TRANSFER AND MAINTENANCE EFFECTS OF *N*-BACK WORKING MEMORY TRAINING IN INTERPRETING STUDENTS: A BEHAVIOURAL AND OPTICAL BRAIN IMAGING STUDY

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ASİYE ÖZTÜRK

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Submitted by ASİYE ÖZTÜRK in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Cognitive Science Department, Middle East Technical University** by,

Prof. Dr. Deniz Zeyrek Bozşahin
Dean, **Graduate School of Informatics**

Prof. Dr. Cem Bozşahin
Head of Department, **Cognitive Science**

Assist. Prof. Dr. Murat Perit Çakır
Supervisor, **Cognitive Science Dept., METU**

Assoc. Prof. Dr. Annette Hohenberger
Co-Supervisor, **Cognitive Science Dept., METU**
Institute of Cognitive Science, Osnabrück University

Examining Committee Members:

Prof. Dr. Deniz Zeyrek Bozşahin
Cognitive Science Dept., METU

Assist. Prof. Dr. Murat Perit Çakır
Cognitive Science Dept., METU

Assoc. Prof. Dr. Cengiz Acartürk
Cognitive Science Dept., METU

Prof. Dr. Aymil Doğan
Translation and Interpretation Dept., Hacettepe University

Assist. Prof. Dr. Özkan Kılıç
Computer Engineering Dept., Yıldırım Beyazıt University

Date: 29.08.2018

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Asiye Öztürk

Signature : ____________________

ABSTRACT

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Öztürk, Asiye
Ph.D., Department of Cognitive Science
Supervisor: Assist. Prof. Dr. Murat Perit Çakır
Co-supervisor: Assoc. Prof. Dr. Annette Hohenberger
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Working memory training is seen as an effective tool for enhancing performance during a variety of high level cognitive tasks for different groups such as children, older people, and individuals with cognitive problems as well as practitioners of highly cognitive demanding professions. Even though there has been some controversy regarding the efficiency of working memory training interventions, it has been shown that *n*-back working memory training results in improvements in working memory capacity as well as in reasoning skills which points out that it yields both near and far transfer effects. Considering the crucial role of working memory in interpreting profession, this thesis targeted interpreting students in order to investigate transfer and maintenance effects of *n*-back working memory training through a comprehensive analysis of near, moderate, far transfer effects and possible transfer to consecutive interpreting. Combining behavioural data collection methods and fNIRS (functional near-infrared spectroscopy) as an optical brain imaging technique, the thesis was designed as a longitudinal study in which participants completed a series of tests (*n*-back and dual *n*-back tasks, letter and digit span tasks, reading span task, Bochum Matrices Test (BOMAT), short consecutive interpreting) before and after the training as well as three months after the completion of the training sessions. The findings revealed that compared to an active control group, *n*-back group had larger performance gains in near and far transfer tasks, and more importantly in consecutive interpreting scores as a result of enhanced working memory capacity, suggesting that common working memory processes such as maintenance and updating of information and attention are employed in the tasks. Significant neural activity patterns observed in prefrontal cortex especially in dorsolateral prefrontal cortex and dorsomedial prefrontal cortex reflect the shared cognitive processes of *n*-back training and consecutive interpreting, which is supported by performance improvements in consecutive interpreting and increased neural efficiency. In this regard, it is believed that findings of this thesis will have valuable and original contributions to the field.

Key Words: *n*-back working memory training, near and far transfer effects, consecutive interpreting, fNIRS, neural efficiency

ÖZ

SÖZLÜ ÇEVİRİ ÖĞRENCİLERİNE VERİLEN *N*-GERİ İŞLEYEN BELLEK EĞİTİMİNİN AKTARIM VE DEVAMLILIK ETKİSİ: DAVRANIŞSAL VE OPTİK BEYİN GÖRÜNTÜLEME ÇALIŞMASI

Öztürk, Asiye
Doktora, Bilişsel Bilimler Bölümü
Tez Yöneticisi: Yrd. Doç. Dr. Murat Perit Çakır
Eş Tez Yöneticisi: Doç Dr. Annette Hohenberger

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İşleyen bellek eğitimi, çocuklar, yaşlılar, bilişsel sorunu olan bireyler hatta yüksek düzeyde bilişsel beceri gerektiren meslek grupları gibi pek çok farklı kesimin çeşitli üst düzey bilişsel faaliyetlerdeki performanslarını geliştirmek için etkili bir araç olarak görülmektedir. Her ne kadar işleyen bellek eğitimi müdahalelerinin etkililiği tartışılan bir konu olsa da çalışmalarda *n*-geri işleyen bellek eğitiminin, işleyen bellek kapasitesini ve muhakeme becerilerini geliştirdiği görülmüştür, bu da *n*-geri görevinin yakın ve uzak aktarım etkisine işaret etmektedir. İşleyen belleğin sözlü çeviri mesleğindeki önemli rolünü dikkate alarak bu tez sözlü çeviri öğrencilerini hedefleyerek *n*-geri işleyen bellek eğitiminin yakın, orta ve uzak aktarım etkileriyle birlikte ardıl çeviriye olabilecek muhtemel etkisini kapsamlı bir Figurede incelemeyi amaçlamıştır. Davranışsal veri toplama metotlarıyla birlikte optik beyin görüntüleme tekniği olan işlevsel yakın kızılötesi spektroskopisi (fNIRS) tekniği kullanılarak uzunlamasına çalışma düzeni oluşturulmuştur. Katılımcılara eğitim öncesi ve sonrasında ayrıca eğitimin bitişinden üç ay sonra bir dizi test uygulanmıştır (*n*-geri ve ikili *n*-geri görevleri, harf ve sayı dizisi testleri, okuma dizisi/aralığı testi, Bochum Matris Testi (BOMAT), kısa ardıl çeviri). Bulgular *n*-geri grubunun aktif kontrol grubuna kıyasla işleyen bellek kapasitesinin artmasıyla yakın ve uzak aktarım testleri ve özellikle de ardıl çeviride daha yüksek performans gösterdiğini ortaya koymuştur. Gözlemlenen bu etki bilginin tutulması ve güncellenmesi ve de dikkat gibi işleyen bellek süreçlerinin bu tür görevlerde ortak olduğunu göstermektedir. Prefrontal korteksin özellikle dorsolateral ve dorsomedial prontal korteks bölgelerinde gözlemlenen nöral aktivite *n*-geri eğitimi ve ardıl çevirideki ortak bilişsel süreçleri yansıtmaktadır, bu gözlem de ardıl çevirideki görülen performans artışı ve artan nöral etkililik ile desteklenmektedir. Bu bağlamda tez bulgularının alana özgün ve değerli katkıları olacağına inanılmaktadır.

Anahtar Sözcükler: *n*-geri işleyen bellek eğitimi, yakın ve uzak aktarım etkileri, ardıl çeviri, fNIRS, nöral etkililik

To My Beloved Mother and Father, and My Dearest Sister

Şükriye and Fahrettin Öztürk, Ayşe Öztürk

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LIST OF ABBREVIATIONS

BA	Broadmann Area
BOMAT	Bochum Matrices Test
DLPFC	Dorsolateral Pre-Frontal Cortex
DMPFC	Dorsomedial Pre-Frontal Cortex
EEG	Electro-Encephalography
fMRI	Functional Magnetic Resonance Imaging
fNIRS	Functional Near-Infrared Spectroscopy
FOA	Focus of Attention
LTM	Long-term Memory
OFC	Orbito-Frontal Cortex
PET	Positron Emission Tomography
PFC	Prefrontal Cortex
STM	Short-term Memory
WM	Working Memory

CHAPTER 1

INTRODUCTION

In daily life, people always try to be fit and healthy with the help of physical training. They wish to train their skills and enhance their performances on various tasks. The main idea behind cognitive training is also similar to physical training; improving skills that are trained and seeing their effects on a number of other cognitive tasks. This desire for enhancement of performance through both physical and cognitive trainings is relevant for all individuals throughout their life spans. Therefore, there is a growing interest in cognitive training. According to Encyclopaedia Britannica, cognition refers to the set of all mental states and processes related to knowledge, perception and judgment. It entails processes of knowledge accumulation which are carried out consciously or unconsciously. As a fundamental term in cognitive science, it refers to all kinds of knowing and thinking involved in perception, learning, problem-solving and decision making, language use as well as emotional experience (Thagard, 2012). As can be easily understood from the definition of cognition, poor performance or impairments in cognition at any level could jeopardize daily lives of individuals. Therefore, as in physical training, cognitive training plays a vital role for young or older adults or even children because such training enhances not only performance in daily tasks but also performance in professional or academic life.

Cognitive training's main assumption is the plasticity of the brain, in other words, the capability of the brain to change in time through learning and experience. Typically cognitive trainings are administered aiming at increasing performance of a single (e.g. working memory) or multiple (e.g. working memory and reasoning) cognitive skills (Kueider, Krystal, & Rebok, 2014). It should be noted that the goal of cognitive training is to enhance and ease the cognitive performance of individuals in their daily lives not just the performance in the laboratory (Morrison & Chein, 2011). Therefore, it is of significant importance to understand the mechanisms of plasticity in mind and brain and to what extent cognitive training interventions yield transferable effects. Whether, how, and under which circumstances different types of cognitive training interventions yield performance improvements and transferable effects should be carefully investigated with experimental and neuroscience methods because the interest in cognitive training is still considerably strong because of its academic and societal relevance (Schmiedek, 2016).

Recent studies on cognitive training have shown that transferability of training-induced gains to untrained tasks is possible and generalizable effects through training can be achieved especially with cognitive training regimes with a focus on working memory or executive functions (Strobach & Karbach, 2016). Various studies on cognitive training have shown that trainings on different aspects of cognition can yield positive results (e.g., Buschkuehl, Hernandez-Garcia, Jaeggi, Bernard & Jonides, 2014; Dahlin, Stigsdotter-Neely, Larsson, Bäckman, & Nyberg, 2008; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Klingberg et al., 2005; Morrison & Chein, 2011, Schmiedek, Lövden & Lindenberger, 2014). Moreover, it has been revealed in a meta-analysis that cognitive and neural plasticity is present even among older adults and they can show similar patterns in plasticity as in younger adults with respect to training in the domains of executive function and working memory (Karbach & Verhaeghen, 2014).

Working memory (WM) training has been one of the most studied areas in the literature of cognitive training mainly because of the assumption that working memory plays a predominant role in a variety of cognitive processes ranging from language, mathematics to reasoning and decision making. It has been suggested that WM training can result in performance improvements in untrained tasks that strongly rely on domain general components of WM and control of attention. Considering the role of WM capacity as a limiting factor for performance in various cognitive tasks and its relation to cognitive tasks, WM training is assumed to improve not only functioning of WM itself but also other cognitive functions, suggesting that both near transfer to non-trained WM tasks and far transfer to a range of other cognitive functions can be achieved. Even a slight improvement in WM functioning might have significant implications for everyday life (Könen, Strobach, & Karbach, 2016). Furthermore, WM training could be a valuable source of improvement for people whose academic or professional performance or everyday life can deteriorate because of low WM capacity (Klingberg, 2010).

Various studies on cognitive training have been conducted on clinical and healthy populations by researchers from different fields. However, particular professional groups whose cognitive skills are critical for their professional performance or training have not been addressed widely. For example, it has been suggested that military personnel can greatly benefit from cognitive training especially WM training because military operations require a wide range of cognitive skills. Therefore, adopting a targeted, outcome-based approach with an emphasis on near and far transfer effects can be a great tool to improve human performance in military operations (Blacker, Hamilton, Roush, Pettijohn, & Biggs, 2018). Similarly, WM is at the forefront of interpreting profession, and interpreting performance in either simultaneous or consecutive mode depends largely on cognitive skills and WM processes. As emphasized by researchers, future research on transfer effects of cognitive training should focus on what training regimes and what training conditions yield the best transfer effects, and investigate underlying neural and cognitive mechanisms. It should be noted that individual differences play important role in cognitive trainings, and which target group can benefit from such a training, and what could be the impacts of training on applied domains of cognition should be one of the main forces for research (Jaeggi, Buschkuehl, Jonides, & Shah, 2011). Therefore, it is plausible to target such a special group of individuals whose performance rely on efficient use of WM capacity and proper allocation of attention processes, and to pursue a WM training intervention in order to investigate transfer effects of WM training.

1.1.Aims and Scope of the Thesis

WM and its role in language interpreting have been generally investigated with an emphasis on simultaneous interpreting. Executive control and predictive power of WM span tasks have been studied by various researchers (Chmiel, 2018; Hiltunen, Paakkönen, Vik, & Krause, 2016; Timarová, 2012; Timarová et al., 2014). Although WM plays a crucial role in consecutive interpreting, there have been relatively few empirical/experimental studies on consecutive interpreting especially with cognitive approaches (Andres, 2015). Consecutive interpreting is mainly a two-phase language interpreting process involving listening and analysis phase (with note-taking if necessary) and reformulation phase. While language comprehension and reformulation are carried out almost at the same time in simultaneous interpreting, phases of consecutive interpreting are carried out sequentially, which puts additional load on WM operations. WM is crucial for both language comprehension in one language and production in another language. Even though interpreters are able to take notes in consecutive interpreting while listening, it is in a way a distractive process and it is not a practical and wise thing to spend effort to write down everything the speaker says. The notes are just tools to jog the memory of the interpreter and they are not the only source for reformulating the utterances in another language. Therefore, it would be highly beneficial to train interpreters on WM thus enabling them to better comprehend and recall what has been uttered by the speaker. It seems that student interpreters who are still in the process of learning and improving their skills would be a valuable sample because there would be still some space for gaining new skills and development compared to professional interpreters who might have developed effective strategies to reduce their cognitive load and to overcome WM capacity limitations based on experience in their working life. Interpreting students seem to be a proper sample for representing the transfer to everyday skills and tasks in terms of WM training intervention. The main motivation for choosing this sample was to provide an efficient tool for interpreting students to improve their performance in consecutive interpreting and eventually to make consecutive interpreting less challenging and effortless in terms of load on WM operations.

Considering the nature of consecutive interpreting and the role of WM in this process, this thesis mainly aims at investigating transfer effects of one of the most common WM training tools; namely *n*-back task on interpreting students. Taking into account the transfer effect of *n*-back task on WM capacity and executive aspects of WM as well as far transfer in other cognitive tasks, it seems highly valuable to carry out a study on immediate and long-term transfer effects of *n*-back WM training with respect to near, moderate and far transfers as well as possible transfer to consecutive interpreting performances of student interpreters in a randomized pre-, post-tests and follow-up (delayed post-test) experimental design by including an active control group trained on simple letter span.

When it comes to WM training, there are still some issues regarding the duration of the training, the tasks used in experimental and control group, and most importantly whether and which effects are maintained for a longer period of time after the end of the training. Therefore, the combination of training studies and longitudinal studies is desirable to gain a deeper understanding of maintenance and long-term effects of cognitive trainings (Schmiedek, 2016). Therefore, a detailed methodological design was adopted taking into account limitations of WM training studies stated in the literature, and tests were run at three time intervals in order to measure immediate and long-term effects of *n*-back WM training. Furthermore, it has been pointed out that generalizations of effects to real-life cognitive tasks such as everyday skills and educational or occupational/professional achievements can only be shown with direct measures of these tasks (Schmiedek, 2016). Combining common measures of transfer effects with a direct measure of interpreting, the thesis aimed at filling a gap in the literature and showing possible implications of *n*-back WM training in an applied domain of cognition.

In addition to the behavioural method, an optical brain imaging method was applied by means of fNIRS (Functional Near-Infrared Spectroscopy). fNIRS is a portable device with a flexible sensor and its sensor can be easily placed on the forehead, which provides a comfortable quiet environment to run tests even on children and clinical populations. It can even be used in real-life settings (Herff et al., 2013). Furthermore, it has higher temporal resolution and it is much easier to monitor brain activities in prefrontal cortex during a wide range of motor and cognitive tasks under more “natural” and variable conditions (Masataka, Perlovsky, & Hiraki, 2015). Such features of fNIRS make it a suitable tool for running tests of *n*-back task and consecutive interpreting which are mostly dependent on WM operations that are associated with functions of the prefrontal cortex. Methods of cognitive neuroscience such as positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and electrophysiological approaches (EEG) have been greatly applied in language and interpreting studies to investigate brain function and plasticity (see Rinne et al. 2000; Hervais-Adelman et al, 2014; Moser-Mercer, 2010). They are valuable tools for studying complex processes of interpreting in which brain systems related to language and communication interact (Moser-Mercer, 2015). However, the studies incorporating cognitive neuroscience approaches into interpreting have largely focused on simultaneous mode of interpreting. Therefore, it is hoped that the findings of this thesis would contribute greatly to understanding neural mechanisms of consecutive mode of interpreting which has not been tackled so far based on the literature review by means of fNIRS. Such an integrated and elaborative approach with multidimensional elements would pave the way to gain a better insight into underlying neural mechanisms of transfer effects of *n*-back WM training as well as task-relevant processes of consecutive interpreting. In this way, possible increases in training-related performance gains due to transfer to trained, untrained and daily/everyday tasks would be better understood, and efficiency of such a WM training intervention and possible implications for interpreting training programs would be presented.

1.2. Research Questions of the Thesis

Considering the main aims of this thesis and major assumptions of transfer of skills, the investigation areas of the thesis can be grouped as follows with specific research questions:

1. **Investigating immediate transfer effects of *n*-back WM training in terms of change from pre-test to post-test**
   How do *n*-back and control groups differ in terms of performance gains at near transfer tasks measured with digit simple task and dual *n*-back task?

How do *n*-back and control groups differ in terms of performance gains at moderate transfer task measured with reading span task?
How do *n*-back and control groups differ in terms of performance gains at far transfer task measured with BOMAT matrix reasoning task?

2. **Investigating maintenance of transfer effects of *n*-back WM training in terms of change from post-test to follow-up**
   To what extent are near, moderate and far transfer effects maintained?

3. Investigating transfer effect of *n*-back WM training to real-life/everyday skills
   How do *n*-back and control groups differ in terms of performance gains in their consecutive interpreting performances based on their content accuracy scores?

4. Investigating neural mechanisms of transfer of *n*-back WM training as well as neural activity during *n*-back task and consecutive interpreting
   To what extent does *n*-back WM training yield neural efficiency in terms of plasticity?
   What are the functions of specific areas of prefrontal cortex in performing *n*-back task?
   What are the functions of specific areas of the prefrontal cortex in consecutive interpreting without note-taking?

It has been suggested that WM capacity can be a good predictor of simultaneous interpreting performance and WM capacity may account for great variance in simultaneous interpreting (Macnamara & Conway, 2015). Considering that WM capacity is also important for consecutive interpreting, interpreter training setting was believed to have a great potential in terms of WM training not just to improve the performance of students interprets but also to investigate to what extent WM training effects can be achieved and how far the transfer effects can manifest themselves in a real-world setting. Within this respect, an integrated investigation of WM training with neuroimaging method may provide a valuable source of better insight into the mechanisms driving WM training effects in an applied domain of cognition.

1.3.Organization of the Thesis

This PhD thesis is composed of a total of six chapters. Following Chapter 1 (Introduction) which sets the scope and aims of the thesis, Chapter 2 (Theoretical Background) provides a detailed framework of WM and transfer of skills in cognitive training with a special emphasis on *n*-back task. Then, the role of WM in consecutive interpreting was addressed in a separate section of Chapter 2. Final sections of Chapter 2 were devoted to neural correlates of WM and *n*-back WM training, and consecutive interpreting and language comprehension and production.

Chapter 3 (Method) provides elaborative information on participants, test materials and measures, the general procedure of data collection and how the tests were run as well as how optical brain imaging data were collected by means of fNIRS.

Chapter 4 (Results) presents behavioural findings of each transfer task and training-related gains in performance based on proper statistical analyses. Furthermore, optical braining imaging findings based on oxygenation changes were presented for *n*-back and consecutive interpreting tasks with respect to all task-relevant optodes.

Behavioural and braining imaging findings presented in Chapter 4, were discussed in detail within the scope of near, moderate and far transfers as well as transfer to an applied domain in Chapter 5 (Discussion). Observed findings regarding transferable effects were supported with related results of previous studies in the related literature and explanations based on theories and models.

The final chapter, Chapter 6 (Conclusion) provided an overall view of the thesis with respect to its aims and research questions, and set forth limitations as well as contributions of the thesis. Finally, future directions and possible future work were presented in the light of the experience gained in the process of this thesis.

CHAPTER 2

THEORETICAL BACKGROUND

Considering interdisciplinary nature of the thesis, this chapter includes separate sections on concepts and frameworks from different fields such as psychology, learning and cognitive training, language and interpreting and cognitive neuroscience. This chapter is composed of a total of seven sections. Definitions and models of working memory are presented in the first section which leads to detailed information working memory training and transfer of cognitive skills in training in the second section. Since the thesis focuses on *n*-back working memory training, a separate section has been devoted to this issue. Following the overall framework of *n*-back WM training, fourth section dwells on role of WM in consecutive interpreting. In line with theoretical background on WM and WM training, neural correlates of WM and WM training with an emphasis on functions of prefrontal cortex are presented in the fifth section. Last two sections specifically focus on neural correlates of *n*-back task and consecutive interpreting, respectively.

2.1. Working Memory

Working memory (WM) has been one of the dominant fields of cognitive and behavioural research and it has been shown in various studies that WM has implications for a wide range of fields such as language, learning, reasoning and fluid intelligence, education, etc.. It is possible to find numerous definitions of working memory (WM) and especially after Baddeley and Hitch (1974) it has become a common term used in various research areas. WM can be defined as a maintenance and processing of information in a simultaneous and controlled way (Baddeley & Hitch, 1994) or a cognitive system for the temporary storage and manipulation of remembered information which can work as an interface between perception, LTM and action (Baddeley, 2003), the type of memory that is active and only relevant for a short period (see Fuster, 1995; Goldman-Rakic, 1995) or the process by which a remembered stimulus is held on-line to guide behavior in the absence of external cues or prompts (see Goldman-Rakic, 1996) (cited in Owen, McMillan, Laird, & Bullmore, 2005, p.46). According to Baddeley (2003), WM is special among memory systems in a sense that it is largely dependent on top-down processing and selective attention, which enable focusing attention on relevant information and ignore distractors (Brem, Ran & Pascual-Leone, 2013). Cowan has proposed a generic definition for WM. Accordingly, WM refers to “ensemble of components of mind that hold a limited amount of information temporarily in a heightened state of availability for use in ongoing information processing”. This definition is mainly based on the assumption that retention of information in WM is limited and does not provide specific components for operations of WM (Cowan, 2017b). It refers to the retention and manipulation of information over a brief period of time/temporarily which is necessary for a wide range of cognitive tasks or processes such as planning comprehension, problem solving and reasoning as well as academic achievement in for example reading or mathematics (Cowan, 2014, 2017a).

It should be highlighted that WM can be considered a system which holds "specific information that is necessary only in a particular situation" (Funahashi, 2017). It is fundamental for academic learning and higher-level cognitive functions from many aspects and it has been shown that measures of WM which include both storage and processing are more correlated with intellectual aptitudes and fluid intelligence than STM measures (Cowan, 2009). While explaining WM and its features, it seems plausible to distinguish short-term, long-term and working memory. The main differences between long-term and short-term memory are the temporal decay and capacity limits. Short-term memory (STM) is mainly related to holding a limited amount of information for a short period of time such as a telephone number. WM includes STM and other processing mechanisms that make use of STM. While STM is only storage-related, WM is related to concurrent deployment of storage and processing. Dehn (2008) provides a nice comparison of WM and STM in order to provide a better understanding of WM. Accordingly, while STM holds information in a passive way, WM processes the information actively; WM is less domain specific while STM is completely domain-specific and divided into as visual and verbal; while WM involves conscious retrieval of required information from LTM, STM operates automatically on data stored in LTM, while WM relies on LTM structures in its operations, STM operations can be independent of LTM (Dehn, 2008, pp. 3–4). It should be noted that WM has a retrospective function and a prospective function which differentiate WM from STM. While retrospective function involves activation of information that has been stored in LTM, prospective function depends on the activation of goal-directed actions (Fuster & Bressler, 2012). Main functions of WM can be summarized as follows (Oberauer, Süß, Wilhelm, & Wittman, 2003).

1. Simultaneous maintenance and processing of information in memory, main processes of WM,
2. Supervision of ongoing processes which corresponds to executive control,
3. Coordination of elements into structures for actions and behaviours.

As can be seen from various definitions and main functions of WM, WM is strongly associated with high level cognitive functions and it has not only information procession operations but also executive functions. Therefore, variations in WM capacity among individuals can be used as a predictive tool for performances in high level cognitive functions such as fluid intelligence, reasoning, mathematics, language as well as academic performance (Cowan et al., 2005). However, it should be noted that the individual differences in WM capacity result from variability in attentional control over what is stored in WM rather than the "absolute amount of storage". This efficient attentional control in highly demanding cognitive tasks seems to be the common ground connecting WM to performance in a variety of demanding cognitive tasks (Eriksson, Vogel, Lansner, Bergström, & Nyberg, 2015, p. 36). It is even stated that WM is indispensable part of attention and it can be even defined as "sustained attention focused on an internal representation", which is critical for reasoning, speech and goal-directed behavior. It should be noted that WM involves temporary activation of updated LTM for future actions which highlights future prospective aspect of WM. This makes WM distinguishable from STM (Fuster, 2015, p.198). The processing function of WM in other words updating, manipulating and coordination information makes WM a "*working system*" on its own. This processing function is necessary for information processing in above mentioned complex cognitive tasks (Rac-Lubashevsky & Kessler, 2016).

As can be seen from the definitions of WM, based on different WM aspects, different frameworks or models have posited regarding components of WM and its functions. Models of WM are generally based on either content material (e.g. verbal and visuospatial) or constituent processes (e.g. updating and maintenance). With regards to a number of behavioral, neuropsychological and neuroimaging studies, it is possible to separate WM into verbal and visuospatial storage units (see Baddeley, 2002), but in terms of executive WM there is no agreement on whether it is content-general or content-specific. Recently, it has been suggested that executive WM can be grouped into two as a dorsal system (visuospatial "where" information) and ventral system (verbal and object-based "what" information) (Waris et al., 2017). Within the framework of the thesis, two specific models have been explained in detail; Baddeley's multicomponent model and Cowan's embedded processes model of WM.

