthy older people.
Interestingly, the great improvement might also cause from a so-called learning effect. Since the participants already performed the test before the intervention, the process efficiency and productivity might be increased by the repeated times.

Generally, it is well-know, that physical training enhances cognitive and functional fitness and counteracts the degenerative processes during aging (Gokdemir et al., 2020). According to literature, the dual-task training provides an effective method to affect the fitness and cognitive skills of individuals and reduce risk of falls and in general the morbidity rate. Important to mention, physical fitness is correlating positively with brain structures such as the PFC. In agreement with the literature, in that experimental study, the functional fitness could improve in the individuals after the intervention. Considering the percentage of the improvement, the HA participant had always worse initial values and greater improvements afterwards. Hence, a daring hypothesis can be state out to say that the dual-task training affected both, but the HA more effectively.

3.2.4.4 DRT Behavioural Data

Looking at the behavioural data of the DRT tests, interesting results can be interpreted. Coinciding with Berchicci et al. (2013) the physical status of older people correlates with the response time (RT), counteracting the neural over-activation in the PFC. Similar results can only be observed in the HA participant, since all fitness tests were improved and the response time as well, while the preparatory activity in the PFC increased. In contrast, the NA participant showed a slightly slower response time, while the activity increased. Specifically, the response time could improve about 41% in the HA participant reaching 550 ms, while the NA participant increased a bit from 520 ms to 550 ms.
Literature has mentioned that the activity gets greater to compensate or dedifferentiate more to get better performance outcomes seeing for example in the better response time. Hence, the results of the NA participant, presenting a slower RT and a higher pN activity is not in line with the hypothesis.
In agreement with the previous research, both have a slower RT compared to the young participants (450 ms). The RT correlates negatively with a better accuracy. Hence, more

time gives you a better chance to be more accurate while performing the task. Noteworthy, the hyper-activation leads to a highly controlled top-down behaviour. Additionally, a greater pN correlates with a greater top-down control. (Di Russo et al., 2017)

Moreover, literature has reported, that the slowdown of processing are associated with the impaired daily life activities, such as driving, crossing street, or grasping an object which falls down), not to forget decision making and learning (Berchicci et al., 2014).

However, more knowledge regarding this over-activation combined with the pN activity and the behavioural data of the DRT tests is yet to research. Noteworthy, considering the activity changes of both participants, it is obvious that brain plasticity truly exists.

According to the accuracy of the DRT test, previous literature presented that the CE and OE are affected by the pN activity. So, if the pN activity increases, the false alarms (CE) and the OE (omission errors) decreases. Due to less inhibitory control, participants are less able to prevent the not wanted responses or to respond to the target (Di Russo et al., 2019).

The CE decreased from 25% to 19% and OE from 9% to 4% of the NA participant. Remarkable, both post-results were similar to the results of the young participants. Since a better accuracy is correlating with a slower response time, the NA participant confirmed that with his results (Berchicci et al., 2013). Also, the ICV could improve about 24%. Noteworthy, considering the relative improvement, so there is a reduction of 24% and 56% in accuracy, while the RT only increased about 6%. Highlighting that, there is a better performance outcome after the intervention.

Interestingly, the HA participant could improve almost every behavioural factor. Only the CE, response to no-go's, remained stable (from 23% to 26%). Anyhow, outstanding, the RT is decreased about 42% reaching almost similar results than a healthy person. Also, important to consider, is the OE result, reaching in the pre-test 40% and decreasing in the post-test 26%. Not to forget, that the accuracy is still much lower compared to healthy ones. Relatively, the performance outcomes after the intervention improved immense. Worth to mention, the DRT is activating the process similar to those taking place in the daily life, such as selecting an action as a response to an external stimuli (Di Russo et al., 2019). Hence, assumptions, stating that the participant might also perform better in real life situations, can be stated out.