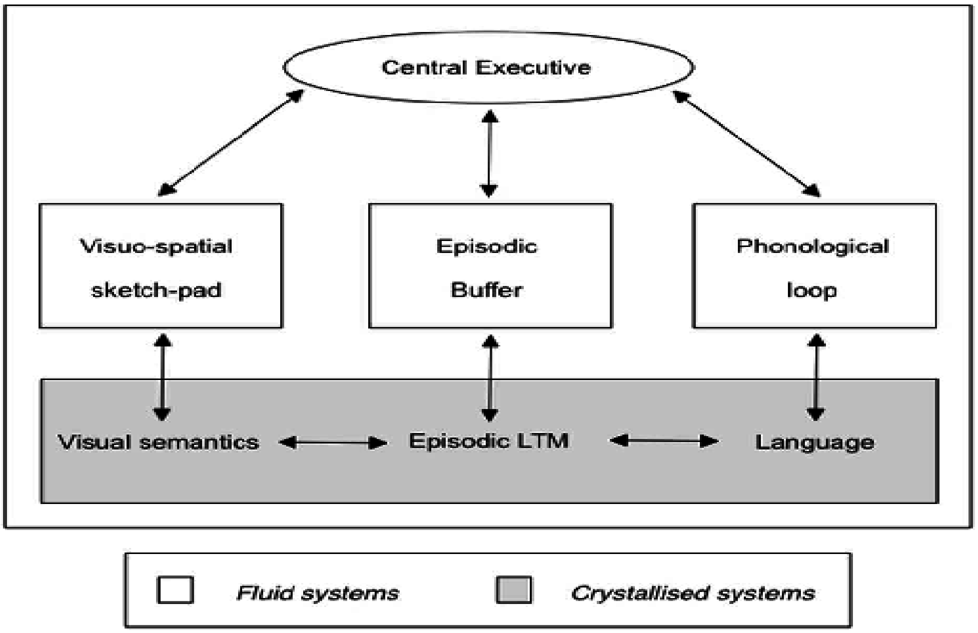

Figure 1: Multicomponent WM model of Baddeley taken from Baddeley (2000)

A multicomponent theory of WM proposed by Baddeley and Hitch provides a framework of WM rather than a theory. The initial framework has been revised in time in a way to explain the relationship between WM and LTM. The original Baddeley and Hitch (1974) WM model consisted of a visuo-spatial sketchpad, central executive and phonological loop. As can be seen in the figure above, current WM Model of Baddeley(2000) represents phonological loop and visuospatial sketchpad as two domain-specific storage systems, the executive control as a supervisory component of WM, and episodic buffer as a general storage and binding component, thus it is a multicomponent system enabling storing and manipulation of information for complex cognitive tasks (Baddeley, 2002). In this model, two slave systems which are visuo-spatial sketchpad and phonological loop involves information maintenance and storage and central executive works as an "attentional controller". While visuo-spatial sketchpad functions for visual materials or items, phonological loop involves speech-based verbal information (Baddeley, 1996). Later on a distinction was made regarding WM as a series of fluid systems requiring temporary activation and LTM involving more crystallized skills. With the addition of episodic buffer (Baddeley, 2000), the link between WM and perception and LTM was better indicated. In this way, the model was modified based on new research and evidence (Baddeley, 2012; Baddeley, 2017).

In this model, the central executive is the core of WM system and has limited processing capacity. As described by Baddeley, central executive is "an integrated alliance of executive control processes including focus of attention, split attention and the control access to LTM. It is solely a system for attentional control without any storage capacity It has been proposed that the central executive has three main functions which are inhibition, switching and updating (Baddeley, 2000, 2010). Episodic buffer on the other hand, is a "temporary storage of multidimensional chunks or episodes with a limited capacity". It accounts for information from various subsystems such as perception, visuospatial and verbal subsystems as well as LTM, and it is assumed that episodic buffer has a limited capacity of storage (Baddeley, 2000).

The central executive is mainly related to controlling all subsystems of WM; namely, visuospatial sketchpad, phonological loop and episodic buffer as well as it regulates and coordinates all cognitive processes involved in WM performance such as allocating limited attentional capacity. Central executive is directly associated with controlling information flow and it is involved whenever information is manipulated in a task such as mental arithmetic. The crucial feature of the central executive is that it is modality or domain free and acts as a bridge between the subsystems which are modality dependent as auditory or visual processing. It should be noted that the central executive has limited resources for storage and processing. Although it may not have a separate storage, it draws on the overall limited capacity of WM (Dehn, 2008, pp.22-23). Individual differences mainly stem from the variability in attentional control over what is stored in WM rather than the "absolute amount of storage", thus individual differences in terms of WM are determined by central executive processes (Eriksson, Vogel, Lansner, Bergström, & Nyberg, 2015; Dehn, 2008).

As opposed to Baddeley and Hitch's multi-component framework of WM, Cowan presents a single storage system composed of elements at various levels of activation while presenting the function-oriented model of WM, emphasizing the significant role of attention. In Cowan's model (1999), WM is based on activated information with central executive processes. WM is composed of the focus of attention and activated LTM. The main difference from Baddeley's model is that there is no separation of information as auditory or visual, according to Cowan, phonological loop and visual sketchpad are just aspects of activated memory (Cowan, 1999, 2009, 2017b). This system can be considered as an embedded part of long-term memory in which current decoded information is processed with already existing information in LTM (Cowan, 2016a). It is "an interface between everything we know and everything we see or do" with a limited processing capacity and elements with higher state of activation fall into the focus of attention since the focus of attention is limited (Cowan, 1993, 2016b). According to the model, all information is considered to activate LTM to some degree depending on attention; therefore, the focus of attention is thought to contain small amount of information which is available for processing directly (Cowan, 1999, 2014b).

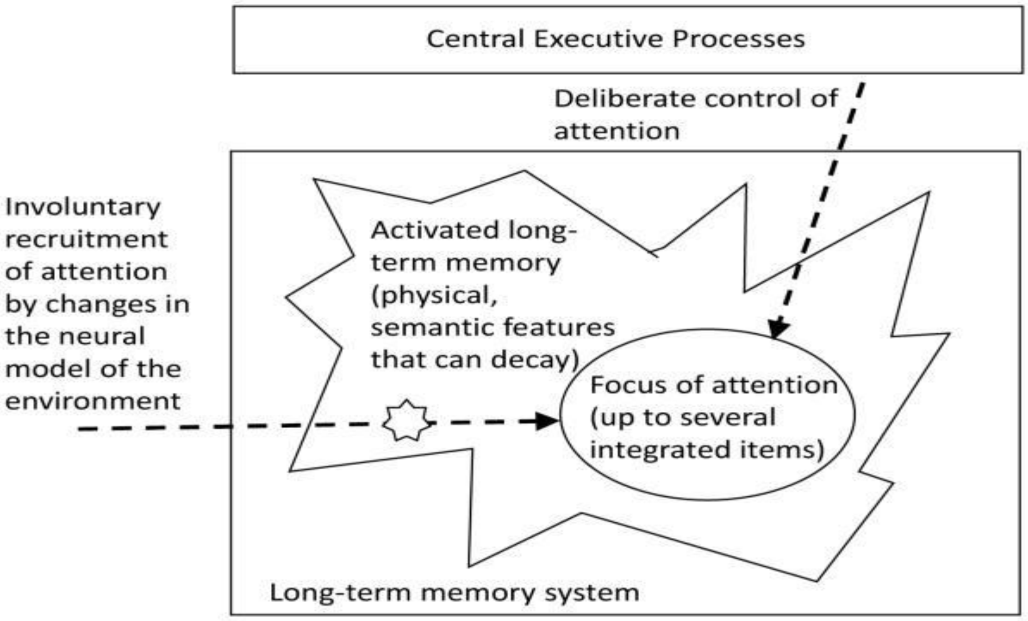

Figure 2: Schematic figure of the embedded-processes model of WM (Cowan, 2016a)

As can be seen in the figure above, in this model, the basic subdivisions of WM are short-term storage components and central executive processes that manipulate stored information. In Cowan's embedded-process model, WM is considered to be a single memory storage system involving elements of information at various levels of activation. WM is embedded into LTM and WM mainly refers to information in LTM which is activated above some threshold. If the activation of information is above the critical threshold, this information becomes easily accessible and is kept in focus of attention. Focus of attention (FOA) is assumed to replace separate storage buffers and the central executive of Baddeley's model. Although only FOA is believed to have limited capacity, this creates limitations on WM retention and processing not on storage capacity (Dehn, 2008, pp.29-30).

In Cowan's Model of WM, there are not specific main modules but rather there are different but overlapping processes for different aspects of information such as semantic, phonological, visual, spatial, auditory, tactile, etc. WM is considered to be "a composite of currently activated segments of LTM" which is accompanied with focus of attention (FOA) (Cowan, 2017a). Differences among individuals in terms of WM result from either "active maintenance in primary memory (focus of attention)" or "controlled search from secondary memory (activated part of LTM)" (Cowan, 2001). Therefore, WM is limited in two ways; limited time and limited item since it is composed of a capacity-limited focus of attention and a temporarily activated LTM. The amount of information that can be held in WM (activated portion of LTM) and capacity-limited focus of attention have various implications for everyday cognition (Cowan, 1999, 2016b, 2017a). The capacity limit of FOA is crucial for academic and cognitive skills. When related information cannot be held in LTM effectively, the capacity limit occurs because of additional load on FOA which is mainly controlled by processes of central executive (Cowan, 2016b).

Although various WM models have been proposed by researchers, one thing is common in all models which is simultaneous maintenance and processing of information. Therefore, it has been shown that WM is essential for various cognitive tasks and it has been argued that WM capacity for storing as well as processing information is limited and individual differences may occur, and thus resulting in constraints in performance of various cognitive abilities (Baddeley, 2012; Oberauer, 2009a). Considering WM capacity, item limits of WM, attentional limits of WM and time limits of WM are commonly addressed and the effects of such limitations of individual's performance have been tackled with various explanations and controversies (Cowan, 2017a). Taking into account that WM is a limited-capacity system of which functions have huge impact on a number cognitive tasks, limitations of WM capacity and more efficient use of WM resources have been the driving force for WM training interventions.

2.2. Working Memory Training and Transfer of Cognitive Skills

WM can be a useful way to predict performance in a variety of cognitive tasks, and WM capacity can predict individual differences in fluid intelligence and executive functioning (Cowan, 2017a; Harrison, Shipstead, & Engle, 2015; Hicks, Harrison, & Engle, 2015; J. Price, Catrambone, & Engle, 2007), reading comprehension (Daneman & Carpenter, 1980), language acquisition (Baddeley, 2003), non-verbal problem solving (Logie, Gilhoolo & Wynn, 1994), and domain-specific reasoning skills (Kane et al., 2004). WM can be a determinant in fluid intelligence (Kane et al., 2004), school achievement (Titz & Karbach, 2014), and a number of cognitive tasks that are relevant in daily life such as language comprehension, writing and following directions (Barrett, Tugade, & Engle, 2004). WM has critical role in not just typical academic tasks but also in creative tasks. It is also necessary day-to-day classroom situations which require high WM demands such as attention (La Lopa & Hollich, 2014, p. 268).

Limitations in WM generally refer to differences at the level of WM and it has been shown that WM capacity is linked to performance in various cognitive tasks such as intelligence and reasoning, multitasking, verbal comprehension and fluency. Low WM capacity has been shown to have adverse effects on not only cognitive abilities but also social abilities. Therefore, the question of whether limitations on WM capacity can be overcome through training has received great attention (Gruszka & Nęcka, 2017). It has been shown in various studies that improved WM of children and young adults could be expanded by extensive training, and performance improvements were observed not just for trained tasks but also non-trained tasks such as reasoning and fluid intelligence (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008).

Training on WM improves not only WM skills but also other complex cognitive tasks which heavily rely on WM processes because WM is assumed to be the underlying shared mechanism in various complex and demanding cognitive tasks ranging from fluid intelligence (*Gf*) to reading skills and mathematics. In a meta-analysis of the efficacy of WM training on learning disabilities, it was concluded that reviewed training programmes showed transfer to both trained and nontrained tasks after training and the transfer effects were maintained after some time (Peijnenborgh, Hurks, Aldenkamp, Vles, & Hendriksen, 2016). In addition to transfer to reasoning skills, transfers were found in attention studies as well. It was revealed that children with ADHD (Attention Deficit Hyperactivity Disorder) showed less inattentive behavior after WM training, which indicates the functional relationship between neural systems responsible for WM and attention (Klingberg et al., 2005).

In WM trainings, two factors may contribute to the transfer effects which are enhanced WM capacity and/or enhanced efficiency in using available WM capacity. While enhanced efficiency is considered to be more process-specific and involved strategy acquisition, enhanced WM capacity is generally the main aim of training interventions and used for the explanation of transfer effects in WM trainings. Enhancing general WM capacity is believed to work on general level which results in transfer effects to other tasks (Könen et al., 2016). The limitations of WM capacity mainly arising from constraints on attentional mechanisms in WM can be overcome at least to some extent through proper WM training interventions (Oberauer, Süß, Wilhelm, & Sander, 2007). It is also reasonable to assume that through effective training, WM may not only increase the capacity but may also expand/enhance cognitive strategies required for maintaining information for a short period of time (Taatgen, 2016).

The relationship between WM and high level cognitive processes can be explained with ***domain-general (executive)*** and ***domain-specific*** factors of WM. While domain-specific aspects of WM are related to maintenance and management of a particular information such as articulatory rehearsal strategy, domain-general factors of WM do not depend on a particular type of information or sensory modality. Domain-general factors are more related to controlling attention and flow of information between the buffers of WM, reducing interference, and governing domain-specific strategies (Morrison & Chein, 2011). Therefore, there is no doubt that domain-general aspects of WM are linked to executive processes which are required in such high level cognitive processes, and trainings targeting these domain-general aspects of WM can pave the way for transfer of effects to untrained tasks, as well along with trained tasks. As stated by many researchers such as Cowan (2005) and Lépine, Gilhooly & Wynn (2005), executive attention processes seem to be fundamental aspects of WM in higher cognitive skills.

Functioning of WM changes among individuals across the life span and it follows an “inverted U-shaped trajectory” and while there is a stability in WM performance between the ages of 20 and 50, WM performance declines from the ages of 55-60 to the ages of 75-80 (Eriksson et al., 2015, p. 39). Therefore, the possibility of strengthening WM by training and experiencing training-related changes attract the interest of people from different spheres of society ranging from academicians and professionals to rehabilitation experts working with adults. In terms of WM training, trainings have mostly focused on either enhancement of WM capacity or increasing the efficiency of WM executive functions. Although WM has long been associated with a limited capacity, it has been shown that it can be expanded with proper targeted training (see Klingberg et al., 2005; Verhaeghen, Cerella & Basak, 2004; Westerberg et al., 2007). However, it is of outmost importance to make a clear distinction between WM training focusing on domain-specific or domain-general aspects of WM because the ultimate goal is to achieve improvements in skills or tasks that go beyond the training task, thus creating transfer effects through process-based training interventions (Jaeggi, Karbach, & Strobach, 2017). For example, if "domain general" improvements in WM training is targeted for someone who cannot add two digits mentally even though she/he knows every step for the correct calculation but cannot keep track of or manipulate the numbers in WM, WM training would train non-math context and have outcome of improvement which transfers to math context (Titz & Karbach, 2014). Other examples could be achieving transfer effects to better performance in reading or sports after training on vision skills (Deveau, Ozer, & Seitz, 2014; Deveau & Seitz, 2014) or transfer of executive function skills to emotional regulation improvement (Hofmann, Schmeichel, & Baddeley, 2012). Highly demanding complex cognitive tasks require WM resources and if mental processing is more efficient in WM, more resources may be allocated to storage. Such processing demands can decrease as the tasks or some components of the task become automated, thus enabling individuals having easy and immediate access to more information. This may give the impression of larger or expanded WM capacity (Dehn, 2008).

Within this perspective, it is possible to divide WM training studies into two groups as **"*strategy training*"** and **"*core training*"** as explained by Morrison and Chein (2011). The main point which they differ from each other is whether the training is targeting domain-specific or domain-general factors of WM. Different versions of ***strategy training*** aim to increase performance in tasks requiring retention of information over a delay. It mainly focuses on encoding, maintenance and/or retrieval from WM. Such training paradigms are more associated with either increasing performance of articulatory rehearsal, executive functioning or encoding strategies. Studies of strategy training support the view that WM can be enhanced by teaching strategies such as rehearsing out loud, telling a story with stimuli or using imagery to make stimuli salient so that the amount of information which has to be recalled can be increased by applying such strategies. However, as noted by Morrison and Chein (2011) the main expectation of strategy training is to increase the performance only with tasks involving materials that are compatible with trained strategy, such training regimes are not expected to yield a performance increase in irrelevant or distant tasks. On the other hand, ***core training*** targets domain-general WM mechanisms. They are designed specifically to limit the use of domain-specific strategies, minimize automatization. Core training requires maintenance of information in case of any interference, and more importantly demand high cognitive workloads or high intensity cognitive engagement.

Single or dual *n*-back tasks, complex WM span tasks are just a few examples of core training which are commonly used by researchers. Such core training regimes aim to demonstrate executive aspects of WM and try to strengthen the domain-general components of WM therefore, improvements in such domain-general aspects through core training are expected to present not just near transfer (high performance in similar tasks) but also far transfer (performance increase in disparate cognitive tasks). In the light of the fundamental difference between strategy and core training, it has been concluded that there should be strong links between executive/domain general aspects of WM and high cognitive processes such as cognitive control, fluid intelligence, reading comprehension, etc. which can be explained by far transfer (Morrison & Chein, 2011, p. 50). A possible explanation for the transfer effects of cognitive training comes from PRIMs Theory which was suggested by Taatgen (2013). According to PRIMs (Primitive Information Processing Element), when specific cognitive skills are learned, this learning process has a "by-product" involving general cognitive skills. These general cognitive skills then can used in different tasks; moreover, these tasks which share general skills can be different from each other but just share same patterns for directing information within the cognitive system. In this way, transfer between skills that are similar in in structure but totally different in content can be better understood. If there is overlap between smaller elements of skills (PRIMs) of different tasks, it means that combined and larger elements learned in one task can transfer to another task, which suggests that effective cognitive training can lead to improvement in general cognitive abilities (Taatgen, 2013).

As emphasized in core training, divide attention, the ability to switch between tasks, to inhibit information depending on its relevance to the task are basic executive functions of WM with respect to multicomponent model of WM (see Baddeley, 1996). The phonological loop and visuospatial sketchpad of the model are content-specific storage systems of WM. It would be of great use to establish the foundation of transfer effects on this multicomponent model of WM. These functionally separate parts of WM can explain the expected transfer effect of a WM training regime. In a broader sense, transfer means expected carry-over effect to untrained tasks via overlaps of involved processes. If the test task includes the same construct as the training task, near transfer occurs; moderate transfer means transfer to tasks that have a lot in common; finally far transfer is observed when related but disparate cognitive resources are employed by the tasks (see Lange & Süβ, 2015). For example;

Near transfer: two separate WM capacity tasks
Moderate transfer: WM capacity and short-term memory tasks
Far transfer: WM capacity and reasoning tasks

Near transfer means improvements in tasks that are similar to the one used in training, and far transfer mean general improvements in skills which are related to the domain of training. In the case of WM training, while near transfer effect refers to performance improvement on WM tasks with verbal and visuospatial stimuli, far transfer effect refers to executive functions such as inhibition, planning, updating, attention and fluid intelligence (Alloway, Robinson, & Frankenstein, 2016). In a nutshell, the distance of transfer is directly related to the overlapping between the trained and transfer construct. In terms of WM capacity, the more WM capacity is employed in transfer construct, the more likely are transfer effects and it is more likely to observe transfer effects if training is effective and there is a strong correlation between trained construct and transfer construct. In other terms, in case of WM training, the more WM capacity is employed in transfer construct, it is more likely to see transfer effects (Lange & Süβ, 2015). When overlaps between the tasks are significant, transfer effects can directly be determined. However, it is also possible that even though the overlap between the tasks is rather small, it is so critical that it produces difference in the performance. This is especially the case when multiple strategies are possible for performing a task and training can lead to a change in strategy in a way that a better strategy is chosen rather than the one that is generally preferred. Such an approach which assumes that general cognitive strategies are learned as a result of task-specific learning can be applied while explaining the transfer effect, the effects of brain training, and various aspects of cognitive development (Taatgen, 2016). Grouping the transfer effects as near, moderate, and far actually helps us to develop a better and comprehensive understanding of transfer effect of a training to a task. These three levels could be regarded as the representation of the gradual development of the transfer effect of a task (Harrison et al., 2013). While evaluating the effect of WM training, training group is compared to a control group at three levels;

(1) improvements in performance on trained WM tasks (training effect),
(2) near transfer to non-trained WM tasks,
(3) far transfer to different cognitive functions(Könen et al., 2016).

In terms of training effects, if there is a control group and presence of near transfer effects to non-trained WM tasks with different types of material and mode of testing, then it can be concluded that training-induced increases have been shown in WM capacity (Klingberg, 2010). When it comes to near transfer effects, recent meta-analyses and reviews have suggested that WM training has near transfer effects to non-trained WM tasks in various age groups ranging from children and younger adults to older adults (Karbach & Verhaeghen, 2014; Melby-Lervåg & Hulme, 2013; Schwaighofer, Fischer, & Bühner, 2015). However, these near transfer effects are generally smaller than training effects and it is important to evaluate near transfer effects taking into account other moderating factors such as individual differences, type or duration of training intervention as well as motivational factors (Könen et al., 2016). Far transfer effects of WM training has been controversial and mixed results can be found in the literature. Far transfer is; however, fundamental assumption of WM interventions which is used to show that training outcomes can have generalizable and transferable effects to other cognitive abilities in people’s daily life (Karbach, Könen, & Spengler, 2017; Könen et al., 2016). In the meta-analysis studies of Au et al. (2015) and Schwaighofer et al. (2015), it was found that there was far transfer effect of *n*-back training on fluid intelligence, however, in another meta-analysis of Melby-Lervag and Hulme (2013) presence of such a far transfer on fluid intelligence was not found.

A variety of studies including video game trainings with a variety of age groups have concluded that cognitive training could have positive effects on perceptual abilities (Deveau, Lovcik, & Seitz, 2014; Polat, Ma-Naim, Belkin, & Sagi, 2004), motor abilities (Hikosaka, Nakamura, Sakai, & Nakahara, 2002) and cognitive abilities such as attention (Green & Bavelier, 2003) and memory (Deveau, Jaeggi, Zordan, Phung, & Seitz, 2014; Jaeggi et al., 2008; Klingberg, Forssberg, & Westerberg, 2002) as well as executive function (Anguera et al., 2013; Dahlin, Nyberg, Bäckman, & Neely, 2008; Smith et al., 2009). All these suggest that cognitive training can result in changes in brain processes and enhance people’s skills and abilities in various daily life tasks, showing that effects of cognitive training can generalize to real-world cognition (Seitz, 2017).

In cognitive training studies, it is also important to show the longevity and maintenance of training-induced improvements. Generally, it seems that near transfer effects are stable over time and in a recent meta-analysis on studies including children and adults, it was shown that immediate near transfer effect sizes were at moderate levels and long-term effect sizes were at small to moderate levels, indicating that near transfer effects have been maintained even after months after the WM training (Schwaighofer et al., 2015). Therefore, it becomes vital to show not only immediate short-term transfer effects but also long-term maintenance effects in cognitive training interventions in order to establish a better explanation for overall transfer effects.

2.3. *n*-back Task as a Working Memory Training Tool

N-back task was originally developed by Kirchner (1958) and then by Mackworth (1959) with increase in *n*-levels. It was introduced to neuroscience by Gevins et al. (1990) as a memory task. In recent years, a number of variations of the "*n*-back" task have been utilized in many studies which investigate the neural dimensions of WM, its relationship with fluid intelligence and matrix reasoning as well as its effect on working memory. Training with *n*-back task is commonly used in various age groups and is even utilized in computerized online environments such as *Braintwister* WM training battery and *Lumosity* cognitive training battery (Könen et al., 2016). Various versions of *n*-back task adaptive or not have often been used as both a WM assessment (Owen et al., 2005) and WM training task (Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008; Jaeggi, Buschkuehl, Perrig, & Meier, 2010; Jaeggi, Buschkuehl, Shah, & Jonides, 2014b; Waris et al., 2017). It is commonly used in studies on aging (Oberauer, 2005; Schmiedek, Li, & Lindenberger, 2009) and WM functions (M Buschkuehl et al., 2008; Dahlin, Nyberg, et al., 2008) and intelligence (Jaeggi et al., 2008; Pereg, Shahar, & Meiran, 2013; Price, Colflesh, Cerella, & Verhaeghen, 2014). Furthermore, it has been shown that *n*-back task is a valid and reliable indicator of WM capacity (Jaeggi, Buschkuehl, Perrig, & Meier, 2010; Wilhelm, Hildebrandt, & Oberauer, 2013).

Typically, *n*-back task entails rather a complex set of cognitive processes including encoding the new item to WM; comparing the item to the one appeared *n* back before; inhibiting irrelevant distraction to the comparison process; updating the position of the item when a new item enters WM; and removing items that are no longer relevant. Demand on storage and various updating operations increases as the level (*n*) is increased from 1 to 3 or 4 (Rac-Lubashevsky & Kessler, 2016). In traditional *n*-back tasks, various subtasks of executive control processes are involved; namely, processing incoming information, maintaining activation of recently processed and potentially relevant information (rehearsal), and discarding irrelevant (potentially interfering) information. In such a demanding task, active control mechanisms is required to temporarily increase or decrease the activation of information depending on its relevance for the task performance (Juvina & Taatgen, 2007). Considering these processes employed in *n*-back task, we can conclude that it dwells upon domain general aspects of WM and executive functions required for various highly demanding cognitive skills and tasks, which could explain its relation to other cognitive tasks such as intelligence, reasoning, problem solving, language and etc..

N-back tasks can be performed either single or dual based the design of the task. Dual *n*-back task has recently been used widely as a tool for improving working memory. In dual *n*-back task, simultaneously with spatial task, a set of auditory stimuli is presented as well. Visual and auditory stimuli have to be processed and matches by the participants whether they are the same as the ones presented *n* back in the sequence. In dual *n*-back task, management of two simultaneous tasks is required; it does not provide any environment for creating task-specific strategies because of the variation in *n* and two different types of stimuli (Jaeggi et al., 2008). In single *n*-back task, participants perform either auditory or visuospatial part of dual *n*-back task in which stimuli are presented in the similar fashion with dual-*n* back task. Participants are expected to match or decide whether the present stimulus is the same with the stimulus presented n trials ago.

The nature of *n*-back task goes beyond traditional WM tasks used in the literature because it encompasses conflicting processes of interference which are required when a current stimulus matches a previous one but not the *n*-back one. N-back task combines both maintenance and manipulation of information, and the level of *n* is considered to be proportional to "WM load" which is "the total demand on the maintenance and/or manipulation processes" (Fletcher & Henson, 2001; Jaeggi, Buschkuehl, et al., 2010a). At cognitive level, *n*-back task entails various executive processes such as active maintenance of the last presented item; updating of new items which enables their active maintenance; binding of items to their serial order for identifying the match between current item and the specific *n*-back item; resolution of any interference from non-matching items (Chatham et al., 2011). Main processes for a successful performance in *n*-back task include familiarity- and recognition-based discrimination processes. Under such circumstances, storage and recalling are not enough. Bindings should be established between the contents and their temporal context for better performance in the task, which is an important feature of *n*-back task (Jaeggi, Buschkuehl, et al., 2010a; Oberauer, 2005). Although both capacity component of WM and executive function or attentional control of WM play active role in *n*-back task, it has been suggested that executive function or attentional control seemed to account for *n*-back performance more, and interference resolution was shown to be an important factor for task accuracy in *n*-back (Harbison, Atkins, & Dougherty, 2011).

It has been shown that training on *n*-back task can yield improvements in non-trained tasks such as reasoning tasks which shows the presence of far transfer. Buschkuehl et al. (2014) underlined that such far transfer could be the result of activation of overlapping brain regions while performing trained and non-trained tasks. This means that both tasks depend on similar overlapping physiological processes (Martin Buschkuehl, Hernandez-Garcia, Jaeggi, Bernard, & Jonides, 2014). Jaeggi et al. (2008, 2010) have also shown that there is a strong relationship with matrix reasoning and fluid intelligence. They concluded that training on both single and dual *n*-back tasks with varying training durations has yielded improvement in fluid intelligence. In a seminal study which investigated the transfer effects of dual *n*-back task, Jaeggi et al. (2008) showed a training-related gain in *Gf* measured with Raven's Advanced Progressive Matrices (RAPM) and Bochum Matrices Test (BOMAT), which was not reported before. Although they presented far transfer effect of WM training, any transfer effects were found in digit span task as well as reading span task (Jaeggi et al., 2008).

In follow-up studies, Jaeggi et al. (2011) investigated short and long term benefits of cognitive training with the participation of children. Children were trained on adaptive spatial *n*-back task. They showed transfer effects to reasoning/fluid intelligence tasks which were measured by TONI (Test of Nonverbal Intelligence) and SPM (Raven’s Standard Progressive Matrices). They have concluded that even though they presented positive far transfer, training and transfer sometimes showed inconsistent results which could be the outcome of methodological deficiencies of individual differences.

In their study which was published in 2014, Jaeggi et al. investigated role of individual differences in cognitive training in which they have controlled all intrinsic factors and experimental design features. They provided evidence for far transfer by using latent variables of the transfer tasks. Such additional elements were initially emphasized by Morrison and Chein (2011) while they were investigating whether WM training really works. They stated that maintenance of training is of significant importance, follow-up tests should be administered, and the degree of motivation, commitment, and difficulty of tasks should be controlled in such training studies.

In a study on immediate and long-term effects of WM training, children aged between 10 and 16 years old were trained on visuospatial *n*-back task over 3 weeks. Compared to a passive control group, immediate and long-term effects were found in auditory *n*-back task and performance improvements were sustained for several weeks. For matrix reasoning task and Stroop task, significant training gains were not found (Pugin et al., 2014). Such results prove that *n*-back task is an efficient tool for WM training and indicate transfer effects in various groups ranging from children to younger and older adults.

2.4. The Role of Working Memory in Consecutive Interpreting

There is no doubt that WM is essential for acquiring knowledge and learning new skills. Almost all complex cognitive tasks rely heavily on WM because multiple processing steps, temporary storage of relevant information, executive functions such as divide attention and focus are important parts of such complex cognitive processes (Jaeggi, et al., 2014). In terms of language interpreting involving speech comprehension in one language and reformulation of the message in another language, WM resources are employed greatly while interpreters carrying out various tasks such as listening, comprehension, information retention, retrieval, production or reformulation, language switching and monitoring (Mizuno, 2005). In both modes of interpreting, namely consecutive and simultaneous interpreting, functions of WM such as executive function and maintenance and processing of information are crucial for quality and better performance in interpreting. In terms of demands on memory and executive control, consecutive interpreting and simultaneous interpreting present different patterns. Compared to SI, there is a higher demand on maintaining information in consecutive interpreting since consecutive interpreting mainly focuses on maintaining and recalling information for changing durations ranging from a few seconds to a few minutes depending on the length of the speech. While simultaneous interpreters are better at inhibiting irrelevant information because they divide their attention between several processes and try to focus on relevant information for interpretation, consecutive interpreters are better at inhibiting phonological, semantic or contextual associations of words or utterances (Hiltunen, Paakkonen, Vik, & Krause, 2016).

Consecutive interpreting can be considered one of the oldest modes of interpreting, which is based on listening to speech or discourse in one language and rendering it into another language in most cases by taking notes. It can be compared to "a chess play in which each piece – in case of consecutive interpreting each units of text – are available before the move" (Alexieva, 1990). It is generally divided into two as long consecutive requiring note-taking and short consecutive without any note-taking. Short consecutive entails interpreting of rather short speeches ranging from one or two words to a few sentences (Russell & Takeda, 2015). It is not always the case that interpreters have the opportunity to take notes while interpreting consecutively; or when the dialogues are short and do not require any note-taking, interpreters do not feel the necessity to take notes. What makes consecutive interpreting different from simultaneous interpreting is that interpreters have the opportunity of getting all the message of the speech before rendering it in another language unlike simultaneous interpreting. In short consecutive interpreting when there is hardly any need for note-taking, then it becomes very similar to simultaneous interpreting but the pace of the whole process is rather slower compared to simultaneous interpreting. Interpreters mainly rely on their memory capacity for producing the message in the target language (Kriston, 2012). Consecutive interpreting is carried out in a sequential order and is mainly a two-stage process, that is, source-speech comprehension followed by re-expression in another language. During the stage of comprehending SL message, the interpreter is required to process information at lexical, phrasal, sentential and discourse levels to carry out analysis of meaning. Skills related to syntactic and semantic knowledge, bilingual and bicultural awareness and knowledge and contextual knowledge are employed. Then, after processing information at all levels, the interpreter reformulates the message and produces it in target language. Cultural and linguistic choices such as planning, formulating and reviewing one's own output are made to provide equivalent message in the target language (see Russell & Takeda, 2015; Pöchhacker, 2011; Russell, 2005).

One of the fundamental features of consecutive interpreting is the separation between the listening and production phase of interpreting, which provides more time for the interpreter to organize his/her utterance. Therefore, during consecutive interpreting, attentive and efficient listening is very important to identify the main points and subordinate ideas within the speech as well as the efficient use of memory. Short-term memory related operations are associated with the interval between the moment information is heard and the moment it is written down or between the moment it is heard and the moment the interpreter decides not to write it down, or again with the interval between the moment it is heard and the moment it disappears from the memory (Setton & Dawrant, 2016).

Consecutive interpreting in interactive discourse situations has been studied not so much as a processing mode but as a communicative activity (Pöchhacker, 2011). Although it heavily relies on memory and attention; there have been very few studies focusing on cognitive aspects of consecutive interpreting especially with empirical methods. Considering the various definitions of working memory which emphasize the executive functions and information retrieval, working memory capacity and efficient control of attentional resource allocation are of significant importance in consecutive interpreting. Therefore, models of interpreting need to focus on component processes of interpreting such as speech comprehension and production, memory, attention and resource allocation and coordination of multiple tasks. Understanding of the interaction between these components and investigating their roles in speech comprehension in one language and expressing the meaning in another language is fundamental to model the process of interpreting (Setton, 2015). Therefore, providing a framework of the mechanisms involved in the process of consecutive interpreting may pave the way for a better insight into CI.

One of the models proposed for understanding the interpreting performance in terms of cognitive load and processing capacity during simultaneous and consecutive modes of interpreting is the Effort Models developed by Daniel Gile (1995). The model was designed to show theoretical and practical aspects of processing capacity (attentional resources) and account for processing difficulties during interpreting. The original model assumed that there are three efforts which are fundamental for interpreting; listening and analysis (L), production (P) and memory (M), then coordination effort (C) was added to the model to reinforce the relationship and interactions between the components of the model (Gile, 1995; Pöchhacker, 2016). In his effort model which is based on the concept of processing capacity, Gile argues that specific effort attributed to each of these components of interpreting must not exceed the interpreter's total available capacity at any time and the processing capacity required for any effort should be sufficient for performing it otherwise performance deteriorations are experiences (Gile, 1995, 2009). According to Daniel Gile's Effort Model (1995/2009), consecutive interpreting which is mainly a two-phased process involving a listening and analysis phase (phase 1) and a reformulation/delivery phase (phase 2) is composed of efforts of listening and analysis, note-taking, memory operations and coordination as shown in the table below and WM is active throughout the whole process:

Table 1: Phases of consecutive interpreting (adapted from Setton & Dawrant, 2016).

Phase 1 / Speaker-paced	Listening and analysis Short-term memory Note-taking (if needed)	**coordination**
Phase 2 / Interpreter-paced	Remembering (LTM) Note-reading (if needed) Production in TL	**rendition**

Listening and analysis effort encompasses all comprehension-related operations ranging from analysis of sound waves reaching interpreter's ear, to analysis of linguistic elements and making a decision about the meaning. Production effort entails producing the message in target language in the most accurate way and monitoring the output (Russell & Takeda, 2015). As pointed out by Gile (1995), some mental operations are non-automatic requiring attention and comprehension in interpreting is a non-automatic process relying on limited cognitive processing capacity. Therefore, when the subskills employed in consecutive interpreting become more routinized and automatic, then more attention can be devoted to other aspects of interpreting process such as contextual clues or rendering accurate and coherent meaning which cannot be routinized (Patrie, 2004).

In her PhD thesis, Ya-shyuan Jin (2010) investigated the role of WM in consecutive interpreting through a series of eight experiments. On-line measures were used to have a better understanding of interpreting process and the involvement of working memory. It was shown that WM was utilized largely during language production in discourse interpreting. The thesis highlighted the need to further analysis the role of WM in interpreting. With respect to the role of WM in interpreting, in a study of

WM advantage in conference interpreting, Chmiel (2018) also found that English reading span scores of interpreting students correlated with high quality performance in simultaneous interpreting when they were tested after two years of university education, which suggests the link between memory and interpreting quality. Furthermore, Dong and Cai (2015) stated that studying the role of WM in consecutive interpreting rather than simultaneous interpreting can be more useful. According to them, simultaneous interpreting requires the coordination of two tasks namely comprehension and production, thus, coordination and suppression seem to be more important than WM capacity. On the other hand, consecutive interpreting requires interpreters first to comprehend the speech and try to recall as much as possible then produce the message in a coherent way based on retrieval of what has been said. This demanding feature of consecutive interpreting shows the close relation between storage and processing definition of WM and consecutive interpreting processes.

With regards to WM and its relation to language, Cowan's model of WM was regarded as a valuable model for showing the interaction between memory system and language system. This model of WM has been largely used in explaining interpreting processes, as well. Even Cowan (2000) himself provided a detailed and comprehensive study in which he provided information on the potential use of his model in interpreting studies. He explained related parts of his model in terms of their relevance to interpreting with regards to selective attention and WM capacity. Cowan stated that capacity of the focus of attention in other words the capacity of memory is no doubt an important asset for an interpreter. He suggested that an analysis of interpreting of larger contexts and immediate speech in terms of WM capacity can be helpful to understand the interpreting process under different situations. WM can be considered as both a storage and attentional control network in interpreting, thus WM capacity and efficient control of attentional resource allocation seem to be vital for a successful performance in interpreting (Pöchhacker, 2016).

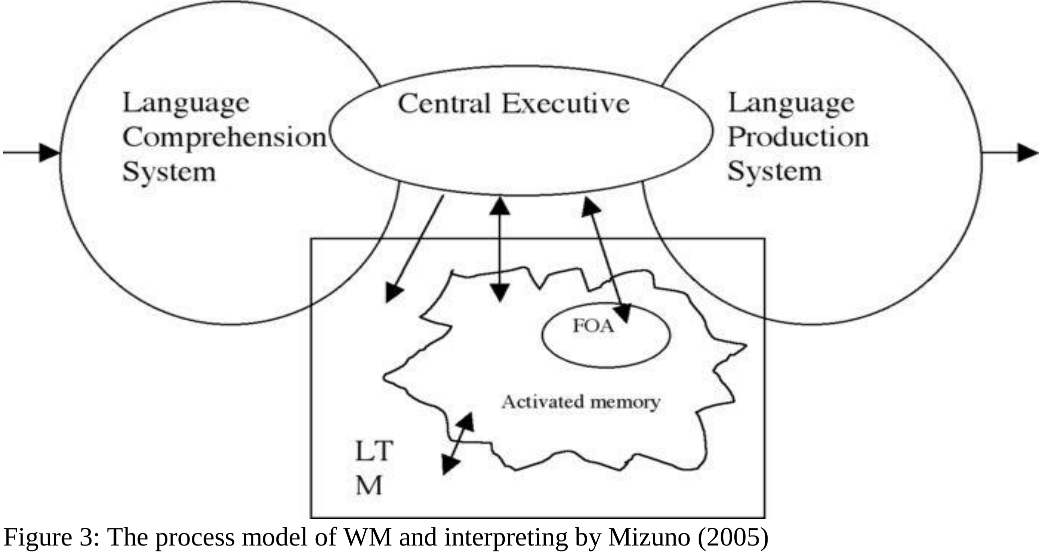

Figure 3: The process model of WM and interpreting by Mizuno (2005)

Since it was highly employed in language processing studies, Mizuno (2005) adapted the model for simultaneous interpreting as shown in the Figure 3 and showed that central executive and long term memory overlap with language comprehension and language production and WM systems and language comprehension and production systems are indispensable components. According to enlarged embedded processes of simultaneous interpreting proposed by Mizuno (2005), LTM entails lexicon of both source and target languages. One of the highlights of his process model of WM and interpreting is that it provides a separation between language comprehension and language production systems indicating two stages of interpreting both in consecutive and simultaneous interpreting.

Further attempts of cognitive models of interpreting have been towards adopting a neurocognitive approach and investigating neural correlates of interpreting with the aid of existing knowledge in language and bilingualism. Based on evidence from lesion studies and their effects on language, Paradis (1994, 2004) identified four main functionally independent systems for L1, L2, L1-L2 translation and L2-L1 translation, and stated that simultaneous interpreting activates two languages at the same time but not to the same extend and involves both hemispheres to different degrees during interpreting. She suggested that during interpreting while left hemisphere is activated for decoding of lexical items (phonological, morphological, syntactic, lexical), right hemisphere is activated for inference of meaning based on existing knowledge, situation, prosody and other paralinguistic elements. Based on this understanding, Paradis presented a dynamic model of simultaneous interpreting presenting eight overlapping operations which happen simultaneously and may take different times during interpreting. Accordingly, each incoming segment of speech undergoes following cognitive steps: echoic memory, linguistics decoding, meaning representation, target language encoding, output, own output in echoic memory, linguistic decoding of own output, and comparison of input and own output (Setton, 2015). These steps can also be applied for consecutive interpreting in a sequential order with a separation of language comprehension and analysis and language production and reformulation. Based on Paradis' dynamic model, Daro and Fabbro (1994) proposed that there are two routes for interpreting process; chunks from WM are either transferred to one of the translation modules suggested by Paradis (L1-L2 translation or L2-L1 translation) or to LTM. This process facilitates the language production in a target language and provides necessary information for the reformulation of the speech.

In an attempt to investigate the effect of dual *n*-back WM training on simultaneous interpreting, in her MA thesis Sakallı (2015) carried out a study on 20 3rd year interpreting students based on a one-group pre-test post-test design. Participants received regular training on dual *n*-back task and were tested on simultaneous interpreting performance in a total of 30 passages which were divided into three as "passages for lexical items", "passages for sequential evets" and "passages for figures". This findings of the thesis revealed that dual *n*-back WM training positively affected participants' simultaneous interpreting performance especially their ability to recall lexical items, sequential events and specific figures. It was shown that dual n-back WM training may result in better comprehension during simultaneous interpreting, and enhance their interpreting performance.

Consecutive interpreting entails highly demanding processes such as decoding, comprehension and reformulation; therefore, a great amount of sustained effort is required in terms of memory and attention throughout interpreting, which can lead to high cognitive load while performing the task. If WM resources are enhanced efficiently, it eases the comprehension processes in a way that interpreters can become quicker in terms of access to lexical and semantic information in LTM. They might even perform necessary cognitive tasks effortlessly with less load on memory (Bajo & Padilla, 2015). Considering the vital role of WM functions in consecutive interpreting, the main aim in memory training in interpreting seems to facilitate especially the comprehension of the source speech because understanding the speech is the first and foremost step of a successful performance in interpreting (Zhong, 2003). Furthermore, it was posited that consecutive interpreting involving complicating decoding, comprehension and reformulation processes requires higher amount of sustained effort in terms of memory and attention. This is mostly due to high level of cognitive load which is imposed by these processes (Bajo & Padilla, 2015). These explanations indicate that particularly in short consecutive interpreting, WM capacity of interpreters may have profound effect on successful speech comprehension and production depending on the duration of speech. Therefore, considering related studies in the literature and recent findings of dual *n*-back study in simultaneous interpreting, it was believed to be useful to conduct a WM training study on interpreting students with respect to the possible effect on consecutive interpreting performance.

2.5. Neural Correlates of Working Memory and Working Memory Training

The processes of WM involve temporary maintenance and manipulation of information which is required for short-term behavioral goals. The influential WM models of Baddeley and Cowan provide different cognitive neuroscience predictions. While the Baddeley's WM model suggests two separate regions for storing information in WM and LTM, Cowan's model suggests that these are the same regions. In terms of storage and rehearsal, Baddeley's model again suggests different brain regions while Cowan's model does not. Therefore, it has been argued that Cowan's model is more likely to support neural findings (Purves et al., 2013). WM involves interactions between processes such as attention, prospection, LTM and perceptual representations. Therefore, different brain regions such as "executive" regions in PFC, parietal cortex and basal ganglia are employed during WM, and neural activity in different brain regions is observed during WM operations including maintenance and integration of information. Although WM relies on dynamic interaction of various brain regions including PFC, parietal cortex, basal ganglia, striatal, medial temporal lobe, it has been established that PFC has a critical role in WM as an integral part of successful WM performance and its subdivisions or regions play specific roles in WM functioning (Eriksson et al., 2015; Goldman-Rakic & Leung, 2002).

The fundamental function of PFC is "the representation and execution of new forms of organized goal-directed action". It is vital for cognitive functions such as planning, decision-making, attention, WM and inhibitory control (Fuster, 2015, pp. 1-4). Each executive function of PFC has a dominant or specialized regional location in PFC and meta analyses have also shown regional specificity of PFC in WM, suggesting that frontal lobes are involved in central executive processing and posterior parts are generally involved more in focus of attention and information storage (Cowan, 2017a). Three regions of lateral frontal cortex; namely, ventrolateral, dorsolateral and anterior regions, are mainly referred to in WM studies using functional neuroimaging. Activation patterns in these areas are generally attributed to specific functions; ventrolateral PFC for updating and maintenance of information, dorsolateral PFC for selection, manipulation and monitoring of that information, anterior PFC for selection of processes and subgoals (Fletcher & Henson, 2001). Furthermore, posterior dorsal parts called as dorsomedial PFC including anterior cingulate gyrus are associated with executive function and this region monitor behaviour and provides a signal when there is a need for increased allocation of executive control. Executive functions which rely on WM capacity such as maintenance and manipulation operations are generally related to PFC (Purves et al., 2013).

Various neurophysiological studies have established the relationship between WM and dlPFC and how active maintenance of information in WM is achieved in dlPFC. dlPFC is considered to be critical in utilizing WM to maintain information for a short period of time (Funahashi, 2006; Goldman-Rakic & Leung, 2002). It has been shown that maintenance-related processes regardless of stimulus type are distributed across both hemispheres of PFC. However, it seems that maintenance of verbal information is strongly linked to left posteroinferior PFC, maintenance of spatial and non-spatial information has weak lateralization. If manipulation of this stored information is required while performing a task, dlPFC is significantly involved to a greater extend (D'Esposito & Postle, 2002).

A number of studies were conducted while subjects were performing a variety of WM tasks with sensory or motor content. For example while left ventral PFC is generally involved in verbal WM tasks, right dlPFC is involved in spatial WM tasks in terms of maintenance of information. Tasks related to updating and manipulation of content in WM have been shown to involve more dlPFC as compared to maintenance tasks (Nee et al., 2013; Owen, McMillan, Laird, & Bullmore, 2005; Wager & Smith, 2003). However, it is crucial to note that no matter what type of material type is in WM, activation in PFC is related to memory load. The activation in PFC increases depending on complexity or number of information held in WM, indicating a load-related activation in PFC (Fuster, 2015). Increased activation in lateral PFC has been associated with WM load; namely more information that needs to be hold in WM, and it has been observed that activation seems to get larger if the task requires manipulation of information rather than simply holding the information in WM. Moreover, it has been shown in fMRI studies that dlPFC is largely employed for manipulation of information in WM (Purves et al., 2013).

PFC is linked not only to information maintenance and processing in WM but also to executive functions. Especially dlPFC which is closely related to WM functions receives sensory, motor, motivational and emotional information from other cortical and subcortical areas. Therefore, it is believed that dlPFC can operate in visuospatial and linguistic information processing as well as any multimodal information processing. The role of dlPFC in information maintenance and processing in WM is more likely crucial for performing the current task (Funahashi, 2017). Considering the role of PFC in WM and neural mechanism of WM training, it has been proposed that there can be four possible brain activation patterns that can be induced by cognitive training based on a review of 18 WM training studies (Martin Buschkuehl, Jaeggi, & Jonides, 2012):

1. Decreased activity after training
2. Increased activity after training
3. A combination of these two patterns
4. A change in activation pattern in different brain areas

Increased activity in a specific brain region generally means strengthening of that region after long-term training. However, activation in the main regions associated with WM training; namely prefrontal and parietal cortex seem to decrease rather than increase after the training. Decreased brain activity in a region after training indicates neural efficiency (Garavan, Kelley, Rosen, Rao, & Stein, 2000; Jansma, Ramsey, Slagter, & Kahn, 2001; Landau, Garavan, Schumacher, & D'Esposito, 2007). According to neural efficiency hypothesis developed by Haier et al. (1988), individual differences in performance in cognitive abilities result from how efficiently brain works during the task rather than how hard it works. This efficiency can be directly associated with disuse of brain areas which are not relevant for the task and more focused use of brain regions which are crucial for good performance in the task, suggesting a negative correlation between brain activity and performance. (Jaušovec & Pahor, 2017a). While decreased activity after training is generally related to neural efficiency hypothesis, increased activity pattern is observed following training on sensory or motor tasks. A combination of these two patterns may mean decreased activity in brain regions of general processes such as attentional control as well as increased brain activity in areas which have task-specific functions for better performance in the task (Martin Buschkuehl et al., 2012). Different patterns of activation before and after WM training in the same area refer to "more efficient engagement of task-specific cognitive processes and reduced demands on attentional control processes" in other words more efficient processing in task-related areas (Kelly & Garavan, 2005; Kelly, Foxe, & Garavan, 2006; Schneiders et al., 2012).

Understanding neural correlates of WM training tasks and other cognitive functions which are tested in such studies is of significant importance and thanks to various types of neuroimaging methods it has now possible to find neuroimaging studies on WM training. It has been concluded that performance increases in WM after training were associated with changes in brain regions such as dlPFC, posterior parietal cortex and basal ganglia which are believed to be related to WM functioning (Morrison & Chein, 2011). If training and transfer tasks employ overlapping mechanisms of neural processing and overlapping brain regions, it is more likely to have far transfer effect (Dahlin, Neely, et al., 2008). Although type of WM training and stimuli used in tasks may differ in studies, training-induced changes in activation have been mainly reported in two brain regions which are dlPFC and regions of intraparietal cortex which are mainly associated with WM function, and increased activation in these regions can imply improvement on WM (Alloway et al., 2016). It has been shown that repeated performance in activities can induce changes in brain structure as a results of synaptic connections based on brain plasticity. Even short trainings have been shown to lead to changes in brain structures of specific areas which are related to the training and it seems that the duration of training may have effect on brain activity. While shorter trainings (less than 3 hours) have generally shown a decreased pattern in brain activity, longer trainings have presented mixed results in a way that both decreased and increased brain activity have been observed (Jaušovec & Pahor, 2017b).

Far transfer effects in WM training studies can be regarded an indicator of the fact that WM being a fundamental cognitive ability is malleable and the plasticity of the brain exhibits itself in WM, as well. Neuroimaging studies focusing on the effects of WM training have shown changes in brain activity during WM tasks and to what extend changes occur when the neural activity is measured before and after the training. Increases or decreases in neural activity in different regions can be associated with increases in WM capacity. WM training results in changes in the activity patterns of networks that are already involved in a WM task before training, which suggests a gradual improvement of a capacity rather than learning a new behaviour (Constantinidis & Klingberg, 2016). Neuroimaging and neurophysiological studies on WM training indicate that far transfer effects generally involve domain-general features of WM and tap on mainly basal ganglia, dlPFC and posterior parietal cortices (Moreau & Conway, 2013).