A growing body of literature has stated out that specific brain areas, such as the PFC supporting the EF, are more sensitive to a physical training than other areas (Berchicci et al., 2014). As described in detail above, the EF are needed performing in an unusual situation initiating a goal-directed behaviour (McAlister & Schmitter-Edgecombe, 2016). The dual-task training is targeting those skills requiring especially the top-down system of the attentional control. Additionally, directing the attention externally by the dual-task training with giving feedback, the task irrelevant stimuli should increase, while the goal directed system increases. This is in high interest for anxious people, considering the threat related process which leads to the less goal directed attention (Derakshan & Eysenck, 2009; Shi et al., 2019).

According to the current state of art, anxiety is also influencing the EF, especially the working memory. Resulting from a poor cognitive control system or from the inability to use control mechanism to screen out task-irrelevant processing and focus on the task (Balderston et al., 2017). Compared to the results of this study, similar effects could be interpreted, since the HA participant showed a better anxiety level, while having better behavioural results at the DRT test.

3.2.4.5 Brain activity

During the DRT, the preparation activity could be mainly observed at the SMA and PFC, as also presented in previous literature (Di Russo et al., 2019).

Compared to the young group, the healthy older participant showed a greater activation in the PFC. This might cause from the general degeneration affected by the age, meaning that an over-activation comes either from a poor neural specialisation and non-selective recruitment. In contrast, the over-activation could express through the recruitment of additional brain areas or the overactivation compensates for behavioural deficits. Hence, two hypothesis could be found in the literature causing the neural over activity in older people calling the compensation hypothesis and dedifferentiation hypothesis (Berchicci et al., 2013).

Additionally, looking at the figure 21, the onset of the pN activity raised earlier in elderly compared to the young participants. The phenomena of the PFC activity in the preparatory phase of the different target groups can be explained, considering the complex of the task. While the young healthy participants did not need any the PFC control activity to perform a quite simple task, it is required for older people. Additionally, the PFC activity of the anxious older people is less, due to the hypothesis of limited brain activity resources which are more required for handling a stressful situation (Berchicci et al., 2013; Di Russo et al., 2017).

The well-known BP is also presenting a slow-rising negativity before an external event, although it is more known for self-paced movements. However, literature has reported that in both situations the BP peaks in medial frontal electrodes, such as the CPz. Moreover, the BP correlates with the response time positively (Di Russo et al., 2019). This hypothesis can be confirmed with the HA participant. As seen in the figure 21 and 22, the BP increased in both participants, but way more in the HA woman. Additionally, the rising slope was at the beginning steep and more flat right before the stimuli onset in the HA participant. Noteworthy, the BP activity in the post-test was almost similar to the young group. Considering the onset of the BP activity, the older participants showed no differences between the time points and compared to the young participants. Although, literature has presented that older people an earlier BP onset (Di Russo et al., 2019). However, generally, more activity difference compared to the younger people are pictured in the pN figure than in the BP.

3.2.4.6 Limitations

Due to the COVID-19 situation, there are various limitations, which affected the study.
Only two participants were recruited because a limited number of people were allowed to stay in the lab at the same time. Hence, just a very time consuming, inefficient procedure was possible. Additionally, recruiting older people had been a difficult process, since the target group was categorized as a high risk group for COVID-19 disease. People were worried to get infected and the mobility to get to the lab presented a big barrier. Moreover, the intervention was supposed to take place in a training group at a gym hall, so more people at the same time could have been trained. Hence, this study cannot be considered as a study with quantitative and significant results for relevant future considerations. The study should be more seen as a pilot study, aimed to present qualitative preliminary data to plan the proper experimental study in the future.
Furthermore, the time period of the intervention was decreased to 1 month, as the start of the study needed to be postponed due to COVID-19 restrictions and there was no more time available to collect the experimental data and deliver the thesis in time. Results might be different (probably clearer) if the intervention would have last 2-3 months.
Having only 2 participants, with a big age difference between both participants, could have influenced out results. Additionally, the participants had to wear the face masks for COVID-19 protection, which was another unpleasant factor, especially for older people and during the summer times, which could have influenced our findings.
The EEG screening test was difficult for one participant which should be considered in the planned future study.The HA participant struggled to follow and remember the visual stimuli in the first screening tests. Different visual patterns, which are easier to distinguish might be an option to achieve a better study run. Next, since the experiment took place in Rome, the participants were only speaking Italian which sometimes led to a language barrier. Hence, another instructor with Italian language skills was required.