Understanding common neural processes for active maintenance of information regardless of the modality of information can give a better insight into how WM functions are performed in the brain with a structure-based or process-based model of WM (Funahashi, 2006). It is, therefore of significant importance to provide the associations between WM functions and the specific brain areas which are related to these functions in order to better understand the role WM plays in everyday cognitive tasks and to what extend WM training is related to brain plasticity. Although the neural correlates of *n*-back task have been largely studied with various neuroimaging methods (see Owen et al., 2005 for review), there have been a small number of studies on the neural correlates of *n*-back training and measurements were carried out by means of fMRI or similar methods (Buschkuehl et al., 2014; Hempel et al., 2004; Schneiders et al., 2012; Schneiders, Opitz, Krick, & Mecklinger, 2011; Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013)Considering limited studies on WM training especially which investigate neural mechanisms of *n*-back WM training, it seems plausible to tackle the neural correlates of WM training with a special focus on training-related activation changes in *n*-back WM training by means of an optical brain imaging method, fNIRS (functional Near Infrared Spectroscopy).

2.6. Neural Correlates of *n*-back Task

n-back task is composed of multiple processes which are encoding of stimuli, monitoring, maintenance and updating of stimuli and matching the current stimulus to the one in correct *n*-back position, which suggests that different neural activity patterns can be observed primarily in bilateral prefrontal and parietal cortices (Jaeggi, Buschkuehl, et al., 2010a). Different versions of *n*-back task have been investigated in neuroimaging studies using various methods such as fMRI, PET scanning, fNIRS, etc. in order to provide an overview of brain activation while performing the task. In a study on both verbal and spatial 3-back, bilateral activation in dlFC and anterior FC was reported and it was found that while verbal *n*-back showed greater activation in left dlFC, spatial versions had greater activation in right dlFC (Smith, Jonides, & Koeppe, 1996). Similarly, in another study investigating spatial and non-spatial 2-back task, activation differences were observed in posterior regions and bilateral activations were observed in dlFC and anterior FC (Owen et al., 1998). It was suggested that such results indicate bilateral activation of dlFC in manipulation processes (Fletcher & Henson, 2001). In an fMRI study on verbal *n*-back task, Braver et al, investigated WM load in *n*-back ranging from 0 to 3 with letter stimuli. A linear relation between activity in specific areas and *n*-back level and greater activations were found in dlPFC and vlPFC bilaterally as well as parietal cortex (Braver et al., 1997). In another study applying evet-related fMRI on brain activation during *n*-back task, Cohen et al., both prefrontal cortex and parietal cortex were found to be actively employed during the task. Furthermore, greater activation in dlPFC was associated with high memory-demanding conditions of the task which indicates specific involvement of this region in WM (Cohen et al., 1997).

Studies on *n*-back task using fMRI have commonly shown activation patterns in Broca's area (BA44), posterior parietal area (BA40) and dlPFC (BA9/46), which indicates the use of executive control processes as well as information maintenance in *n*-back task. It was suggested that BA44 indicates articulatory rehearsal; BA40 indicates short-term storage; BA BA9/46 indicates excitatory or inhibitory activation (Juvina & Taatgen, 2007). The involvement of all these brain regions in *n*-back task provides evidence for subtasks such as processing incoming information; maintaining relevant information; avoiding irrelevant information. In their fMRI study in which they used adaptive *n*-back training, Schneiders et al. (2012) showed that cognitive training can result in improvements only in the tasks which share similar or overlapping brain regions. They found decreases in activation after the training in two regions in the right inferior frontal gyrus. In their study, Ayaz et al. (2010) investigated the cognitive workload of air traffic controllers during a verbal *n*-back task and during air traffic scenarios. They utilized fNIRS to measure cognitive workload during these two tasks. They showed that as the difficulty of *n*-back task increased, oxygenation changes increased. This was an indication of cognitive workload during a demanding task. Significant results were obtained especially in left inferior frontal gyrus.

Considering various studies on neural correlates of *n*-back task, PFC seems to have an important role in the processes of WM with respect to the associated workload tapped on memory during *n*-back tasks (Herff et al., 2014). With this in mind, Owen et al. (2005) showed the importance of PFC in *n*-back tasks in their meta-analysis. In their meta-analysis, 24 *n*-back studies with visual or auditory stimuli were reviewed in terms of neural underpinnings of the task, and the main aim was to identify which brain regions were mainly activated while performing an *n*-back task. Based on the results of the studies included in the meta-analysis, six main cortical areas were identified with respect to neural activation in *n*-back task (Owen et al., 2005):

1. Medial and lateral posterior parietal cortex including BA7, 40.
2. Bilateral premotor cortex (BA 6,8)
3. Anterior medial/cingulate premotor cortex including supplementary motor areas (AB32,6)
4. Bilateral rostral PFC (BA10)
5. Bilateral dorsolateral PFC (BA9, 46)
6. Medial ventrolateral PFC (BA45, 47)

It shows that five out of these six cortical regions are associated with frontal lobes, and half of them are associated with the PFC. This meta-analysis clearly shows the role of PFC in performing *n*-back task, thus, making fNIRS a suitable method for investigating the underlying neural mechanisms of *n*-back WM training because fNIRS can easily be applied to directly measure hemodynamic responses in PFC with high accuracy.

2.7. Neural Correlates of Language and Consecutive Interpreting

In human verbal communication while using language even for short dialogues, WM as the ability to temporarily store, process and manipulate information, is crucial in speech perception and production. Therefore, it is vital to understand neural basis of WM for verbal language use. Based on the results of various functional neuroimaging studies, it has been concluded that a distributed network of frontal, temporal and parietal brain areas are activated especially for actively maintaining information in WM and it is not possible to pinpoint one single area for that rather there are functional interactions between frontal and posterior regions (Buchsbaum, 2016).

Language related activities such as speaking, reading, listening and writing require temporal integration and organization, and mobilize related cognitive processes and functions, thus activating different regions of PFC. Complexity and novelty of the language activity has a direct impact on deploying executive functions of PFC thus increasing the activation of PFC largely in left hemisphere (Fuster, 2015). When it comes to using two languages for different purposes such as interpreting, the focus of research has been on investigating related brain areas for language switching, how it happens in speech production and which factors are in play in speech comprehension and production. It has been suggested that specific brain areas such as left caudate, lateral prefrontal cortex, left inferior parietal cortex are generally activated in language control which is necessary for language switching. However, it should be noted that these areas are not specifically dedicated to only language control but play fundamental role in the process (Costa, Branzi, & Ávila, 2016). Studies focusing on bilingual and multilingual people have shown that the dominance of left hemisphere can diminish and different areas can be activated in comprehension of different languages (Fuster, 2015). In a study with bilingual Chinese and English subjects, it was shown that same prefrontal areas were activated during WM operations of two languages (Xue et al., 2004). For example, left lateral PFC including dorsolateral and ventrolateral parts is involved in language control by having a role in response selection and inhibition among languages and especially in WM. In a picture naming study on English-Spanish bilinguals, it was found that there was an increased activation in left inferior frontal cortex, suggesting that the need for switching between languages in such a task requires increased involvement of executive control areas as well as increased activation in bilateral dlPFC indicating the importance of goal related information maintenance (Hernandez, 2009). vlPFC seems to be involved in processes required for controlling stored long term representations of knowledge. In terms of word and sentence production and comprehension, it plays a fundamental role in top-top biasing at semantic and lexical level (Nozari & Thompson-Schill, 2016).

Speech production and comprehension, including manipulation of words or speech segments generally activates lateral and medial regions of PFC including mainly Broca’s area (areas 44/45), area 46 corresponding to dorsolateral PFC, area 47 corresponding to ventrolateral PFC and area 10 corresponding to frontopolar cortex as well as associative regions of posterior cortex (Fuster, 2015, p.337). Especially left ventrolateral PFC including Broca’s area has been shown to be involved in motor production of language with an important role in storing articulatory representations, phonetic encoding, retrieving or generating articulatory codes. In addition, expansions have been made regarding the role of vlPFC in language with a focus on semantic processing of words and sentences and domain-general processes, as well as WM (Nozari & Thompson-Schill, 2016). A number of cortical areas in left hemisphere are activated during speech production and comprehension, translation activities across languages, or verbal representation of memories and dreams. However, the activation in PFC can become bilateral even may shift to right to some degree if the verbal task gets complex and the load on memory processes increase (Fuster, 2015, p. 341).

In terms of interpreting, neuroimaging studies have been mostly performed on simultaneous interpreting with different samples ranging from student interpreters to novice and expert interpreters. It has been shown that there is a strong correlation between simultaneous interpreting performance and working memory, suggesting that interactions and overlaps between underlying neural networks of WM (prefrontal cortex, parietal cortex, anterior cingulate) ensure that interpreters maintain verbal information while performing language switch during interpreting. It has been shown in neuroimaging studies on simultaneous interpreting that interactions between neural networks related to WM such as prefrontal cortex, parietal cortex and anterior cingulate enable interpreters maintaining information and performing language and modality switch at the same time, indicating a left-lateralized fronto parietal network for language control and comprehension in multilingual people (Hervais-Adelman, Moser-Mercer, & Golestani, 2011). In their fNIRS study on oxygenation changes during translation and language switching, Quaresima et al. (2002) revealed that translation of short sentences and language switching significantly employed left inferior frontal cortex including Broca’s area and the observed activation pattern in this area was not affected by the direction of the translation (Quaresima, Ferrari, Van Der Sluijs, Menssen, & Colier, 2002).

Various neuroimaging studies using fMRI, PET, NIRS or EEG have aimed at revealing localization of language related regions in bilinguals. Studies on language switching have shown that predominantly left hemisphere is activated in this process and cortical regions such as superior temporal sulcus, superior and inferior parietal lobule, dlPFC, inferior frontal gyrus, right anterior anterior cingulate cortex have been greatly mentioned in such studies, suggesting a fronto-parietal network for language switching. Studies investigating neural basis of translation showed involvement of regions such as anterior cingulate cortex, left anterior insula, anterior portion of left hemisphere in addition to left inferior frontal gyrus, dlPFC and inferior temporal cortices (Hervais-Adelman et al., 2011). In their study on neural activation during translation Klein et al. (1995) presented that left putamen was specifically activated during translation from L2 to L1 in addition to left-lateralized inferior frontal, dorsolateral prefrontal and inferior temporal cortices. Moreover, Lehtonen et al. (2005) similarly demonstrated activation increases in left inferior frontal gyrus and putamen during translation from L2 to L1, which may suggest that different activations during two processes; namely semantic information retrieval in left inferior frontal gyrus and control of production and output in basal ganglia (Hervais-Adelman et al., 2011). Taken together, all these results suggest dominant involvement of left hemisphere and interactions of different cortical areas in language studies including translation and interpreting. It is hoped that investigation of underlying neural basis of consecutive interpreting via fNIRS will provide great contributions to the literature.

CHAPTER 3

METHOD

In this chapter, detailed information about participants of the study, training and transfer tasks administered during the study, and the procedure followed during the experiments was provided in order to present methodological framework of the study. Training and transfer tasks used for investigating near and far transfer effects were illustrated one by one. Speeches used in consecutive interpreting task were presented in detail in a separate part with a special emphasis on an idea-unit protocol which was developed for scoring the content accuracy of interpreting output. In addition to general procedure followed throughout data collection, the procedure of optical braining imaging technique (fNIRS) and its data collection and analysis processes were explained in the last part of the chapter.

3.1. Participants

A total of 18 students from Atılım University Department of Translation and Interpretation took part in this study. 9 third-year and 9 fourth-year students were included in the study. 5 male (mean age: 23 years; ranging from 21 to 28) and 13 female (mean age: 22.76 years; ranging from 20 to 30) students volunteered to participate in the training and testing phases of the study. The imbalance between the number of female and male students in the study is quite a representative of the general situation of gender distribution at Departments of Translation and Interpreting not only in Turkey but also around the world. It is a well-known fact that this profession is preferred and exercised by mostly women (Ryan, 2015), thus the sample of the study was mostly composed of female students.

Table 2: General information about participants of the study

	***n*-back Group**	**Control Group**
Number of participants	9 (2 male, 7 female)	9 (3 male, 6 female)
University Year	5 fourth-year students 4 third-year students	4 fourth-year students 5 third-year students
Age	M=23.55 (ranging from 20 to 30)	M=22.77 (ranging from 21 to 28)
Reading Span Score (Pre-test)	M=31.77; SD=16.07 (ranging from 12 to 54)	M=29.66; SD=16.38 (ranging from 14 to 57)

All participants of the thesis were right-handed and had normal or corrected to normal vision. Participation was completely voluntary with no payment or additional points to grade in any course at the university. The reason for not paying or providing extra benefit is to have intrinsically motivated participants in the study. All

18 participants completed 14 training sessions and attended pre- and post-tests phases of the study. 15 out of 18 participants took part in the delayed post-test phase of the study (follow-up), 3 fourth-year participants could not attend the follow-up since they moved to another city after their graduation from the university.

Participants were randomly assigned to one of the two groups; experimental group (referred as *n*-back group) and active control group (referred as control group), in a block design so that the two groups would be as similar as possible on the following variables: gender, age, study year and performance on pre-test reading span task (see Table 2). In this way, groups included participants with similar skills and similar levels of performance on the selected task. During pre-test, participants were asked whether they received any specific WM training before and whether they were familiar with any of the tasks that would be administered. It was important to ensure that participants were naïve to the tasks used in the study especially reading span task since they would be divided into one of the groups based on their scores in this task. Furthermore, it was of utmost importance to avoid having participants who were already skilled in one of the training regimes. Furthermore, participants were not aware of their group affiliation during pre-test and they were informed about their group affiliation at the first training session, which made sure that participants were completely naive during performing the tasks in pre-test. All participants signed an informed consent form which was approved by the Ethics Committee of METU (see Appendix I).

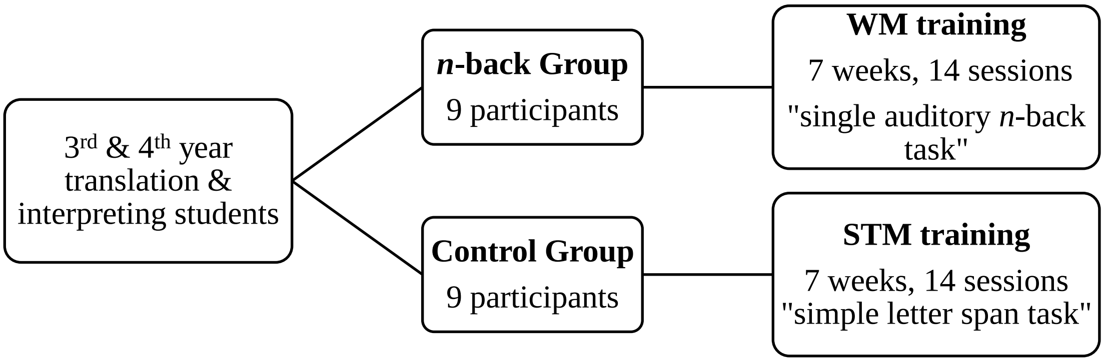

Figure 4: Participants in n-back and active control groups

It was of significant importance to have an active control group in the study since previous studies in literature with no or only a no-contact control group indicate that findings can be problematic and questionable in terms of reliability and robustness. Comparison to a no-contact control group in which participants complete pre- and post-tests but have no contact with the intervention or training, is a very common approach in studies showing far transfer (see Chein & Morrison, 2010; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Olesen, Westerberg, & Klingberg, 2004; Schmiedek, 2010; Vogt et al., 2009). But such an approach is considered to be weak in terms of effort and expectancy levels of participants taking part in the study. The level of cognitive effort and engagement has been shown to be higher in experimental groups, which hinders comparisons between both groups in the study. Therefore, one of the main criticism against studies on cognitive training and transfer effects was the lack of intervention in the control group. In order to overcome this criticism, various alternatives have been utilized such as both groups can practice on the same task with differing difficulty levels; a non-adaptive form of the same training can be used for control group; both groups can train on the same task with different versions of it e.g. single vs. dual *n*-back task; control groups may receive a shorter version of the training for example 1/3 of the duration of the experimental group (Persson & Reuter-Lorenz, 2008). However, it has been suggested in the literature that the training regime of both groups; namely experimental and control group, must be equally adaptive, challenging and engaging (see Morrison & Chein, 2011; Jaeggi, Buschkuehl, Shah & Jonides, 2014; Oberauer, 2009). Adaptive training was shown to enhance performance improvement and foster plasticity, thus increasing transfer effects over time (Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010).

It is essential to include an active control group which practice a plausible cognitive training task while the experimental group is trained on a chosen task because such a methodological choice would allow the researcher to compare the performance of the two groups and make sure that the improvement is not due to some general random improvement but a result of the well-specified and well-designed training regime. It is stated in the literature that training regime of active control group should be as motivating and challenging as the training group's regime. The likelihood of transfer of training on a specific to another task relies on common cognitive capacities of the tasks and shared underlying neural correlates. Therefore, while selecting a tasks for control group in an *n*-back working memory study, the task should not be a WM task. But, it seems difficult to find a proper active control training condition in which the active control group does not specifically and solely train on WM (Könen, Strobach, Karbach, 2016). In order to create similar training conditions for both groups and to collect reliable data, simple letter span was specifically chosen as active-control group's training task. Simple letter span draws on only temporary storage system of memory; however, *n*-back task relies on constant maintenance and updating of stimuli and inhibition of irrelevant stimuli. While experimental group; namely *n*-back group practiced on single auditory *n*-back task (auditory) as a WM training task; control group was trained on simple letter span (visual) as a STM training task for the same period of time in an adaptive fashion.

3.2. Design and Procedure

This study aimed at investigating the transfer and maintenance effects of single *n*-back task. Therefore, participants completed a total of seven different tasks including training tasks at three testing phases; pre-test, post-test and follow-up (delayed post-test) in order to measure different levels of transfer of skills. Since each testing phase included several tasks to complete, the testing process was divided into multiple days which allowed participants take breaks between the tasks. For each participant, the tasks were administered in a randomized order; only *n*-back and consecutive interpreting tasks were always administered on the same day consecutively since data on performance during these tasks were also collected by fNIRS, an optical brain imaging device. While one participant started the session with *n*-back task, the next participant started the session with consecutive interpreting. In addition, individual progress in each training tasks was observed and monitored by keeping a log of performances at each round during the session for both groups.

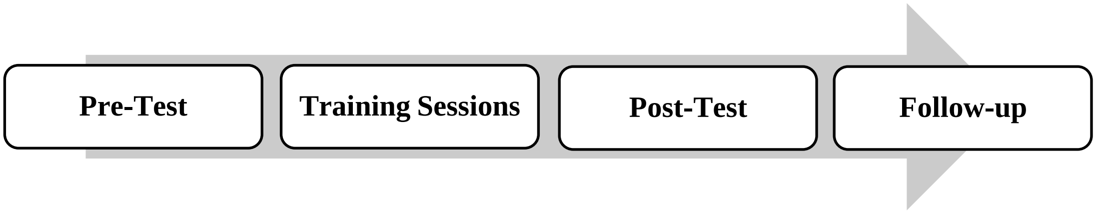

Figure 5: General procedure of the study

As can be seen from the figure above, the study was designed as a longitudinal one which lasted almost 10 months in total and behavioural and optical brain imaging data were collected at three testing times. Most of the studies in the literature include only pre- and post-tests however it has been highly emphasized in cognitive training studies that it is crucial to be able to show that improved performance persist even if the training sessions have been completed. It has been shown in studies with children that training-related gains remain three and six months after completing training sessions. Holmes et al. (2009) even found that a skill that did not show any improvement right after the training was improved six months after the training ended. Therefore, in addition to pre- and post-tests design, a follow-up was conducted to investigate whether transfer effects of the task were maintained. Change over time for each group was measured in a quantitative manner and proper statistical tests were performed. While designing the general procedure of the study, it is important to take into account possible aspects of a behavioural and optical brain imaging study which could have an impact on the results. Controlling factors such as motivation, commitment, difficulty of the tasks, degree of engagement and enjoyment during training is outmost importance especially in transfer of skills studies. Therefore, two questionnaires; The Need for Cognition Scale and Theories of Cognitive Abilities Scale were administered at each testing phase to gather data regarding participants' motivation, and beliefs about the benefits of cognitive training. In addition to collecting behavioural data, fNIRS as an optical brain imaging technique was used during *n*-back and consecutive interpreting tasks. This paved the way to view transfer effects of *n*-back task from different angles and to obtain a comprehensive understanding of transfer effects and the underlying neural and cognitive mechanisms of the effects of WM training. Furthermore, an attempt to gain an insight into neural mechanisms of consecutive interpreting was achieved thanks to data gathered via fNIRS device. The following table lists the tasks that were administered at each testing time and provides detailed information about each task.

After completing pre-test and having preliminary analysis of the tasks, participants were informed about their group affiliation and general design of the study. Then, the schedule for training sessions were drafted for each group and necessary set-up procedures for training tasks were completed. The number of training sessions varies enormously in WM training studies ranging from a single session of 20-minutes to rather long training duration over 10 weeks (see Buschkuehl et al., 2012; Klingberg, 2010). Since this study involved student interpreters, the training sessions spread over their regular semester duration to observe the feasibility of the WM training intervention in an educational setting. Participants trained for 2 days a week and completed a total of 14 training sessions within a single semester. Duration of each training sessions ranged from 30 to 40 minutes. Except for health-related conditions, participants were trained on the same days of the week, and the time of the sessions were arranged according to the weekly course schedule of the participants.

Table 3: Detailed information on tasks and their experimental set-ups

		Level	**Set-up**
PRE-TEST	1.single *n*-back task	1-2-3 back	E-Prime & fNIRS
	2. dual *n*-back task	1-2-3 back	Brainscale.net
	3. reading span task	adaptive	E-Prime
	4. simple letter span task	4-8 letters	Brainscale.net
	5. simple digit span task	4-8 digits	Brainscale.net
	6. BOMAT Form A	29 items	Paper-based
	7. consecutive interpreting	5 speeches	E-Prime & fNIRS
	Need for Cognition Scale (English)		
	Theories of Cognitive Abilities Scale (English)		
TRAINING		**Level**	**Set-up**
	***n*-back Group**	adaptive	E-Prime
		Single *n*-back task	
		A total of 14 sessions	
		20 rounds in each session	
		(auditory / letter)	
	Control Group	adaptive	Brainscale.net
		Simple letter span task	
		A total of 14 sessions	
		20 rounds in each session	
		(visual / letter)	
POST-TEST		**Level**	**Set-up**
	1.single *n*-back task	2-3-4 back	E-Prime & fNIRS
	2. dual *n*-back task	2-3-4 back	Brainscale.net
	3. reading span task	adaptive	E-Prime
	4. simple letter span task	4-9 letters	Brainscale.net
	5. simple digit span task	4-9 digits	Brainscale.net
	6. BOMAT Form B	29 items	Paper-based
	7. consecutive interpreting	5 speeches	E-Prime & fNIRS
	Need for Cognition Scale (English)		
	Theories of Cognitive Abilities Scale (English)		
FOLLOW-UP		**Level**	**Set-up**
	1.single *n*-back task	2-3-4 back	e-prime & fNIRS
	2. dual *n*-back task	2-3-4 back	Brainscale.net
	3. reading span task	adaptive	E-Prime
	4. simple letter span task	4-9 letters	Brainscale.net
	5. simple digit span task	4-9 digits	Brainscale.net
	6. BOMAT Form B	29 items	Paper-based
	7. consecutive interpreting	5 speeches	E-Prime & fNIRS
	Need for Cognition Scale (English)		
	Theories of Cognitive Abilities Scale (English)		

Trainings were held either in computer laboratory or interpreting laboratory of Atılım University under the supervision of the researcher, which allowed participants to adapt to the setting easily and have quiet environment without any distraction. Single auditory *n*-back training task for training sessions was adapted from Jaeggi (2014) and their original set-up and design in E-Prime Version 2.0 Psychology Experiment Design Software Tool was received from Working Memory and Plasticity Laboratory, University of California, Irvine. Therefore, E-Prime 2.0 Run-Time License was received and E-Prime 2.0 subject station which allows only running experiments was installed to laptops of each participant in *n*-back group. For simple letter span, computerized version which is available in http://brainscale.net/memory-span for free of charge was used. Each of training regimes was adaptive and the difficulty level changed depending on performance of the participants. This arrangement was believed to make the training sessions challenging and demanding for participants in this way participants would feel the need and urge to improve their performance incrementally, thus resulting in sustainable motivation level throughout the study.

Following the completion of 14 training sessions, post-test was conducted with some changes in the difficulty levels of *n*-back and span tasks as can be seen in the Table 3. The same procedure with the pre-test was followed. While *n*-back and consecutive interpreting tasks were performed at Human-Computer Interaction Laboratory at METU, remaining tasks were administered at Atılım University. Three months after the post-test was conducted, the follow-up was completed to observe possible long-term delayed effects. The follow-up was administered as a delayed post-test hence the tasks in post-test were used without any change. The same procedure of task administration was followed. With the completion of the follow-up, behavioural and optical brain imaging data collection was finalized.

3.3. Materials

Materials of the study consist of two baseline questionnaires, training and transfer tasks, and consecutive interpreting speeches. Transfer tasks were divided into three as near, moderate and far transfer tasks. 10 short speeches were used while investigating the transfer to everyday life for interpreting students.

3.3.1. Questionnaires

The literature on motivation clearly shows that intrinsically motivated participants are an important part of training performances. Participants' motivation and their beliefs about intelligence have an impact on transfer and training. Such factors may even affect whether participants complete the training sessions (Katz et al., 2016, p.162-163). Motivated participants find the tasks engaging, enjoyable and useful for their academic or daily lives; therefore, they pay their full attention to the tasks and try to concentrate on their performance during the task (Pugin et al., 2014). Individual differences in intrinsic motivation can affect the results of studies which compare different training regimes therefore two scales were used to collect data on motivation and beliefs about intelligence. The scales were administered in English since the participants were fluent in English and there were no language-related concerns regarding participants' understanding of the statements.

3.3.1.1. The Need for Cognition Scale

This scale was developed by Cacioppo and Petty (1982) and it is used to measure "the tendency for an individual to engage in and enjoy thinking" (Morrison & Chein, 2011). Statements such as “I really enjoy a task that involves coming up with new solutions to problems.”, aim to measure participants’ motivation and engagement in activities. Initially, the Need for Cognition Scale had 34 items to rate, later the authors provided a shorter version which consisted of 18 items in collaboration with Chuan Feng Kao (Cacioppo, Petty, & Kao, 1984). In this study, the 18-item scale was used and participants were asked to indicate to what extent the statement is characteristic of them on a 5-point Likert scale (1: extremely uncharacteristic……..5: extremely characteristic). (see Appendix A)

3.3.1.2. Theories of Cognitive Abilities Scale

The scale which was developed by Dweck and colleagues (1999) and is used to gather assumptions of individuals regarding intelligence whether it can be improved or whether it is purely innate which is not affected by any kind of training or development. According to Dweck (2000), people have two different views about intelligence; “entity” and “incremental” theory of intelligence. Those who support the view of “entity theory of intelligence” believe that intelligence is “fixed”, stable and innate thus it cannot be changed. However, those who have the view of “incremental theory of intelligence” consider intelligence to be malleable, fluid and changeable, they believe that intelligence can be changed by experience or training. While people who have the belief that the intelligence is fixed attribute their failures to personal traits, people who believe that the intelligence is malleable attribute their failures to behaviours (Thomas & Sarnecka, 2015). The scale can be either as an integrated scale including both entity theories items and incremental theory items or entity-only scale. The entity-only scale is advised to be used in especially longitudinal studies in which the scale is administered a number of times. Because under such circumstances, participants can easily show a tendency towards incremental theory items since they seem too appealing (Dweck, 2008). Since there were three time points to administer the scale in this study, entity-only scale which is composed of three statements such as “You have a certain amount of intelligence, and you really can’t do much to change it.” was used and participants were asked to rate the items on 6-point Likert scale (1: strongly agree;….6: strongly disagree). (see Appendix B)

3.3.2. Training Tasks

Single auditory *n*-back training task was used for the experimental group; namely *n*-back group and active control group practiced simple letter span (visual) for the same period of time under similar conditions. In both groups, trainings were adaptive and level of difficulty depended on individual performance based on pre-defined success threshold of 90% because when adaptive procedures are used in training interventions, difficulty of the tasks increased or decreased depending on the number of accurate responses in this way challenge to cross the threshold level of performance is personalized (Seitz, 2017).

3.3.2.1. *n*-back Training Task

n-back task is a widespread WM measure which employs especially executive functions of WM. Single *n*-back task can be applied in two modalities; namely visuospatial or auditory which are also components of dual *n*-back task. *n*-back task is considered to be a reliable and valid indicator of WM capacity and it is widely used in WM training studies to measure WM capacity (Wilhelm et al., 2013). In this study, single adaptive auditory *n*-back task was administered as a training regime for experimental group (*n*-back group). The task is considered a verbal *n*-back task since it only included auditory stream of letters and no spatial component. *n* is used as a variable to adjust task difficulty in the task. Depending on the performance it can be increased or decreased. The computerized task was adapted from the study of Jaeggi et al. (2014) and their instructions and the set-up of training sessions were replicated with minor adjustments for example alphabet letters included in the auditory stimuli such as X and W were changed. Set-up file of the task was received from University of California-Irvine, Working Memory and Plasticity Laboratory. The training task was uploaded to laptop of each participant in experimental group and was run on E-Prime 2.0 which allowed logging of all data regarding the task. Each training session was composed of 20 rounds. In this task, participants heard alphabet letters one after another which were presented in every three seconds (3000 ms.). They were asked to press the key "L" whenever the letter they have heard was the same as the one *n* stimulus back as shown in Figure 6. For example, if they were asked to do 2-back, they had to press the key "L" each time the current letter was the same as the one that presented before the last (i.e. two positions back in the auditory sequence). If the current letter was not the same as the 2-back letter, they did not respond.

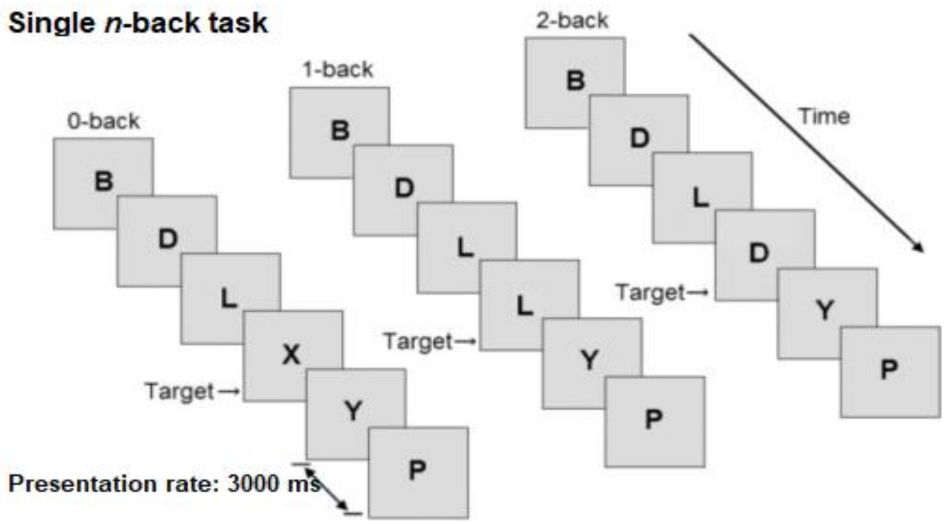

Figure 6: Procedure of single n-back task (Figure was taken from Vermeij, van Beek, Olde Rikkert, Claassen, & Kessels (2012))

The task was adaptive since the level of *n* was adjusted based on each individual's own performance during the session. If the performance of the participant was 90% or above in the current round, the level was increased by one for the next round. If the performance was 70% or below in the round, the *n*-back level next round was decreased by one. Otherwise, the *n*-back level remained the same in the next round (see Jaeggi, Buschkuehl, Shah, & Jonides, 2014; Salminen, Strobach, & Schubert, 2012). Participants were notified about their performance after each round with a scoring note on the screen. In this way, the task was continuously kept challenging and engaging for participants during the training sessions. The pilot study showed that it took almost 30-40 minutes to complete a 20-round training session therefore participants were instructed accordingly regarding the duration of each training session. The first training session started with 1-back and the *n*-back level was continuously updated depending on the participant's performance. The number of trials in each round ranged from 21 to 45 letters depending on *n*-back level and congruent trials in the rounds which required key press varied between 3 and 10.

3.3.2.2. Simple Letter Span Training Task

It is possible to define simple memory span as the longest list of items such as letters, digits, words, shapes of positions that can be remembered in the correct order right after seeing or hearing the items (Unsworth & Engle, 2006, p.70). Spatial or verbal versions of simple span task can be used to investigate STM depending purely on storage capacity of the memory. For this study, participants in the control group practiced simple letter span in an adaptive fashion. Participants completed the task online on http://brainscale.net/memory-span/training. In this task, participants were asked to remember alphabet letters in the order they appeared on the screen. Letters were presented one by one as shown in Figure 7, each letter was presented on the screen for 1500 ms. and participants had to remember each letter and then type the letters in the correct order to advance to the next trial.

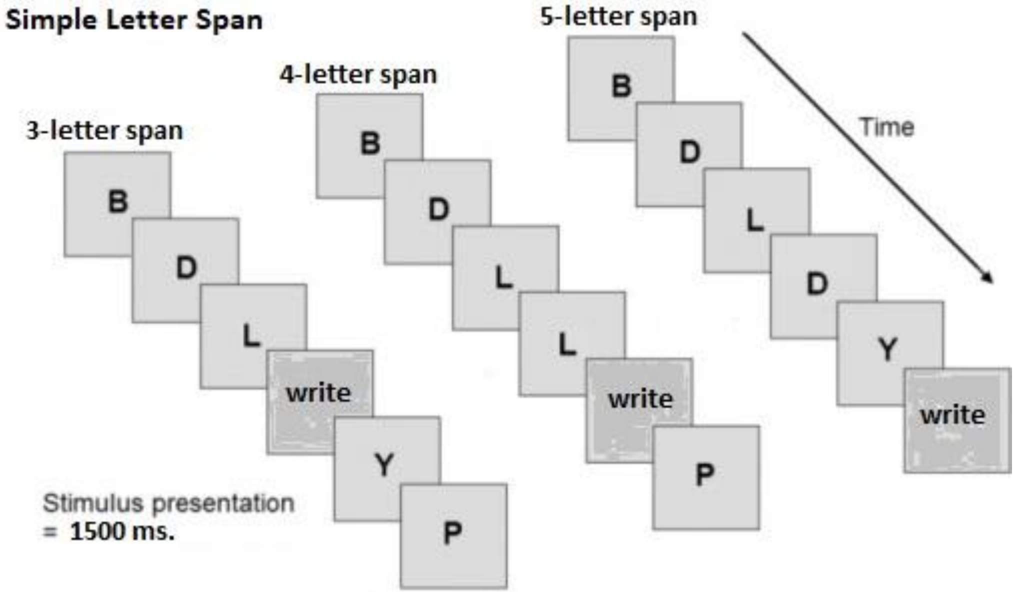

Figure 7: Illustrative Figure of Simple Letter Span

Fall-back and advance levels during the task were regulated depending on participant's own performance in the previous round. Participants were always informed about their performance on the screen after each round. The threshold for advancing the level (the list length) was 90% or above and the threshold for fall-back was 70% or below as in the single *n*-back task. Each round involved 6 trials (6 lists) and when all trials in a round were completed, the performance was shown on the screen and recorded in an online log on the website. Participants had to complete 20 rounds in each training session. The level of the first round in each session was determined based on the performance shown in the previous session.

3.3.3. Transfer Tasks

A total of 5 transfer tasks and 2 training tasks were administered in testing phases of the study to investigate to what extend *n*-back training has a transfer effect on various levels of transfer. As can be seen in the table below, there were two near transfer, one moderate and one far transfer tasks as well as an applied domain task specifically chosen to study the transfer effect of WM training on everyday life tasks.

Table 4: Training and Transfer Tasks

	Training and Transfer Tasks	Transfer
1	Trained WM task: *n*-back task (experimental group)	Training gain
2	Trained STM task: simple letter span task (control group)	Training gain
3	WM task: dual *n*-back task	Near transfer
4	STM task: simple digit span task	Near transfer
5	Complex WM task: reading span task	Moderate transfer
6	Reasoning task: Bochum Matrices Test (BOMAT)	Far transfer
7	Consecutive Interpreting	Applied domain

3.3.3.1. Single *n*-back Task

Single *n*-back task was administered at pre- and post-tests and follow-up while participants were attached to fNIRS device. Single *n*-back task was adapted from Ayaz et al. (2010). The E-Prime set-up of the task was received from Associate Research Professor Hasan Ayaz (Ph.D.). The original task was visual *n*-back task in which letters were shown on the screen and participants were asked to perform 0-1-2-3 back tasks. In the present study, instead of visual stimuli, auditory stimuli were used and 0-back was excluded. Participants performed 1-back, 2-back and 3-back tasks in pre-test. After preliminary analysis of pre-test scores in the *n*-back task, it was realized that 1-back condition was already at peak level from the onset and participants considered it too easy. Therefore, for post-test and follow-up, 1-back condition was removed and 4-back condition was added to be able to gain a better view of difference between groups in a more demanding level.

Table 5: Detailed information about single *n*-back task

Test	*n*-back level	number of rounds	# of trials in each round	Sum of correct trials
Pre-test	1-back	7	21	43
	2-back	7	22	42
	3-back	7	21	44
Post-test	2-back	7	22	42
	3-back	7	21	44
	4-back	7	31	46
Follow-up	2-back	7	22	42
	3-back	7	21	44
	4-back	7	31	46

While administering the task, the exact procedure of the original study was followed. The order of *n*-back conditions was pseudo-randomized which facilitated data collection in fNIRS data. Participants were asked to press any key whenever the letter they have heard was the same as the one *n* stimulus back. The task was presented in an E-Prime running laptop while COBI Studio software was running on a separate desktop computer for collecting brain imaging data. As in single *n*-back training task, auditory alphabet letters were presented in every three seconds (3000 ms.).

Detailed information about the number of rounds and trials were provided in the table below. The task included seven rounds of each *n*-back condition. Number of trials in each condition varied from 21 to 31. The number of correct responses (key-press trials) in the rounds of 1-back ranged from 4 to 9 correct responses. In 2-back condition, the number of correct responses varied between 3 and 8; in 3-back condition the number of correct responses ranged from 4 to 9. In 4-back condition, the number of correct responses varied between 4 and 8.

3.3.3.2. Dual *n*-back Task

In this task as shown in the figure, participants were presented with a sequence of visual and auditory stimuli at the same time. Computerized version of dual *n*-back task was used in http://brainscale.net/dual-n-back/training. Audio stimuli were alphabet letters and visual stimuli were blue squares shown on the screen. Participants were asked to press a key whenever the current square on the screen was the same position as the one *n* stimulus back and simultaneously they were asked to press another key whenever the letter they have heard was the same as the one *n* stimulus back. The key “L” was used for audio match and the key “A” was used for visual match.

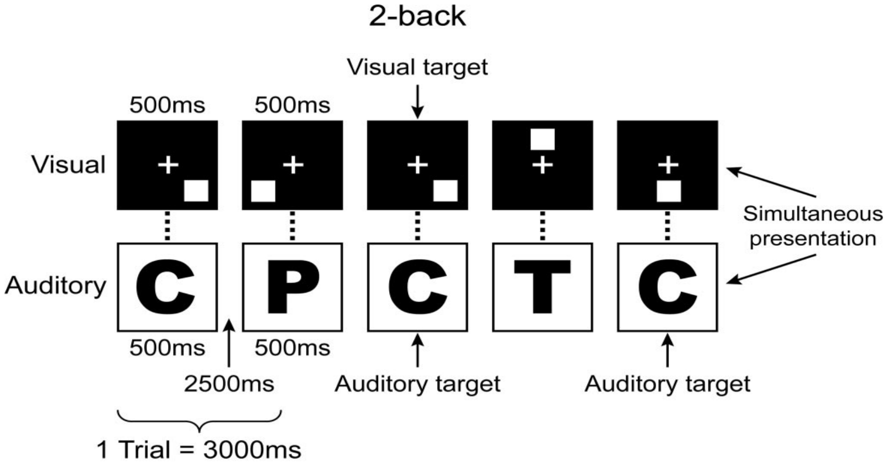

Figure 8: Illustrative Figure of Dual 2-back task

Dual *n*-back task also included seven rounds of each *n*-back condition. *n*-back conditions were presented randomly and performance at the task was recorded online in the website and a short report on error based analysis was provided for each part of the task separately (auditory and spatial) as well as cumulative performance for each *n*-back condition in the task. After pre-test, dual 1-back was removed and *n*-back level was increased to 4-back in post-test and follow-up. Stimuli were presented in every 3 seconds (3000 ms.).

Table 6: Detailed information about dual n-back task

Test	**Dual *n*-back level**	**# of rounds**	**# of trials in each round**	**Sum of correct responses**
Pre-test	Dual 1-back	7	21	35
	Dual 2-back	7	24	42
	Dual 3-back	7	29	49
Post-test	Dual 2-back	7	24	42
	Dual 3-back	7	29	49
	Dual 4-back	7	36	63
Follow-up	Dual 2-back	7	24	42
	Dual 3-back	7	29	49
	Dual 4-back	7	36	63

As can be seen in the Table 6, as the *n*-back condition increased, the number of trials in each condition also increased and it varied from 21 to 36. The number of correct responses (key-press trials) in one round of dual 1-back was 5. In dual 2-back condition, the number of correct responses was 6; in dual 3-back condition the number of correct responses was 7. In dual 4-back condition, the number of correct responses was 9.

3.3.3.3. Simple Letter and Digit Span Tasks

Simple span tasks require participants to remember a list of stimuli such as digits and letters. As the level is increased, the length of the lists is increased. There are two versions of simple span tasks; forward span tasks and backward span tasks. In forward span tasks, participants are asked to recall the items in the presented order, in the back ward span tasks items are recalled in the reverse order. Therefore, while forward span tasks require only temporary storage, backward span tasks rely on central executive functions of Baddeley’s WM model (Könen, Stroback, Karbach, 2016).

In this thesis, participants were asked to recall visually presented lists of items in the presented order (forward) in both letter and digit span tasks. Participants completed online versions of the tasks in http://brainscale.net/memory-span/training. Visual stimuli (digits and capitalized letters) were presented in the middle of the computer screen one by one for 1500 ms. then they had to recall and type the items on the provided slots on the screen. In pre-test, the list length ranged from 4 letters and digits to 8 letters and digits. Then, in preliminary analysis of pre-test data, it was seen that both groups had significantly high performance even in longer lists, hence in post-test and follow-up, lists of 9 letters and digits were also added. Both letter and digit span tasks included 7 rounds of each list length in a randomized order. There were five trials of each list-length (4-8). Overall performance percentages in the each level were automatically averaged and calculated based on correct trials.

3.3.3.4. Reading Span Task

Complex span tasks are composed of both simple span tasks and an unrelated secondary task. Therefore, storage and processing units of WM are employed (Könen, Stroback, Karbach, 2016, p. 61). Reading span is one of the mostly used complex working memory span tasks. In this task, participants carry out processing and storage concurrently. While a list of letters is presented for recalling, participants are also asked to judge sentences. A shortened version of reading span was adapted from (Oswald, McAbee, Redick, & Hambrick, 2014) and the test set-up file for e-prime version 2.0.10 was received from Attention and Working Memory Lab of Georgia Institute of Technology.

Following the instructions of the study of Oswald et al. (2014), participants read sets of 3 to 7 sentences and judged whether they make sense or not and they were asked to recall the letters shown after each sentence. Approximately, half of the sentences were sensible. The task started with practices of both sentence and recalling part of the task to adjust the level and timing of the task. After completing the practices, participants started the trials. The trials consisted of 3 sets of each set-size, set-sizes ranged from 3 to 7. There were a total of 75 letters and 75 sentences in the test. The test was run in an adaptive fashion based on individual performances in the sets. Participants were instructed to keep their reading accuracy at or above 85% at all times. During recall, a percentage in red was presented in the upper right-hand corner. The percentage during recall must be kept at or above 85%. While calculating the reading span score, all perfectly recalled sets were summed. For example, if a participant recalled correctly 2 letters in a set size of 2, 3 letters in a set size of 3, and 3 letters in a set size of 4, the score would be 5 (2 + 3 + 0).

3.3.3.5. Bochum Matrices Test (BOMAT)

Bochum Matrices Test measures logical deductive reasoning of individuals which is associated with fluid intelligence (Gf). Fluid intelligence can be defined as a complex human ability which enables adapting to new problems or situations therefore BOMAT is used as a Gf test which measure domain-general nonverbal abilities which are crucial for performance in a variety of cognitive tasks (Brem et al., 2018).

There are three available levels of this test which are advanced, advanced-short and standard. It is a well-designed and reliable test which is especially used in studies targeting college or university students (Jaeggi, Studer-Luethi, et al., 2010a; Jaeggi et al., 2008). The standard sample of BOMAT consists of individuals whose age range between 18 and 35 (Hossiep et al., 2001, p.24). In this study, paper-based BOMAT–Advanced–Short Version was used (Hossiep, Turck & Hasella, 2001). This version included two 29-item BOMAT tests (Form A and Form B). Reliability and validity of both forms were proved to be high. Internal consistency for each form was as follows: Spearman Brown (split half) and Guttmann (split half) values were .89 for both Form A and Form B. Cronbach's Alpha was .92 for both Form A and Form B. Validity coefficient value (r) was .58 for Form A and .51 for Form B (Hossiep et al., 2001, p.35-37). In this thesis, Form A was used in pre-test, and From B was used in post-test and follow-up.

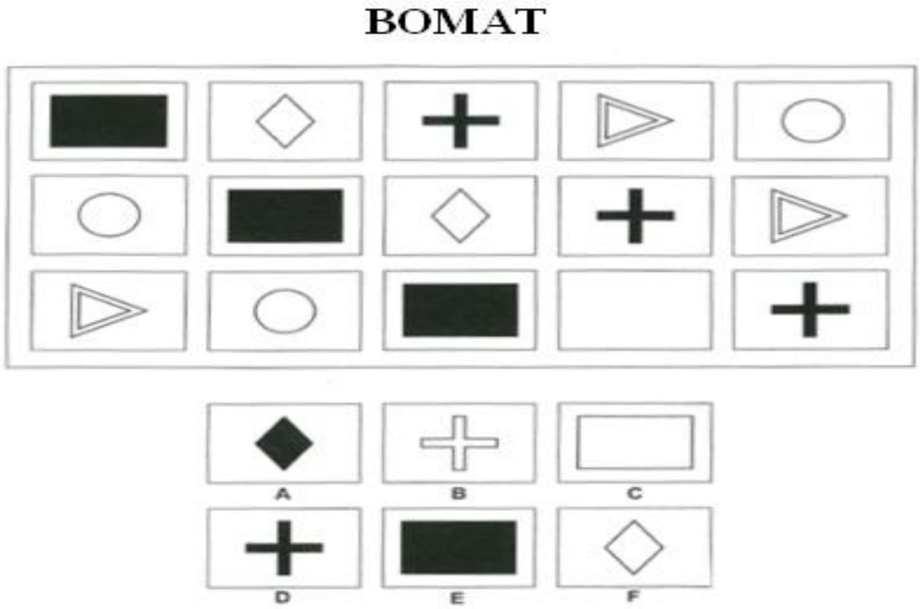

Figure 9: An Example from Bochum Matrices Test (BOMAT)

In BOMAT, a 5x3 matrix of figures was presented with one empty position as shown in the figure. There was a time restriction of 45 minutes, and participants were encouraged to try their best to complete as many items as possible. Participants were informed that difficulty of items in the test was gradually increased and it would be better to complete the item sequentially. The tasks started with 10 practice trials, and then main 29-item test started. Participants were asked to figure out from the alternatives provided which one should be in the empty position of the matrix. In order to find the correct figure, one should infer a pattern from the provided figures which requires WM operations, and apply it to the empty slot (Moody, 2009, p. 327).

3.3.3.6. Consecutive Interpreting Speeches

In order to investigate transfer of training on *n*-back task to consecutive interpreting which is an applied domain of cognition, participants were asked to interpret English speeches in a consecutive mode without taking notes. They carried out consecutive interpreting only into their mother tongue (A language) since it is the common standard of the professions accepted by international associations. Two separate sets of speeches were administered to the participants. Ten English speeches on various topics such as history, technology, economy, etc. were selected from the book “Mastering Skills for the TOEFL IBT, Listening-Advanced (Macgillivray, Yaney & Malarcher, 2006) (see Appendices C & D).

Familiar topics which did not require terminological preparation were deliberately chosen. Each test was composed of five texts. Transcriptions of real-life speeches were not deliberately chosen because redundancy is generally observed in such speeches. Language use, coherence and cohesion in speeches and clear structure of information flow were main criteria while choosing the speeches. As can be seen from the Tables 7 and 8, the speeches were at varying length in terms of both words and duration. Each participant interpreted speeches in a randomized order while they were attached to the fNIRS device.

Table 7: Speeches used in Pre-test

Speeches used in Pre-test	Length / second	Number of Words
Alexander the Great	44 seconds	109
Communication Theory	44 seconds	105
Benefits of Pets	47 seconds	110
Poisonous Plants	60 seconds	170
Invention of the Telescope	45 seconds	120
Mean	**48 seconds**	**122.8 words**

Table 8: Speeches used in Post-test and Follow-up

Speeches used in Post-test	Length / second	Number of Words
Uses of Money	40 seconds	105
League of Nations	45 seconds	110
Magna Carta	55 seconds	142
Culture	52 seconds	132
Genealogy	50 seconds	112
Mean	**48.4 seconds**	**120.2 words**

The experiment was designed on E-Prime, which allowed automatic recording of utterances during interpreting phase. After listening to a speech with full concentration without taking notes, participants were instructed to provide their interpretation when they saw the sign on the screen saying “start interpreting”, and to press any key when they finished interpreting to continue with the next speech.

Test reliability is one of the major concerns in interpreting studies. Input variables such as speech rate of information density of the materials can create problems in terms of the quality of the test design (Liu, 2002). Therefore, test materials namely ten speeches were evaluated by external raters in both qualitative and quantitative manner. The validity of the speeches was ensured on the basis of a short questionnaire administered to three experts in the field of interpreting who are both professional conference interpreters, and who have expertise in the field of interpreter training. They were asked to evaluate the speeches on specific criteria which were difficulty, familiarity, and speed on a 5-point Likert Scale, and were asked to comment on the structure, appropriateness and content of the speeches qualitatively (see Appendix E). The inter-rater reliability was found high when all rates for difficulty, familiarity and speed of ten speeches were taken into account (Krippendorff's Alpha=0.80). The raters stated that the speeches were appropriate for short consecutive interpreting in terms language use and information flow considering that they would be practiced by student interpreters.

3.3.3.6. Scoring Content Accuracy of Consecutive Interpreting in terms of Idea Units

When it comes to evaluate or assess interpreting performances in terms of accuracy either in consecutive or simultaneous mode, the issue gets a little complicated since there is no consensus among researchers or trainers on how to carry out assessment and which criteria should be followed. It is clear that not everyone has the same criteria since their expectations from interpreting performances differ from each other. However, there is a large consensus on some translation/interpreting quality parameters such as fidelity, linguistic correctness, stylistic and terminological acceptance (Gile, 1994, p. 42). Concepts such as equivalence; “similarity of meaning”, congruence; “similarity of meaning and form” and correspondence; “formally closest translation between the two languages” are useful in terms of assessing interpretation process. For example, fullest possible translated text (correspondent text) can provide insights into what the interpreter omitted, added or replaced, and why (Kopczynski, 1994, p.88). Interpreting quality evaluation sheets, propositional analysis of the output, error analysis of interpreted text based on idea units, questionnaires, self-evaluation forms, etc. are commonly used both in academia and research.