3.2.4.7 Conclusion

In conclusion, the experimental study investigated preliminary data about the effect of dual-task training with feedback on the pN activity, the cognitive and fitness level as well as the anxiety level of older people. Conclusively, this presented work added the cognitive part to the well-known physical training expecting a greater effect to all mentioned factors.
The results were interpreted qualitatively and should give some tendencies for future considerations. Major results are in line with previous literature, highlighting the even greater effects on the HA participants and the achieved low anxiety level. From an expanded perspective, especially the EF are on great interest to improve, presenting in detected data, such as DRT behavioural data, cognitive and functional tests and the ERP data.
From a public health point of view, efficiently working EF is crucial for the quality of life, since EF are needed to perform under dual-task conditions, which appear many times a day. Further, poor EF are associated with risk of falls, which also presents an enormous issue in the health sector (Montero-Odasso et al., 2012). Summarizing, that a dual-task intervention might lead to many benefits for elderly but also for anxious older people, not to forget the additional effect when giving feedback.

3.3 Conclusion

This thesis should offer insights into possible opportunities to boost cognitive and functional fitness in elderly, especially with anxiety. The theoretical part described the current state of the art regarding the thesis topic. Hence, health relevance and the gap of knowledge were summarized and presented. Highlighting, that GAD still presents a disorder, where the cause and the treatment are still not 100% clarified. Moreover, it is mostly mixed up with other disorders. It is known that affected people require the brain activity resources for threat-related stimuli in an attention demanding task, occurring multiple times a day. Therefore, brain areas, such as the PFC, are affected with less activity correlating with for example poor EF and leading to poor physical and cognitive performance.
Generally, recent research has presented, that dual-task training might be a new approach to counteract the declining EF during aging. Also, anxious people can benefit from it, increasing their PFC activity. Moreover, it could lead to a greater health benefit, showing better functional and cognitive results, compared to either physical or cognitive training (Lord et al., 2018).
The preliminary study aimed to proof the hypothesis that feedback given to anxious young people increase the preparatory activity in the PFC which gives the initial foundation of the

main experimental study. Therefore, the target group was set for older people with the purpose to improve their degenerated capabilities, which are needed to perform a daily life. A dual-task intervention lasting 1 month were performed including physical and cognitive demanding tasks. The results of the study were mainly in line with the expectations, showing improvement in almost all assessed tests in both participants. Hence, the dual-task training combined with feedback may be a promising method for this aim. As expected, the results of the study show tendencies that all, functional fitness and cognitive fitness, as well as the activity in the PFC are sensitive to that intervention. Moreover, the anxiety level was also improved by the intervention, showing a great result in the HA participant at the post-screening. This represents an incentive for further scientific work in that research field. Noteworthy, the results of the experimental study with the two participants show only tendencies and focus on qualitative interpretations as data collection of a higher number of participants was not possible within the time frame of the thesis due to the COVID-19 restrictions.

Nevertheless, the pre-limenary findings of this thesis might be of high clinical relevance, since many factors, such as EF, are associated with risk of falls, morbidity, and other health-related issues affecting the health care system. Further studies with a larger participant number and a longer lasting intervention are needed to evaluate if the intervention used in this thesis could lead to less medical and psychotherapeutically treatment in the long run and easement of the enormous health care costs in elderly people.