In the field of interpreting, accuracy and language use and delivery are considered the most important aspects. However, it may be difficult to measure them. One common way is to use scoring units and segment the source text into basic units of related concepts, then accuracy is rated according to correctly rendered units in the target language. The advantage of scoring accuracy based on units is that it allows assessing the accuracy of meaning which is established in structurally defined and separate units of the text or speech (Liu, 2015, p.21). Item of information / idea unit / meaningful unit / unit of meaning are used interchangeably in the literature of conference interpreting research and they have been utilized to develop reliable constructs for interpreting assessment. Units of meaning in interpreting which have proposed by Lederer (1978) mainly refer to segments or chunks of sense which appear in interpreting as the interpreter grasps the message of the speech he/she listens. They are mainly a collection of a number of words kept in short-term memory. However, it should be noted that units of meaning are not “grammatical segmentation of language into syntactic units”. These units of meaning are representations of sense in the minds of interpreters which are formed as a result of thinking processes which are involved in understanding and speaking. When the literature was reviewed, the most common term which has been used widely in various fields ranging from listening and reading comprehension in second language to memory recall tasks in texts or speeches was the term “idea unit” which primarily refers to the same principles of “units of meaning”. In order to have terminological coherence with related studies in the literature, the term “idea unit” was chosen for developing a content accuracy scoring procedure for consecutive interpreting outputs.

Idea unit scoring is a very widespread method of scoring recall and content accuracy both in language and memory studies. Idea units have been used by researchers who want to measure reading, writing, listening comprehension in second language (Winke & Gass, 2016). As emphasized by Sun-Young et al. (2016), it is a common procedure to measure content accuracy by the total number of correctly recalled idea units for assessing content accuracy in a recall task which reflects the degree of learners’ reading or listening comprehension skills and (see Carrell, 1985; Chang, 2006; Lee, 2007; Riley & Lee, 1996).

In general terms, idea units refer to individual words or chunks of words within a text or speech which have high value in terms of information (Baddeley, 2003a, p. 202). According to Chafe (1985), idea units in spoken language encompass as much information as one can hold in working memory. There are some characteristics of idea units in spoken language. In spoken language, idea units are generally shorter and have simpler syntax. They are generally combined together by conjunctions such as and, or, but, etc. (cited in Buck, 2011, p.10.). Generally, listeners construct meaning of an idea unit by combining the meaning of individual words and the meaning of whole utterances. They form a summary or gist of the message. Parsing of idea units requires establishing a relationship between the small parts of utterances based on syntactic and semantic factors. Depending on complexity or easiness of semantic and syntactic factors, processing and comprehension of idea units can become challenging (Buck, 2011, p.16).

While studying the role of background knowledge in reading and text structure in reading, Carrel (1983) and Carrell (1985)adopted recall protocols from reading passages based on idea unit scoring. Idea units were defined as simple individual sentences, basic semantic propositions or phrases. Idea units were not categorised in any way such as minor or major. Riley & Lee (1996) studied reading comprehension in second language and measured free recalls of the participants. They compared summary and recall protocols in terms of idea units, main ideas and details. The text was divided into idea units by two raters and those which were agreed on a consensus basis were used as units of analysis. They also adopted Carrel’s (1983, 1985) definition, individual simple sentences, basic semantic propositions or phrases were regarded as idea units. Lee (2007) investigated the effects of textual enhancement and familiarity in reading and used idea unit scoring for the analysis of texts and three raters conducted the idea unit analysis of the texts used in the study. A single clause, main or subordinate which includes adverbial and relative clauses made up an idea unit of the texts. Infinitival constructions, gerundives or nominalized verb phrases were also regarded separate idea units.

Ellis and Barkhuizen (2005) provided a definition of idea units as “a message segment consisting of a topic and comment that is separated from contiguous units syntactically and/or intentionally” and that is dependent on semantic content. Shin, Lidster, Sabraw and Yeager (2016) studied the effects of second language proficiency in a collaborative text reconstruction tasks and used idea unit scoring in their method. They used Ellis and Barkhuizen’s (2005) definition of idea unit and as can be seen in the examples below, the idea units were in full topic and comment structure. Therefore, they have identified semantic features in each idea unit and assigned weight to parts of the units, and carried out scoring according to these weights.

Idea Unit 1: In 2001 the UN reported that the world’s population has reached 7 billion people
Idea Unit 2: However, not all populations seem to be increasing.

Brantmeier, Strube & Yu (2014) studied pausal and idea units in scoring written recalls. They adopted the definition of Riley and Lee (1996) that is the idea unit is an idea, proposition, or constituent structure. In Riley and Lee (1996), each piece of information that adds meaning to the recall is classified as an idea unit. Based on this approach, Brantmeier, Strube & Yu (2014) identified the idea units of the texts used in their study (see example 2) with a high inter-rater reliability (.96) and scored the written recalls of the participants whether the idea unit is present or not with 0 or 1 scores.

Example 1: First impressions /[1] are the initial judgments /[2] we make about people /[3] and they play an important role /[4] in social perceptions /[5]. Idea units
Example 2: First impressions are the initial judgments we make about people /[1] and they play an important role in social perceptions /[2]. Pausal units

In a study which investigates students' accuracy in their recall of definitions and how to improve the accuracy of recall, Lipko, Dunlosky and Hartwig (2009) developed an idea unit standard of definitions for middle school students and suggested that using standards helps to reduce overconfidence of students in evaluation their own recalls. After students were tested on their recall of definitions, they were presented with a priori determined idea units of the definitions and asked to indicate whether those idea units were present in their responses. Although the method of idea unit identification was not explained, a table showing both definitions and their idea units were provided in the Appendix as seen below (Lipko et al., 2009, p. 318).

Definition of Genetics Meiosis: A process that requires two cell divisions, and the chromosomes only copy once in the formation of sex cells or gametes.
Idea Units: **(1)** process requiring two cell divisions **(2)** chromosomes copy once **(3)** formation of sex cells or gametes

Dunlosky, Hartwig, Rawson and Lipko (2011) used again an idea-unit standard in their study to investigate college students' evaluation of text learning. They tried to evaluate which concepts of psychology were recalled better by students. Rather than the term "proposition", Dunlosky et al. (2011) adopted the term "idea unit" as an intermediate conceptual unit of information. The term "idea unit" was assumed to indicate the key unit of conceptual information. They conducted two experiments, in the first one students were asked to recall the definitions of 16 psychology concepts and then judge their quality of recall. Another groups of students were asked to judge their recall while seeing their own response and pre-determined idea units of the definition. They were instructed to state whether the idea units were present in their definitions. In the second experiment, a new groups was added. In this groups, participants were also asked to generate idea units from the provided definitions. They were instructed to divide the definitions into small chunks of information namely idea units which were defined as “the most important chunk of information that should be present in the answer.” An example of idea units of a definition provided by the researchers is as follows:

Definition of Proactive Interference: Information already stored in memory interferes with the learning of new information.
Idea Units: **(1)** information in memory **(2)** interferes with learning **(3)** new information

Idea unit scoring is also used in listening comprehension in second language and recall in interpreting studies. In their study on listening comprehension and recall in French as a second language, Ableeva and Lantolf (2011) applied idea unit scoring based on Lee and Riley's approach (1996) which classifies idea units into main ideas, supporting ideas and details. Idea unit segmentation of the text was carried out by three external raters and a second group of different raters ranked the idea units according to the classification (Ableeva & Lantolf, 2011, p. 141).

While studying recall in amnesia and its implications for working memory, Baddeley and Wilson (2002) measured prose recall using idea units. Even though they did not provide any information regarding the idea unit analysis in their study, they presented all the recall results based on mean number of idea units which were correctly recalled and reproduced. They showed that patients with impaired LTM could recall a passage including more than 20 idea units, which suggested that WM and episodic buffer were deployed (Baddeley & Wilson, 2002, p. 1739).

In a similar fashion, Ward et al. (2016) investigated effects of verbal working memory on recall of short stories. Participants' recall was scored via an idea unit scoring approach in which minimal idea units were divided into hierarchical levels as higher level and lower level idea units. An example was provided showing how idea unit scoring scheme looked like (Ward, Rogers, Van Engen, & Peelle, 2015, p. 101).

Example Sentence: A lion and a boar stopped to take a drink from a small well.
Idea Units of the Example Sentence: A lion and a boar stopped (1st order) / to take a drink (2nd order) / from a well (3rd order) / a small well (4th order).

In their study on the effect of expertise in simultaneous interpreting, Minhua, Schallert and Carroll (2005) compared professional and student interpreters. They carried out the measurement of content accuracy by applying idea unit scoring. Idea units were divided into as essential idea units and secondary idea units. The importance of idea units were identified by two raters. Then, idea units which were reproduced correctly received 1, if not 0 (Liu, Schallert, & Carroll, 2004, p. 26). Macnamara and Conway (2015) investigated the relationship between working memory capacity and simultaneous language interpreting performance. For analyzing interpreting performance, they applied idea unit scoring based on the presence or absence of an idea unit. They divided the story used for interpretation into 22 units however their method of identifying the units was not specified. Each idea unit was scored from 0 to 4; 0: completely absent, 1: idea appeared where most of the information is missing or incorrect, 2: idea appeared where half of the information is missing or incorrect. No clear division was provided for score of 3 and score of 4 (Macnamara & Conway, 2015, p. 4)

Although idea unit scoring is commonly applied in reading and listening, and memory and recall studies, a firm and solid definition has not been proposed and the issue of defining an idea unit still remains problematic. Definition of an idea unit and the method used for identifying idea units vary based on the task in question and individual approaches of researchers. When the literature was reviewed in terms of use of idea unit scoring, it is possible to encounter a variety of applications and definitions. Most importantly, most of the researchers who have used idea unit scoring did not explain how thy segmented the texts or sentences into idea units, how they tested reliability, therefore, it is of significant importance to properly apply idea unit scoring by providing detailed information on the steps taken to come up with an idea-unit scoring protocol. It is fundamental to develop a scoring rubric or protocol which can be used to score content accuracy by giving weights or points to each idea units that were recalled completely. Therefore, an idea-unit protocol was developed for this study by collecting data from professional and student interpreters. Based on this protocol, consecutive interpreting outputs of student interpreters were evaluated based on content accuracy through scoring correctly recalled and interpreted idea units. The method of analysing idea units; whether they were omitted, partially accurately rendered or perfectly rendered was applied, and a final decision was made regarding the overall score.

3.3.3.7. Developing an Idea-Unit Protocol for Scoring Consecutive Interpreting

In this thesis, the idea unit scoring protocol was adopted for scoring recall and content accuracy of interpreting performances considering various studies on language and memory which applied this method in different ways. It is assumed that the idea-unit scoring would be a suitable option for analysing content of interpreting output referred to as "information transfer" in interpreting process by Gile (2009) (cited in Tiselius, 2015, p.4). It was believed that this would yield some insight into how much information was transferred during interpreting and whether the information was accurate and enough. However, it was fundamental to develop a reliable and valid idea-unit scoring protocol. Rather than asking two or three raters to identify the idea units of the speeches used in pre- and post-tests, gathering data from a survey administered to more people was believed to be a better choice. With this in mind, idea unit generation experiment of Dunlosky et al. (2011) was adopted and a simple questionnaire was prepared for this purpose (see Appendix F).

The questionnaire was administered to 15 participants of the study after they completed follow-up test, and it was also distributed to 10 interpreter trainers and professional conference interpreters. All speeches used in the study were attached randomly to the survey for each respondent (see Appendix F). In the questionnaire, respondents were asked to identify idea units of speeches by intuition after seeing an operational definition and an example from Brantmeier, Strube & Yu (2014) as shown below:

Idea unit is an idea, proposition, or constituent structure. Individual words or chunks of words within a text or speech which have a high information value and add meaning to the text or speech can be classified as an idea unit.

Example of Idea Units: First impressions / are the initial judgments / we make about people /, and they play an important role / in social perceptions /. We are more likely to form opinions / of others quickly / based on first impressions /, than to refrain from forming opinions / until we have more information /. These first impressions may change / as we get to know a person better /, but we often tend to hang on to them / even in the face of contradictory evidence /. Thus, initial opinions may have a strong impact / on our future interactions with people /.

Respondents were instructed to divide each sentence into idea units that they consider the most important chunk of information for an accurate and coherent interpretation and that they consider should be definitely present in the utterance of an interpreter considering their correspondence in Turkish. They were simply asked to put vertical slashes between the idea units taking into account recalling process during interpreting. However, it is vital to show the reliability of the judgment of numbers of idea units in some way (Alderson, 2001).

Percentage agreement is a simple method, which shows the percentage of agreed annotations but it can be biased to present higher agreement because it is not corrected for chance agreement. Therefore a chance-corrected method is required to have a reliable and valid result. Kappa coefficients which factor out the chance agreement are commonly used for inter-rater/coder/annotator agreement. While Cohen's kappa is a measure of the agreement between two raters, Fleiss' kappa (1971) is a measure of the agreement among multiple raters. However, nominal or categorical variables are needed for this measure (Krippendorff, 2011). Therefore, exact matches for each idea unit were calculated and then used for Kappa agreement (see Zeyrek et al., 2013). The number of exact matches for idea units was obtained by running a Java code. The code gave three separate files; one for agreement among all respondents; one for agreement among only student respondents and one for agreement among only expert respondents.

For example, for the speech titled "Alexander the Great" which was composed of seven sentences, a total of 54 idea units were generated by the respondents. While some respondents identified rather short and high number of idea units, some of them kept the units rather long, which resulted in such a variance among respondents. The sentence below taken from "Alexander the Great" illustrates how idea units were generated.

Sentence: Alexander the Great began his quest to conquer the world at the age of 20, when he became the king of Macedonia.

Table 9: Idea units generated for the speech "Alexander the Great"

Generated Idea Units	Number of Exact Matches
Alexander the Great	**20**
Alexander the Great began his quest to conquer the world	**4**
Alexander the Great began his quest to conquer the world at the age of 20	**1**
began his quest	**5**
began his quest to conquer the world	**10**
began his quest to conquer the world at the age of 20	**5**
to conquer the world	**4**
to conquer the world at the age of 20	**2**
at the age of 20	**18**
when he became the king of Macedonia.	**25**

For this sentence, 10 different idea units were generated by respondents. As can be seen in the table, while a majority of respondents preferred to divide the sentence into smaller units, only two or three respondents came up with rather long units comprising of a huge amount of information.

Even though by just looking at the number of exact matches for the units which shows how many respondents identified exactly the same idea unit, it cannot be solely used to justify and validate the protocol. Therefore, percent agreements and Kappa measures were calculated for each speech with respect to all possible units generated by respondents in order to present judgment agreement for the speeches in terms of generated idea units. While calculating Kappa measures, units which were agreed by only 3 or 4 people out of 25 were deleted. Respondents who generated the lowest and highest number of idea units were excluded since they were considered to be outliers. It was realised that most of the disagreements among respondents of the survey resulted from dividing units into multiple small units or having rather longer units (in some cases one single sentence was identified as a single idea unit).

As can be seen from Table 10, even though the number of raters/respondents ranged from 8 to 10 for experts and students considering the excluded ones, the percentage agreements were high, and Kappa measures showed moderate and acceptable level of agreement among respondents. This shows that the idea units that were identified by them can be used as a reliable source of analysis. Therefore, idea units which had high number of exact matches as a sign of agreement by the highest number of raters were used as the basis of the idea unit protocol for scoring consecutive interpreting performances.

Table 10: Agreement measures for raters of speeches in terms of idea units

		Percentage Agreement		**Kappa Measures**			
				Fleiss' Kappa		**Krippendorff's alpha**	
		expert	**student**	**expert**	**student**	**expert**	**student**
Pre-Test	**Alexander the Great**	74	80	0.42	0.60	0.43	0.60
	Communication Theory	76	78	0.51	0.55	0.51	0.56
	Benefits of Pets	87	80	0.74	0.59	0.74	0.59
	Poisonous Plants	80	80	0.60	0.56	0.60	0.56
	Invention of Telescope	87	82	0.74	0.62	0.74	0.62
Post-Test	**Uses of Money**	80	82	0.57	0.62	0.57	0.62
	League of Nations	84	87	0.63	0.74	0.63	0.74
	Magna Carta	90	78	0.77	0.55	0.77	0.55
	Culture	84	77	0.60	0.53	0.60	0.53
	Genealogy	78	81	0.52	0.53	0.52	0.53

According to the final idea-unit protocol for the speeches (see Appendix G), the number of idea units in speeches ranged from 16 to 23 as can be seen in the table below. The mean number of idea units in pre-test and post-test was found to be the same, which was a good indicator that both tests could have similar level of load on WM resources in terms of recalling the verbal content.

Table 11: Total Number of Idea Units in Speeches used in Pre-test and Post-test

Speeches used in Pre-test	**Number of Idea Units**	**Speeches used in Post-test**	**Number of Idea Units**
Alexander the Great	16	Uses of Money	18
Communication Theory	19	Genealogy	18
Benefits of Pets	19	League of Nations	19
The Invention of the Telescope	20	Culture	19
Poisonous Plants	25	Magna Carta	23
Mean	**19.8**	**Mean**	**19.4**

Participants' reformulations were scored based on the number of the idea units that were recalled and rendered correctly in any propositional order avoiding shifts in the meaning of the message. For each idea unit, participants received 0 if the unit was omitted; 1 if the unit was partially recalled and interpreted and 2 if the unit was fully recalled and interpreted. In this way, consecutive interpreting scores of the participants were calculated for each speech based on a protocol developed within the scope of the study.

3.4. Functional Near-Infrared Spectroscopy (fNIRS) As an Optical Brain Imaging Technique

Functional Near-Infrared Spectroscopy (fNIRS) is a noninvasive optical brain imaging technology that monitors changes in hemodynamic response and blood oxygenation within the cortex. It is portable, small and reliable technique to use even in natural environment of a variety of tasks (Masataka, Perlovsky & Hiraki, 2015). As it is clear from its name, spectroscopy is based on light signals; thus fNIRS device uses specific wavelengths of light within the near-infrared range of electromagnetic spectrum (620-1000 nm) and measures changes in the relative ratios of deoxygenated hemoglobin (deoxy-Hb) and oxygenated hemoglobin (oxy-Hb) in the capillary beds during brain activity (Ayaz et al., 2010; Çakir et al., 2011; Masataka, Perlovsky & Hiraki, 2015; Pascual-Leone et al., 2016; Çakir et al., 2018). When neurons are activated, they need energy which is derived from glucose and oxygen is used to metabolize the glucose. Because of this demand for glucose, oxygen consumption increases. This neuronal activity triggers blood flow because oxygen is transferred to neural tissue via oxy-hemoglobin in the blood. While a decrease in oxygenation in tissue is observed during neural activity, an increase in oxygen supply resulting from increased cerebral blood flow and cerebral blood volume happens. This process is known as neurovascular coupling (Leon-Carrion & Leon-Dominguez, 2012, p.52). This mechanism describes temporal and regional connection between neural activity and cerebral blood flow, which is generally used to gain an understanding of a specific cognitive task (Obrig et al., 2000; Phillips, Chan, Zheng, Krassioukov & Ainslie, 2015). The increased blood flow during a task is directly linked to increase in synaptic activity. Therefore, oxy-Hb and deoxy-Hb can be considered neural correlates of brain activity (Heeger & Ress, 2002, p. 144).

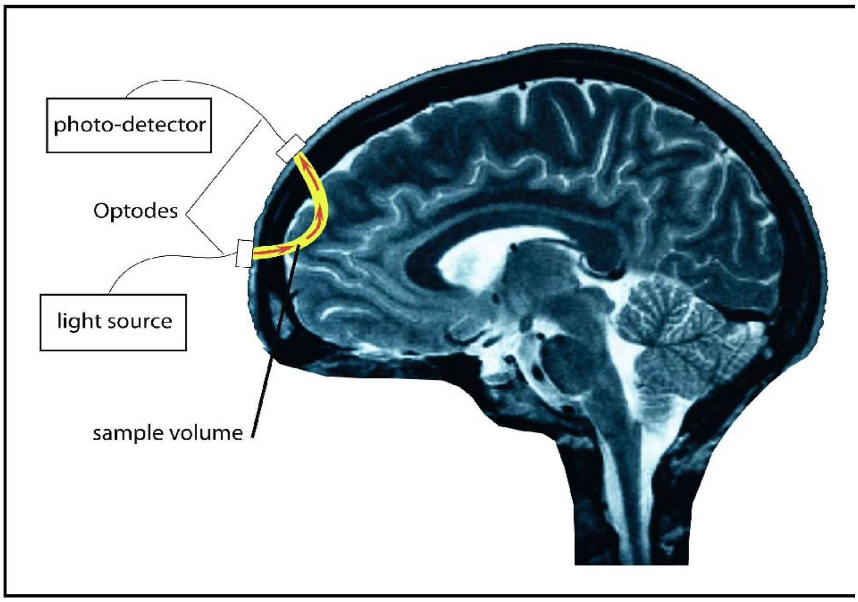

Figure 10: The path that photons follow in the tissue (taken from Leon-Carrion & Leon-Dominguez., 2012)

Biological tissues such as neural tissues have distinct optical features. They have specific characteristics in terms of transparency and absorption. While the near-infrared range of electromagnetic spectrum (700-900 nm.) diffuses through most biological tissues of the head such as skin, skull, etc. since they are relatively transparent to light in this range; then it is absorbed by oxygenated hemoglobin and deoxygenated hemoglobin because of the changes in the oxygen concentrations (Çakir et al.. 2011; Izzetoglu et al.. 2005). Once photons enter into human head through light sources of fNIRS sensor pad, they have three possible paths; (1) they can undergo scattering events and reach the detector; (2) they can be absorbed or (3) they leave the head without detection.

After interactions with chromophores, the light wave that enters into the skin follows a banana-shaped path while going back to the surface of the skin and then is captured by a detector (Leon-Carrion & Leon-Dominguez. 2012. p.48-49). Basically, near infrared light enters the head by a light probe and photons are mostly scattered and partly absorbed when they enter the tissue. While the scattered light leave the head, it can be detected by another probe which is a few centimetres away from the light source (Obrig et al.. 2000. pp. 126–127). Based on the relative transparency of tissue to near-infrared light; it is possible with fNIRS to simultaneously measure the changes in relative concentration of oxygenated and deoxygenated hemoglobin. In this way, regional cerebral blood flow responses can be obtained by using the blood oxygen level as a dependent signal to find the changes in oxygenated (O_2Hb), deoxygenated (HHb) and total hemoglobin (tHb) (Phillips et al.. 2015). The difference in oxygenated and deoxygenated haemoglobin at baseline and at task is measured then location of an increase or decrease in cerebral blood flow can be determined, in this way it can be associated with a specific cerebral activity, which enables studying both spatial and temporal cerebral functions (Leon-Carrion & Leon-Dominguez. 2012).

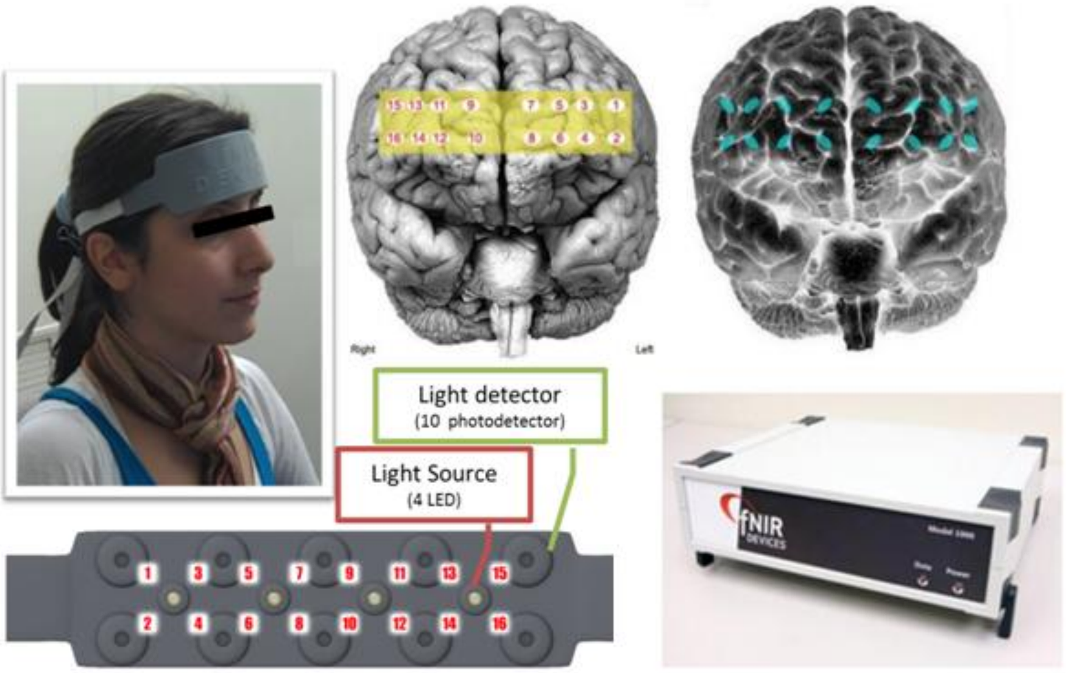
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Figure 11: General Overview of an fNIRS System

A traditional fNIRS system includes a flexible sensor pad, a control box for hardware management and a computer running COBI studio software as shown in the Figure 11. The flexible sensor pad consists of 4 LED light sources which tissue is radiated and 10 light detectors which receive light after its interaction with the tissue and it is easily attached to the forehead in various test settings (Ayaz et al., 2013). The sensor has a source-detector separation of 2.5 cm at a temporal resolution of 500 milliseconds per scan with a sampling rate of 2 Hz. (Çakir et al., 2011; McKendrick, Ayaz, Olmstead & Parasuraman, 2014). With the configuration of 4 light sources and 10 light detectors, fNIRS system collects data from a total of 16 measurement locations (optodes) with at least two wavelengths of light at 730 nm and 850 nm (Ayaz et al., 2012; Çakir et al., 2011).

The system is designed to image cortical areas of PFC and dlPFC which generally occupy the upper and side regions of the frontal lobes. Therefore, it is highly suitable to use while studying working memory, language, reasoning and decision making. etc. by analysing relationships between activated regions of prefrontal cortex and the functions attached to those regions. While optodes from #1 to #8 gather information on the left PFC. optodes from #9 to #16 provide information on the right PFC. The optodes on each side (#1-#6 and #11-#16) correspond to the dorsolateral PFC and dorsomedial PFC; the optodes in the middle (#7-#10) correspond to fronto-polar cortex as shown in the table below (Çakir et al., 2018; Dominguez. et al., 2015).