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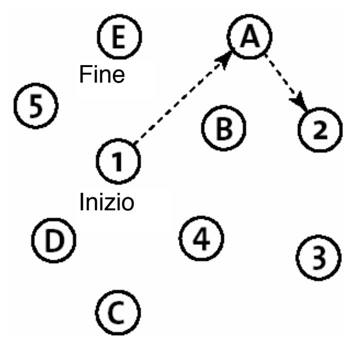
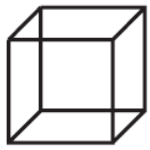
Figures

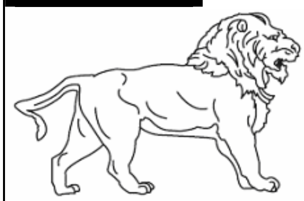
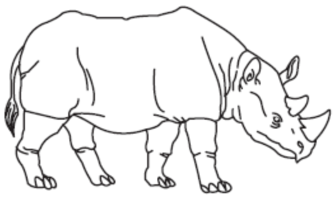
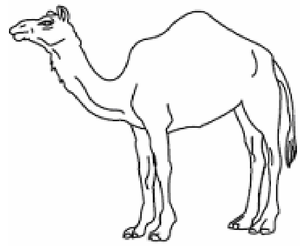
Tables

Attachments

MONTREAL COGNITIVE ASSESSMENT (MOCA)
- ITALIA -

NOME: ____________________
Scolarità: ________ Data di nascita: __________
Sesso: ________ DATA: __________

VISUOSPAZIALE / ESECUTIVO		Copi Il cubo	Disegni un orologio (undici e dieci) (3 punti)	**PUNTI**
 [ ]	 [ ]		[ ] **Contorno** [ ] **Numeri** [ ] **Lancette**	__/ 5

DENOMINAZIONE			
 [ ]	 [ ]	 [ ]	__/ 3

MEMORIA	Leggere la lista di parole: il soggetto deve ripeterle. Fare le prime 2 prove di seguito e il " Richiamo " dopo 5 min.		**Faccia**	**Velluto**	**Chiesa**	**Margherita**	**Rosso**	**0 punti**
		1°prova						
		2°prova						

ATTENZIONE Leggere la serie di cifre (una cifra / sec.)
Il soggetto deve ripeterle [ ] **2 1 8 5 4**
Il soggetto deve ripeterle in ordine inverso [ ] **7 4 2** __/ 2

Leggere la serie di lettere. Il soggetto deve dare un colpetto con la mano sul tavolo ad ogni lettera "A". **0 punti se ≥ 2 errori**
[ ] **F B A C M N A A G H L B A F A H D E A A A G A M O F A A B** __/ 1

Sottrazione di 7 partendo da 100 per 5 volte [ ] **93** [ ] **86** [ ] **79** [ ] **72** [ ] **65** __/ 3
4 o 5 sottrazioni corrette: **3 pt,** 2 o 3 corrette: **2 pt,** 1 corretta: **1 pt,** 0 corretta: **0 pt**

LINGUAGGIO Ripeta:
So solo che oggi dobbiamo aiutare Giovanni. [ ]
Il gatto si nascondeva sempre sotto il divano quando c'erano cani nella stanza. [ ] __/ 2

Fluenza / In 1 minuto, nomini il maggior numero possibile di parole che iniziano con la lettera "**F**". [ ] __(**N ≥ 11 parole**) __/ 1

ASTRAZIONE Similitudini tra per es. banana / arancio = frutti; [ ] treno / bicicletta [ ] orologio / righello __/ 2

RICHIAMO DIFFERITO	Deve ricordarsi le parole **SENZA AIUTO**		**Faccia** [ ]	**Velluto** [ ]	**Chiesa** [ ]	**Margherita** [ ]	**Rosso** [ ]	Punti solo per ripetizione **SENZA AIUTO**	__/ 5
Opzionale	AIUTO	Categoria Seman.							
		Scelta multipla							

ORIENTAMENTO [ ] Data [ ] Mese [ ] Anno [ ] Giorno [ ] Luogo [ ] Città __/ 6

Versione 26 Luglio 2006
www.mocatest.org

Normale: **≥ 26 / 30**

TOTALE __/30
Aggiungere 1 punto se ≤ 12 anni di istruzione

QUESTIONARIO S.T.A.I.
FORMA Y – 1

Nome e Cognome ……………………………………………………………………………………….

ISTRUZIONI: Sono qui di seguito riportate alcune frasi che le persone spesso usano per descriversi. Legga ciascuna frase e poi contrassegni con una crocetta il numero che indica come lei si **SENTE ADESSO, CIOÈ IN QUESTO MOMENTO**. Non ci sono risposte giuste o sbagliate. Non impieghi troppo tempo per rispondere alle domande e dia la risposta che le sembra descrivere meglio i suoi *attuali* stati d'animo.

---

1 = Per nulla 2 = Un po' 3 = Abbastanza 4 = Moltissimo

1. Mi sento calma	1	2	3	4
2. Mi sento sicura	1	2	3	4
3. Sono tesa	1	2	3	4
4. Mi sento sotto pressione	1	2	3	4
5. Mi sento tranquilla	1	2	3	4
6. Mi sento turbata	1	2	3	4
7. Sono attualmente preoccupata per possibili disgrazie	1	2	3	4
8. Mi sento soddisfatta	1	2	3	4
9. Mi sento intimorita	1	2	3	4
10. Mi sento a mio agio	1	2	3	4
11. Mi sento sicura di me	1	2	3	4
12. Mi sento nervosa	1	2	3	4
13. Sono agitata	1	2	3	4
14. Mi sento indecisa	1	2	3	4
15. Sono rilassata	1	2	3	4
16. Mi sento contenta	1	2	3	4
17. Sono preoccupata	1	2	3	4
18. Mi sento confusa	1	2	3	4
19. Mi sento distesa	1	2	3	4
20. Mi sento bene	1	2	3	4

QUESTIONARIO S.T.A.I.
FORM Y – 2

Nome e Cognome ……………………………………………………………………………………….

ISTRUZIONI: Sono qui di seguito riportate alcune frasi che le persone spesso usano per descriversi. Legga ciascuna frase e poi contrassegni con una crocetta il numero che indica come lei *abitualmente* si sente. Non ci sono risposte giuste o sbagliate. Non impieghi troppo tempo per rispondere alle domande e dia la risposta che le sembra descrivere meglio **COME LEI SI SENTE ABITUALMENTE**.

---

1 = Quasi mai   2 = Qualche volta   3 = Spesso   4 = Quasi sempre

1. Mi sento bene	1	2	3	4
2. Mi sento tesa e irrequieta	1	2	3	4
3. Sono soddisfatta di me stessa	1	2	3	4
4. Vorrei poter essere felice come sembrano gli altri	1	2	3	4
5. Mi sento una fallita	1	2	3	4
6. Mi sento riposata	1	2	3	4
7. Io sono calma, tranquilla e padrone di me	1	2	3	4
8. Sento che le difficoltà si accumulano tanto da non poterle superare	1	2	3	4
9. Mi preoccupo troppo di cose che in realtà non hanno importanza	1	2	3	4
10. Sono felice	1	2	3	4
11. Mi vengono pensieri negativi	1	2	3	4
12. Manco di fiducia in me stessa	1	2	3	4
13. Mi sento sicura	1	2	3	4
14. Prendo decisioni facilmente	1	2	3	4
15. Mi sento inadeguata	1	2	3	4
16. Sono contenta	1	2	3	4
17. Pensieri di scarsa importanza mi passano per la mente e mi infastidiscono	1	2	3	4
18. Vivo le delusioni con tanta partecipazione da non poter togliermele dalla testa	1	2	3	4
19. Sono una persona costante	1	2	3	4
20. Divento tesa e turbata quando penso alle mie attuali preoccupazioni	1	2	3	4