Table 12: Optodes and the associated cortical areas (adapted from Çakir et al., 2018)

Optodes	Associated cortical areas in PFC
Optode 1 Optode 2 Optode 3 Optode 4	Left dorsolateral PFC (left dlPFC)
Optode 5 Optode 6	Left dorsomedial PFC (left dmPFC)
Optode 7 Optode 8	Left fronto-polar cortex
Optode 9 Optode 10	Right fronto-polar cortex
Optode 11 Optode 12	Right dorsomedial PFC (right dmPFC)
Optode 13 Optode 14 Optode 15 Optode 16	Right dorsolateral PFC (right dlPFC)

3.4.1. fNIRS Experiment Design and Data Recording

Functional near-infrared spectroscopy (fNIRS) system (fNIR Devices LLC; www.fnirdevices.com) was utilized while participants carried out two tasks namely *n*-back task and consecutive interpreting task which were explained in transfer tasks part of this chapter. The use of this technique enabled to investigate neural correlates of *n*-back task and consecutive interpreting. The main purpose was to investigate the cognitive workload of consecutive interpreting and *n*-back task so that the association between them could be established. Furthermore, it was aimed to investigate training induced changes in the associated regions of PFC and to see whether there was any significant difference between the groups in terms oxygenation changes after receiving different training regimes.

Optical brain imaging data were collected from each participant while they were attached to fNIRS system developed at Drexel University (Philadelphia) during these two tasks. COBI studio software (Drexel University) was used for data acquisition and visualization. The experiments were designed and run on E-prime 2.0 software and a serial cable between the computer that runs COBI studio software (Ayaz et al., 2010) and the E-prime running laptop was used for synchronization between fNIRS signals and E-Prime experiment stimuli.

Participants completed the two tasks consecutively in one session at Human-Computer Interaction Lab at METU and the activation in prefrontal cortex was monitored throughout the entire experiment duration which was about 40-45 minutes. The *n*-back task took approximately 30 minutes for participants to complete and the completion of consecutive interpreting task varied between 10-15 minutes depending on participants' speech rate. At the beginning of the experiment, the baselines were taken while participants were sitting in front of the E-Prime running laptop with their eyes closed to check whether the pad was positioned properly and signal recording was right and then participants started the experiment. During the experiment, participants were left alone in a silent environment where the external light resources were controlled and prevented. While half of the participants started the session with *n*-back task, the other half started with consecutive interpreting task.

3.4.2. fNIRS Data Processing and Analysis

fNIRS data for each task were extracted using time synchronized markers received through serial port during experiment. The time synchronization markers were identified to indicate the onset of the session and the beginning and end of the relevant parts of the tasks. Block analysis was applied. For *n*-back task, separate blocks were created for each *n*-back condition; for consecutive interpreting separate blocks were created for listening and comprehension phase and reformulation phase of each speech. While fNIRS provides a valuable opportunity to study neural activity in a task, it is very sensitive to noise and artifacts in the data. There are mainly three types of noise in fNIRS data which are instrument noise, physiological noise and experiment noise including head motion (Cui, Bray & Reiss, 2010, p. 3040). Therefore, various filters and algorithms are used to reduce the possible noise in the data.

A Finite Impulse Response (FIR) filter is generally used for eliminating physiologically irrelevant noise such as effects of respiration and heart pulse, and instrument noise. It is an adaptive filter whose coefficients or weights change according to the changing input signal's characteristics (Izzetoglu et al., 2005. p. 155). Head movement can cause the detectors of fNIRS to shift and lose contact with the skin which causes sudden large spikes in fNIR data. Therefore, it is necessary to remove motion artifact from fNIR data. **Sliding-window motion artifact rejection (SMAR)** filter is used to minimize the effect of motion artifacts. SMAR algorithm basically scans through local variation changes to identify segments with sudden

spikes or bursts with amplitudes much higher or lower than regular cortical activity related optical signal values (Cui et al., 2010, p. 3040).
While analysing the fNIRS data in fNIRSoft software, raw fNIRS data were first checked for signal quality and noise and if needed, filters were applied. A rather conservative approach was followed and FIR low pass filter was applied for high frequency and equipment noise in data as well as SMAR filter was used for motion artifact because it was observed that participants showed tendency to move their heads during the tasks especially while interpreting. Saturated channels were eliminated and also some channels were excluded after running SMAR filter. Then based on the tasks' block design, changes in concentrations of deoxygenated hemoglobin (deoxy-Hb) and oxygenated hemoglobin (oxy-Hb) within each 16 optode were calculated with reference to resting periods at the beginning of each block. Raw light data collected via fNIRS sensor can be turned into deoxy-Hb (HbR), oxy-Hb (HbO) and the total hemoglobin concentration values by using optical algorithms.

One of the most commonly used algorithms is The Modified Beer-Lambert Law (MBLL) to calculate the mean oxygenation changes. It basically explains the linear relationship between absorption of a lightwave and the path it follows. Optical density is measured at two wavelengths and concentrations levels of Hb and HbO_2 are measured relative to the baseline therefore calculated values of concentration cannot be absolute (Leon-Carrion & Leon-Dominguez, 2012, pp.53-54). This law shows the light intensity loss in tissue and assumes that changes in the light intensity are mainly related to the changes in deoxy-Hb and oxy-Hb. This law takes into account the wavelength used in the measurement, chromophore concentrations, extinction coefficient of chromophore, the distance between light source and detector, differential path length factor and the law accounts for scattering dependent losses of photons (Scholkmann et al., 2014, p. 15).

When the concentrations levels were calculated with MBLL for each block of the tasks, the hemodynamic response at each optode was averaged across time for each block with respect to local baseline measured at the beginning of each block which is approximately five seconds before each block, which enables more reliable and accurate measurement of oxygenation change within the task. In this way a mean hemodynamic response at each optode was obtained for each block (1-back. 2-back. 3-back. 4-back; comprehension and reformulation). After checking signal quality and filtering noise in the data via SMAR and FIR, there were still problematic cases or outliers in which data were too noisy to include in the analysis. These cases belonged to 4 participants and their data were always too noisy in pre- and post-tests as well as follow-up. Two of these participants were in *n*-back group and two of them were in control group. Therefore, their fNIRS data were excluded from the analysis, which decreased the total number of data-collected participants to 14 at pre- and post-tests. All analyses were carried out based on averaged HbO values across 16 optodes of final 14 participants. The main reason for choosing to use mean HbO concentrations is that HbO has been shown to highly correlate with BOLD signals used in fMRI (Sato et al., 2013). This enables the discussion of the results in relation to fMRI findings of relevant studies, as well. Following necessary analyses and calculation on fNIRSoft software, all data files showing averaged oxygenation values for each participant during every block of the tasks across 16 channels were exported as excel files for further statistical analyses in IBM SPSS Statistics 24.

3.5. Summary of Chapter 3: Method

This chapter explained the general procedure followed throughout the thesis. 18 interpreting students were divided into two as *n*-back group (experimental group) and control group (trained on simple letter span) randomly in a block design based on gender, age, study year at the university, and performance on pre-test reading span task. Both groups had adaptive training regimes within same period of time and under similar conditions. Participants were tested on a variety of measures before the training sessions (pre-test), right after the completion of trainings (post-test), and three month following the post-test (follow-up), which allowed to investigate immediate and long-term effects of the training intervention. Based on the divisions of transfer effects proposed by Lange and Süβ (2015); namely near, moderate and far transfer effects, different tasks were utilized for various levels of the transfer. Dual *n*-back and digit span tasks were used for near transfer, reading span task for moderate transfer, and Bochum Matrices Test (BOMAT) for far transfer. Furthermore, consecutive interpreting task was considered to represent real life skills as an applied domain of cognition. Therefore, participants were also asked to interpret five different speeches in English in a consecutive mode in each testing time. While collecting behavioral data through various measures of WM and other cognitive abilities, optical brain imaging data were collected via fNIRS (Functional Near-Infrared Spectroscopy) during n-back task and consecutive interpreting in each testing phase, which provided valuable results for investigating neural correlates of the tasks and effects of intensive WM training. This integrated and elaborative approach paved the way for better understanding of underlying mechanisms of transfer effects of *n*-back WM training. In addition to these transfer and training tasks, two scales; namely The Need for Cognition Scale and Theories of Cognitive Abilities, were administered to participants in order to measure their engagement and motivation in the training as well as their beliefs about intelligence, whether intelligence is fixed or malleable. With a design of longitudinal study, the thesis aimed to provide explanations for transfer effects of *n*-back WM training from a multidimensional perspective.

CHAPTER 4

RESULTS

This chapter mainly consists of five parts. In the first part, results of two baseline questionnaires were presented. In the second part, performance gains during training sessions were analysed. In the third and fourth parts, cognitive performances in training tasks and transfer tasks were analysed whether near and far transfer effects and transfer to consecutive interpreting differed between groups across pre-, post-tests and follow-up. In the fifth part, optical brain imaging (fNIRS) data were analysed to gain a better insight into the neural correlates of single *n*-back task and consecutive interpreting.

Statistical analyses were performed with IBM SPSS 24 software to investigate performance gains during training, baseline performances of the two groups and intervention-related performance changes between the groups. Descriptive data and results of statistical analysis tests were provided for training, near transfer and far transfer tasks, separately. The normal distribution of the variables in the tasks and scales was tested with Shapiro-Wilk Test since the sample size was lower than 50. Dependent variables in each task were found to be normally distributed (p value was greater than .05 level). The assumption of the homogeneity of variances was tested with the Levene's test of homogeneity of variances, and none of the effects violated the assumption (p value was greater than .05 level). In the analyses, mixed repeated measures of ANOVAs were implemented with group as between-subject factor and time as within subject-factor for all tasks. Planned contrasts were conducted to compare pre-test to post-test and post-test to 3-month follow-up. Significance levels were set to .05 while performing all statistical analyses, and one-tailed tests were applied while comparing the groups since it was expected that *n*-back group would show better performance compared to active control group (see Jaeggi et. al., 2014). Partial eta-squared values were used to show the effects sizes of the tests. Descriptive data were provided either in graphs or tables which present adjusted mean values, and error bars indicating standard errors of the mean.

4.1. Baseline Questionnaires

Two baseline questionnaires; namely Need for Cognition Scale and Dweck’s Theories of Cognitive Abilities Scale, were administered before training, right after training and in three-month follow-up period. The main aim of administering these scales was to gather an understanding of participants’ motivation and engagement levels during training and test sessions as well as their beliefs on intelligence and cognitive training.

4.1.1. Need for Cognition Scale

In this scale, participants were asked indicate to what extent the statement is characteristic of them on 5-point Likert scale (1: extremely uncharacteristic….5: extremely characteristic). There were a total of 18 items in the scale. Half of the items were reverse coded. In other words, while half of the items measure preferences for cognitive challenging situations (e.g., “I would prefer complex to simple problems.”), remaining reverse coded items show the unwillingness for such cognitive endeavours (e.g., “Learning new ways to think doesn't excite me very much.”). The overall score of the scale for each participant was calculated by totalling the ratings for all items. For example, if a statement was considered “(5) extremely characteristics” then the item was given 5 points. If a reverse coded statement was considered “(1) extremely uncharacteristic” then the item was given 5 points (Hevey, Thomas, Pertl, Maher, & Craig, 2012).

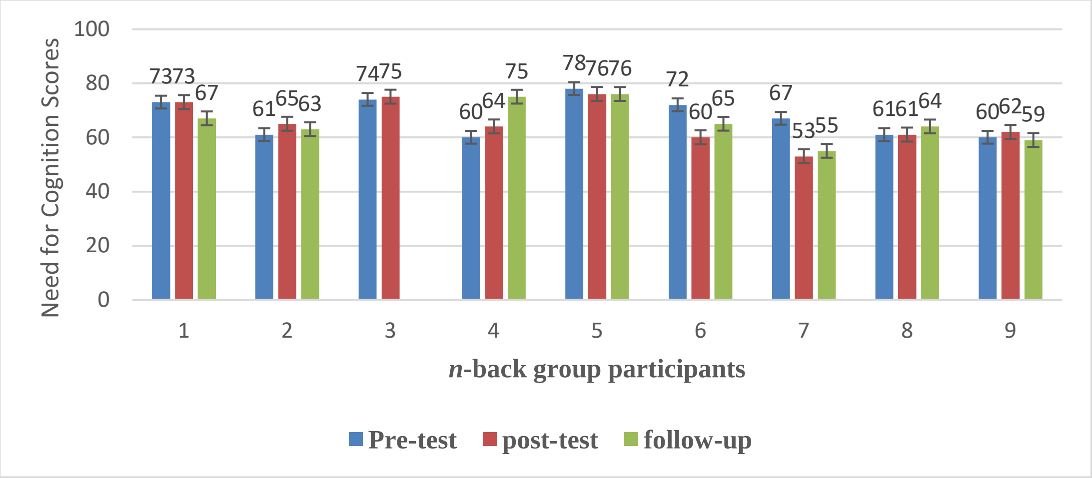

Figure 12: Need for Cognition Scale Scores of participants in n-back group in pre- and post-tests and 3-month follow-up

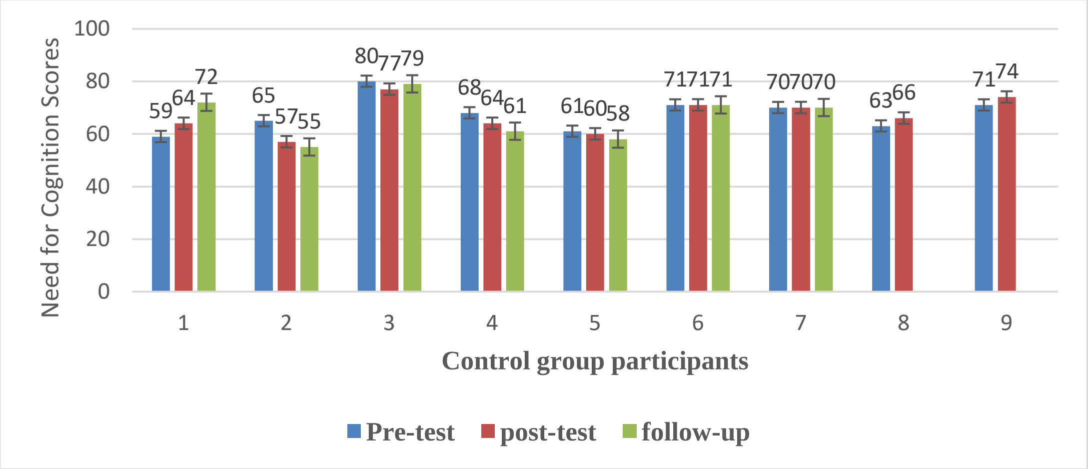

Figure 13: Need for Cognition Scale Scores of participants in control group in pre- and post-tests and 3-month follow-up

Since a 5-point likert scale was used, the score for the Need for Cognition Scale ranged from 18 to 90. As can be seen from the figures above, participants in each group had high scores in the scale. Higher scores indicate the openness and tendency to learning new things and willingness for cognitive effort under challenging situations. It is possible to classify the scores as follows (Benge, 2014) to better understand individual's likelihood to enjoy cognitive thinking:

Table 13: Need for Cognition Scale scores and their implications for likelihood to enjoy thinking

Need for Cognition Score	Likelihood to engage in and enjoy thinking
1-18	Participant is unlikely to engage in and enjoy thinking.
19-36	Participant is slightly likely to engage in and enjoy thinking.
37-54	Participant is moderately likely to engage in and enjoy thinking.
55-72	Participant is very likely to engage in and enjoy thinking.
72-90	Participant is extremely likely to engage in and enjoy thinking.

Mean Need for Cognition scores of groups shown in Figure 14 reveal that in pre-test, *n*-back group (Mean=67.33, SD = 7.07) and control group (Mean=67.56, SD = 6.40) had similar scores in the scale and there was not a statistically significant difference between *n*-back and control groups (t(16)= -0.09, p = 0.95 2-tailed). Participants in each group had similarly high attitudes towards cognitive effort and learning new things. The mean scores in pre- and post-tests and follow-up were within the range of 55 and 72, indicating that participants in both groups were very likely to enjoy cognitive effort in challenging endeavours.

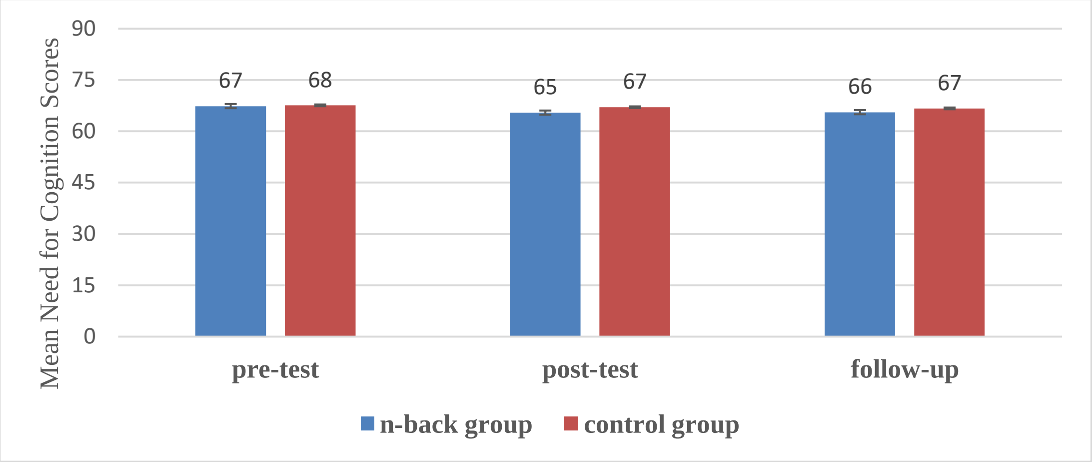

Figure 14: Mean Need for Cognition Scale scores across groups in pre- and post-tests and 3-month follow-up

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) show that there was no main effect of time on scale scores ($F(2,32) = 0.713$, p= .50, $\eta p^2 = 0.05$). The groups maintained their high scores across all three testing times. There was not a significant decrease or increase in their scores There was no main effect of group on scale scores ($F(1,16) = 0.17$, p=.68, $\eta p^2 = 0.01$). There was not a significant interaction between time and group ($F(2,32) = 0.04$, p=.96, $\eta p^2 = 0.003$). These results show that groups did not significantly differ from each other at any testing point in terms of their scale scores, which indicates that both groups equally enjoyed the tasks and had favourable attitudes for engaging in such cognitive activities.

4.1.2. Dweck's Theories of Cognitive Abilities Scale

The Dweck's Theories of Cognitive Abilities Scale is composed of 3 entity-only items such as "You have a certain amount of intelligence, and you really can't do much to change it." on 6-point Likert scale (1: strongly agree;….6:strongly disagree). The overall score of the scale for each participant was calculated by totalling the ratings for all items. The score for the Dweck's Theories of Cognitive Abilities Scale range from 3 to 18. Higher scores show a stronger belief that intelligence is not fixed; it is malleable (Thomas & Sarnecka, 2015). According to two figures below representing individual scale scores of participants in *n*-back and control groups, participants in both groups had high scores, indicating that they were on the opinion that the intelligence is malleable and it can be changed. This implies that participants had positive views on cognitive training.

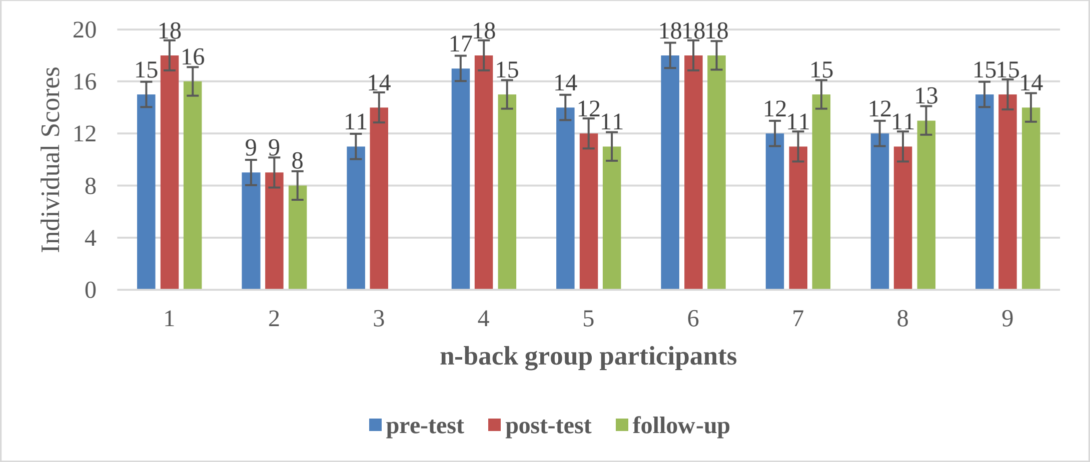

Figure 15: Dweck's Theories of Cognitive Abilities Scale Scores of participants in n-back group in pre- and post-tests and 3-month follow-up

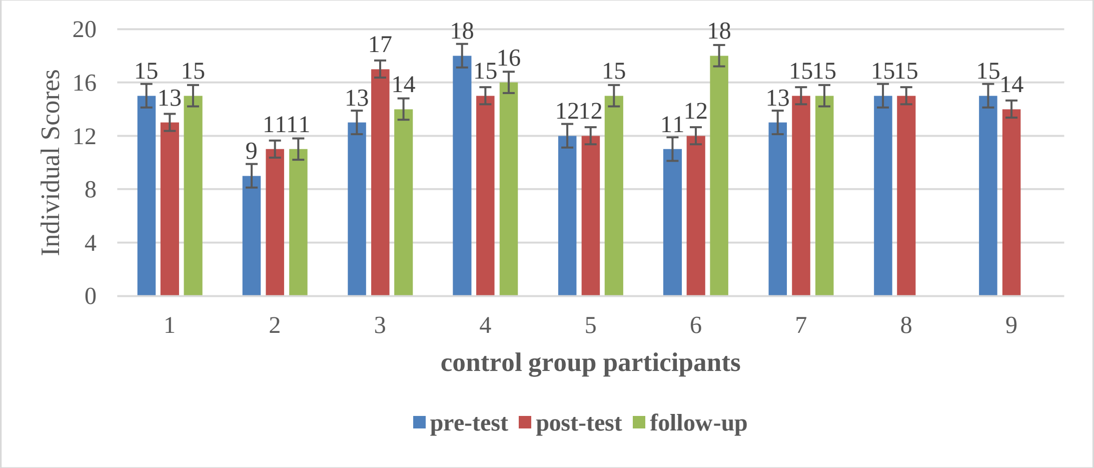

Figure 16: Dweck's Theories of Cognitive Abilities Scale Scores of participants in control group in pre- and post-tests and 3-month follow-up

In pre-test, *n*-back group (Mean=13.67, SD = 2.91) and control group (Mean=13.44, SD = 2.65) had similar scores in Dweck's theories of cognitive abilities scale and there was not a significant difference between *n*-back group and control group (t(16)= 0.17, p=0.87, 2-tailed). This shows that participants in each group had similarly positive belief that intelligence is not fixed rather it is malleable.

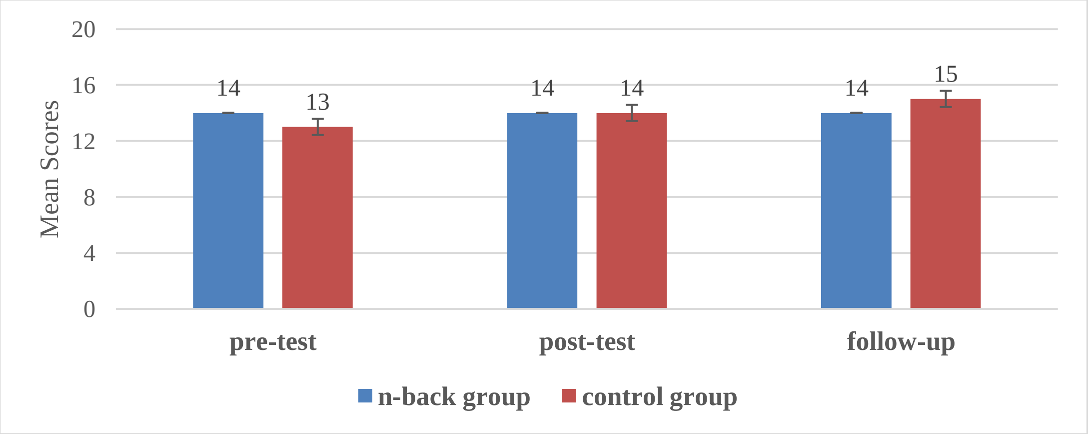

Figure 17: Mean scores of Dweck's Theories of Cognitive Abilities Scale of groups in pre- and post-tests and 3-month follow-up

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) show that there was no main effect of time on scale scores (*F*(2,32)=1.13, p=.34 ηp² = 0,07). The groups maintained their high scores across all three testing times. There was not a significant decrease or increase in their scores. There was no main effect of group on scale scores (*F*(1,16) =0.04, p=0.84, ηp² = 0,002). There was not a significant time and group interaction (*F*(2,32) = 1.10, p=.35, ηp² = 0.003). These results show that groups did not significantly differ from each other at any testing point in terms of their scale scores, which indicates that both groups equally have positive opinions about intelligence and that it can be changed.

4.2. Performance Gains During Training Sessions

Participants trained for 2 days a week and completed a total of 14 training sessions. Both training schemas were adaptive, the span length or *n*-back level that participants were exposed to on subsequent training session was based on their performance during the previous session. In this way, both tasks were kept similarly challenging and engaging for the participants. Figures below show that the adaptive nature of the training sessions allowed groups to gradually increase the level of difficulty.

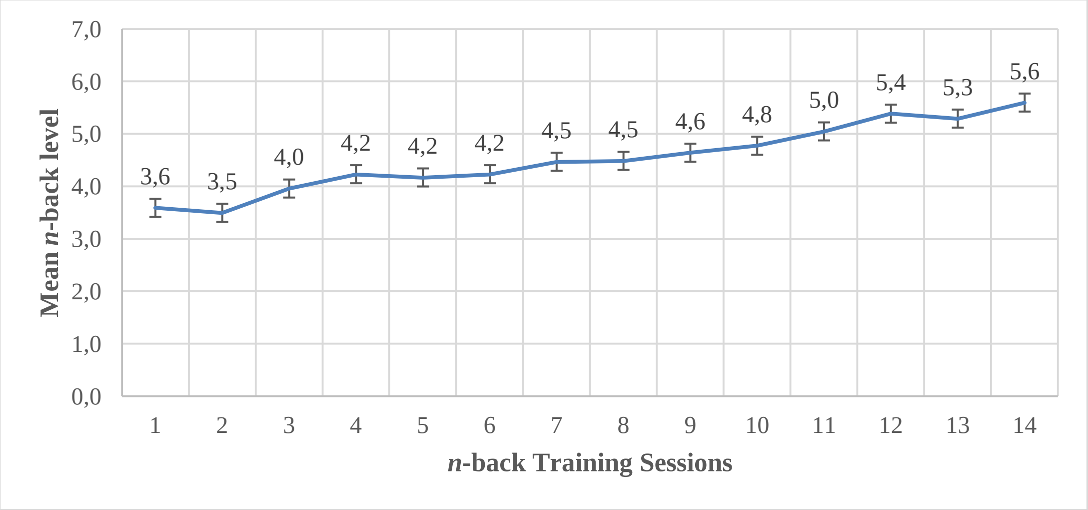

Figure 18: Mean n-back level of n-back group across 14 adaptive training sessions.

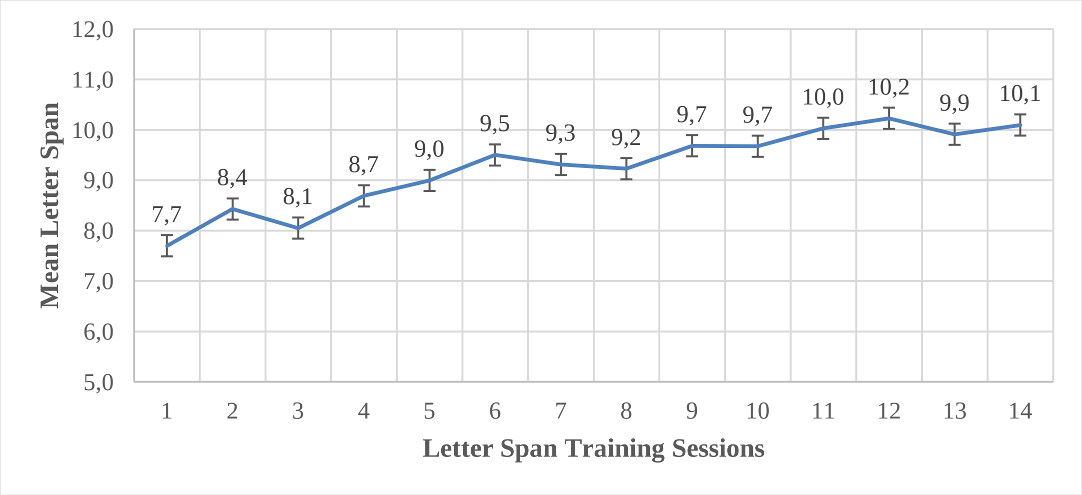

Figure 19: Mean letter span length of the control group across 14 adaptive training sessions.

A repeated-measure ANOVA was conducted to assess the performance gains over seven weeks for each group. Weekly performance of participants; namely average levels they reached during the week were used for analysis (see Jaeggi et. al., 2014; Brehmer et. al., 2012). As a result of the adaptive nature of both training regimes, both groups significantly improved their performance over the seven weeks of intensive training; there was a main effect of time for both *n*-back group F(6,48) = 9.66, p<.05 ηp² = 0,55 and for control group F(6,48) = 9.94, p<.05 ηp² = 0,55).

Table 14: Weekly mean performances of groups during training sessions

	***n*-back Group**		**Control Group**	
Week	**Mean**	**SE**	**Mean**	**SE**
1	3.542	.185	8.064	.225
2	4.092	.324	8.369	.520
3	4.197	.328	9.253	.503
4	4.475	.363	9.269	.387
5	4.706	.469	9.678	.384
6	5.214	.549	10.128	.487
7	5.442	.658	10.003	.454

As can be seen in Table 14, the weekly performances of both groups show that the adaptive nature of the training regimes allowed the groups to challenge themselves and gradually increase their difficulty levels. Although there may be some individual differences among the groups, the averaged group performances indicate an overall improvement.

Figures below compare the highest difficulty levels of the first three and last three training sessions for *n*-back group. At individual level, the group had both steady and unsteady participants over the course of the training. While in half of the participants the *n*-back level drastically increased, in remaining participants, the *n*-back level remained almost similar.

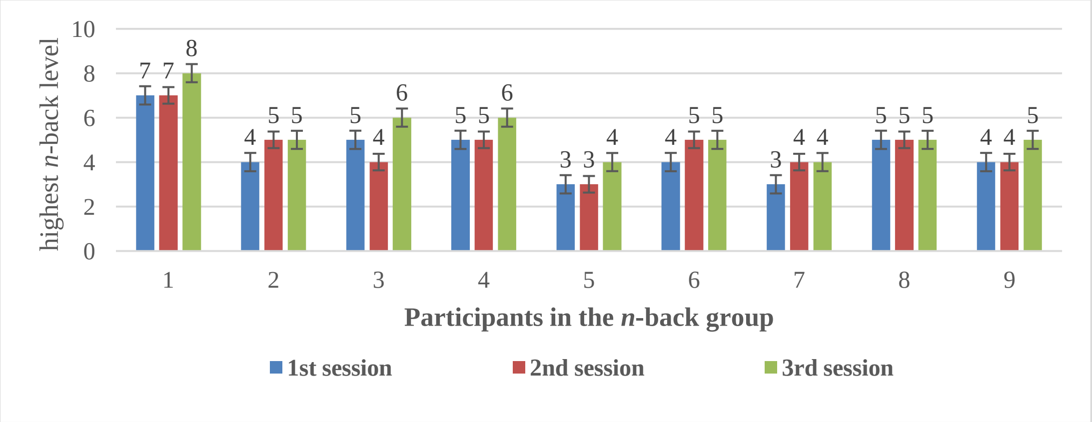

Figure 20: Highest n-back levels reached by 9 participants of n-back group in the first 3 training sessions

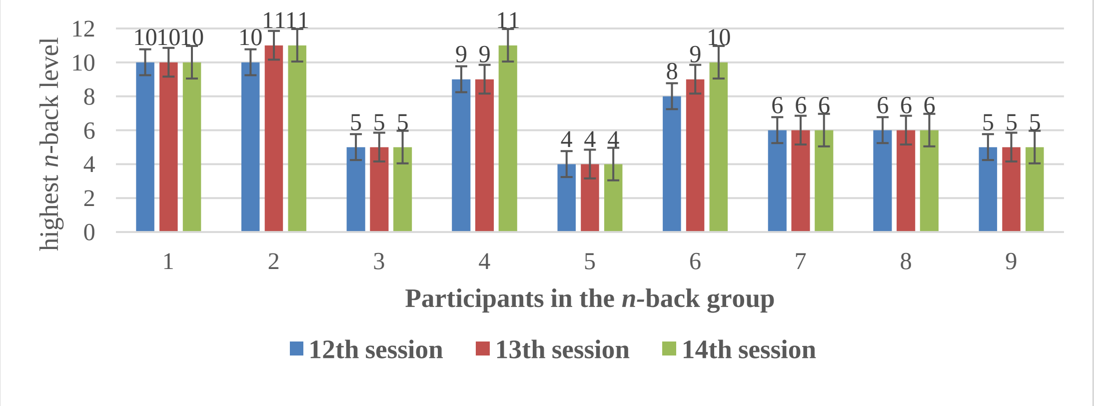

Figure 21: Highest n-back levels reached by 9 participants of n-back group in the last 3 training sessions

For the control group, a similar overall look emerged. As can be seen in Figures below at individual level, while the letter span length drastically increased in most participants, in a few participants, the letter span length remained almost unchanged from the first three sessions to the last three sessions.

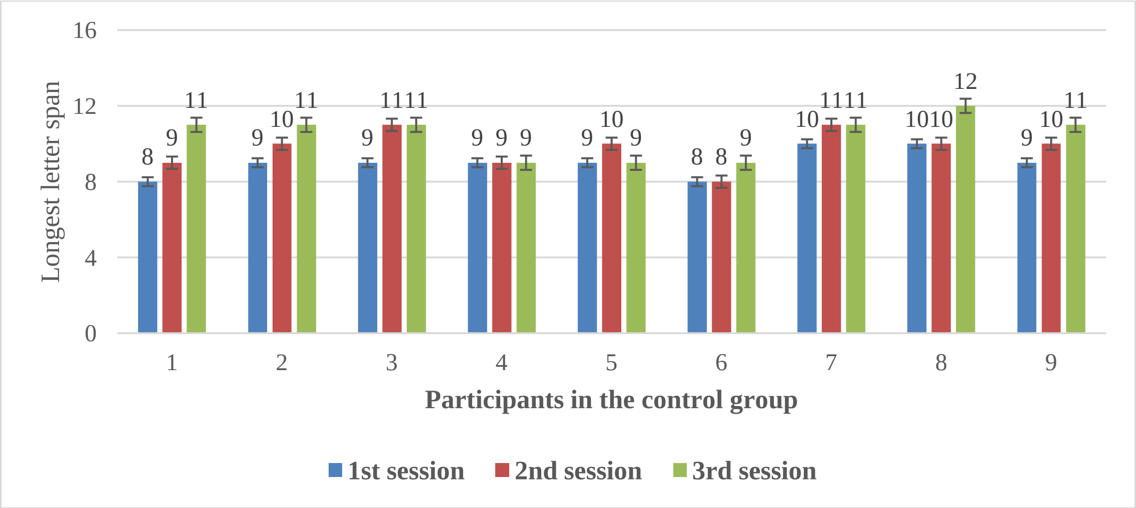

Figure 22: The longest letter span reached by 9 participants of control group in the first 3 training sessions

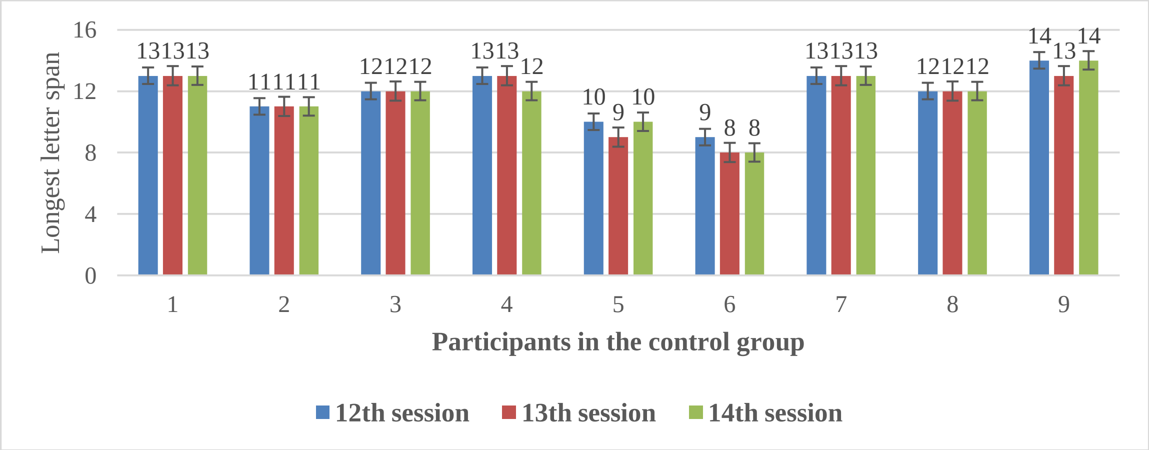

Figure 23: The longest letter span reached by 9 participants of control group in the last 3 training sessions

4.3. Cognitive Performance in Training Tasks

Repeated measures analyses of variance (Mixed ANOVA) were conducted with time as within-subject factor and group as between-subject factor to evaluate the training and transfer gains across groups within three testing times in order to analyse the amount of improvement resulting from the training effect across *n*-back and active control group. Planned repeated contrasts with Bonferroni correction were carried out, gains from pre-test to post-test and from post-test to follow-up were compared between the groups. Initially, single *n*-back task, dual *n*-back task and simple letter and digit span tasks included seven rounds of each condition. While conducting preliminary analysis of behavioural and fNIR data, it was realised that participants were not engaged and not fully concentrated in the beginning of the test; furthermore, most of the participants stated that they felt tired and had slight headache at the end of the test. Therefore, first three and last three blocks of the tasks were excluded from the analysis. Since the blocks were pseudo randomized in these tasks, one round from each level or condition were excluded from the beginning and end of the test. All the analyses with below variables were carried out with this approach.

Independent variables: Group (*n*-back group, control group); Time (Pre-test, Post-test, Follow-up)
Dependent variables: 1) Correct responses (*n*-back task), 2) Reaction times (*n*-back task) 3) Performance Percentages (letter span task)

4.3.1. *n*-Back Task

n-back task consisted of three conditions in each test. 1-back task was only administered in the pre-test because all participants performed already outstandingly well in the task and it was believed that it would not yield any difference between the groups, then it was used as a warm-up with only one round in post-test and follow-up and 4-back was added in post-test and follow-up. The number of rounds was decreased from 7 to 5 while performing analysis, hence the total number of blocks was 15 in this task; 5 rounds of each *n*-back condition. When the number of rounds was decreased to 5, 1-back had overall 32 congruent trials, 2-back had overall 30 congruent trials, 3-back had overall 32 congruent trials and 4-back had overall 32 congruent trials which required key press.

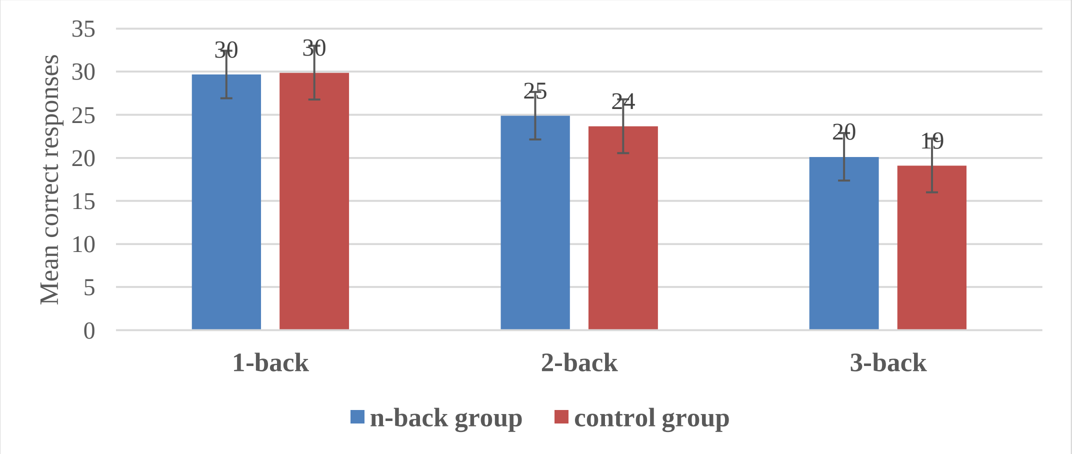

Figure 24: Mean correct responses of groups during n-back task in the pre-test

In the **pre-test**, there was no statistically significant difference between the groups in each level of *n*-back task (1-back t(16)= -0.17, p =.87; 2-back t(16)= 0.44, p=.66; 3-back t(16)=0.42, p=.68, 2-tailed). Both groups had very similar mean correct responses during the task, showing that there was not any baseline difference between the groups in the pre-test. A repeated measures of ANOVA was performed for each group separately in order to investigate whether the task difficulty was present in both groups in similar direction at pre-test. For the ***n*-back group** there was a significant main effect of task difficulty on the mean correct responses (F(2,16)=20.49, p<.05, ηp^2=0.72) and planned pairwise comparisons with Bonferroni correction showed that the number of correct responses significantly decreased from 1-back (Adj. Mean=29.66, SE = 1.06) to 2-back (Adj. Mean=24.88, SE = 1.57) and from 1-back to 3-back (Adj. Mean=20.11, SE = 1.33) as well as from 2-back to 3-back (significant at p<.05 level). Similarly, for the **control group** there was a significant main effect of task difficulty on the mean correct responses (F(2,16)= 22.69, p<.05, $\eta p^2=0.74$) and planned pairwise comparisons with Bonferroni correction revealed that there was a statistically significant decline in the number of mean correct responses from 1-back (Adj. Mean=29.88, SE = 0.82) to 2-back (Adj. Mean=23.66, SE=2.27) and from 1-back 3-back(Adj. Mean=19.11, SE=1.98) as well as from 2-back to 3-back (significant at p<.05 level). These results indicate that as the *n*-back level increases, the correct responses decrease for both groups.

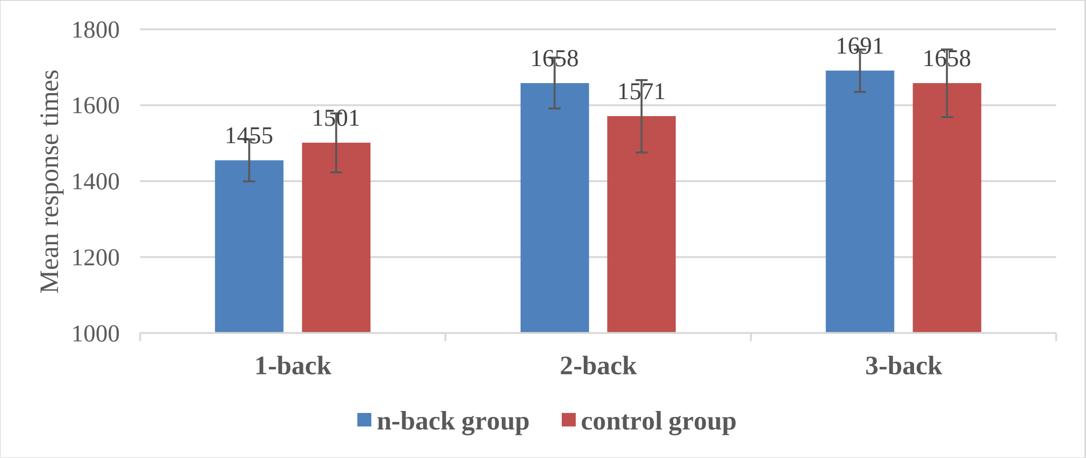

Figure 25: Mean response times of groups during n-back task in the pre-test

In addition to analysis of mean correct responses, participants' performances were also measured in terms response times during the tests. As can be seen in the Figure above, In the **pre-test**, there was no statistically significant difference between the groups in each level of *n*-back task in terms of their response times (1-back t(16)=-0.48, p=.63; 2-back t(16)=0.75, p=.46; 3-back t(16)= 0.32, p=.76, 2-tailed). These results show that there was not any baseline difference between the groups in their response times during the tasks in the pre-test. Furthermore, a repeated measures of ANOVA was performed for each group's response times separately in order to investigate whether the task difficulty was also present in response times in the pre-test. For the ***n*-back group** there was a significant main effect of task difficulty on the mean response times (F(2,16)=13.56, p<.05, $\eta p^2=0.63$) and planned contrasts with Bonferroni correction showed that response times significantly increased from 1-back to 2-back as the task gets harder (F(1,8)=14.56, p<.05, $\eta p^2=0.65$) but not from 2-back to 3-back (F(1,8)=1.07, p=.33, $\eta p^2=0.12$), indicating that 2-back and 3-back were similarly challenging for participants in the group. Response times during 1-back was also significantly lower than 3-back (F(1,8)= 16.37, p<.05, $\eta p^2= 0.672$). Similarly, for the **control group** there was a significant main effect of task difficulty on the mean response times (F(2,16)=6.65, p<.05, $\eta p^2= 0.55$) and planned contrasts with Bonferroni correction showed that response times significantly increased from 1-back to 2-back as the task gets harder (F(1,8)= 5.85, p<.05, $\eta p^2=0.42$) but not from 2-back to 3-back (F(1,8)=3.21, p=.11, $\eta p^2=0.29$), indicating that 2-back and 3-back were similarly challenging for participants in the group. Response times during 1-back was also significantly lower than 3-back (F(1,8)=10.32, p<.05, $\eta p^2=0.56$). As can be seen from these results, participants in both groups had significantly lower response times in 1-back compared to 2-back and 3-back; as the *n*-back level increased, response times increased, showing that task difficulty was also present in response times as in the correct responses.

4.3.1.1. 2-back Task

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) was performed to investigate both training and maintenance effects of single 2-back. It was aimed to analyse whether there was a significant difference between *n*-back group and control group which was trained on simple letter span. The number of total correct responses in single 2-back task was 30 in each test after the number of round was decreased to five.

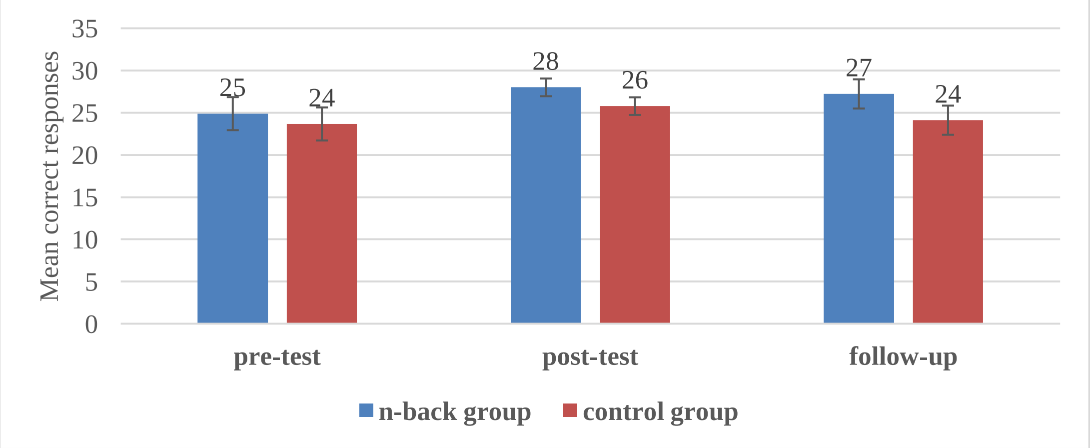

Figure 26: Mean correct responses of groups during 2-back task in pre- and post-tests and 3-month follow-up

There was a main effect of time on 2-back mean correct responses ($F(2,32)=3.45$, $\eta p^2=0.18$), showing performance improvements across time for both groups. According to planned repeated contrasts with Bonferroni correction, 2-back mean correct responses for both groups in the post–test were higher than the pre-test ($F(1,16)=6.96$, $p<.05$, $\eta p^2=0.30$), but the mean correct responses did not differ significantly from post-test to follow-up ($F(1,16)=2.24$, $p=0.76$, $\eta p^2=0.12$), indicating that the performance level reached after the training was maintained by both groups without any significant decrease in correct responses. There was not a significant interaction effect between time and group ($F(2,32) = 0.45$, $p=0.64$, $\eta p^2= 0.03$), meaning that difference in performance gains from pre-test to post-test and from post-test to follow-up was not statistically significant between *n*-back and control groups.

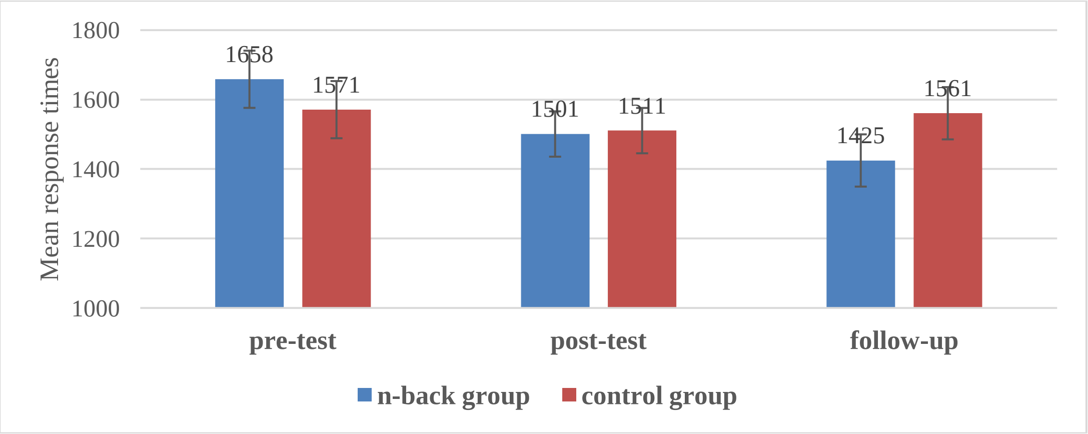

Figure 27: Mean response times of groups during 2-back task in pre- and post-tests and 3-month follow-up

In terms of response times during 2-back task, there was a main effect of time on 2-back mean response times (*F*(2,32)=6.61, p<.05, ηp²=0.29), showing that response times for 2-back gradually decreased across time for both groups. According to planned repeated contrasts with Bonferroni correction, 2-back mean response times in the pre–test were higher than the post-test (*F*(1,16) = 8.98, p<.05, ηp² = 0.36), but there was not a significant difference between the mean response times of post-test and follow-up (*F*(1,16)=0.16, p=.68, ηp²=0.01), indicating that the response times achieved after the training was maintained by both groups. However, there was a significant interaction effect between time and group (*F*(2,32) = 4.62, p<.05, ηp²=0.22). This means that decrease in response times within tasks across times differed in *n*-back and control groups. Planned contrasts with Bonferroni correction revealed that difference in response times from post-test to follow-up of *n*-back group was significantly higher than the control groups (*F*(1,16) = 3.86, p<.05, ηp²= 0.20). This indicates that while both groups maintained their mean response times in follow-up, *n*-back group not only maintained its response times but also showed a significant decrease in response times from post-test to follow-up.

4.3.1.2. 3-back Task

In single 3-back task, the number of total correct responses in 3-back task was 32 and mean correct responses ranged from 18 to 26. A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was a main effect of time on mean 3-back correct responses (*F*(2,32) =5.54, p<.05, ηp²=0.26). Mean 3-back correct responses in post-test were significantly higher than the pre-test (*F*(1,16)=12.82, p<.05, ηp²=0.45), whereas mean correct responses did not differ significantly from post-test to 3-month follow-up (*F*(1,16)=2.38, p=0.07, ηp²=0.13), the performance was maintained without significant decrease or increase.

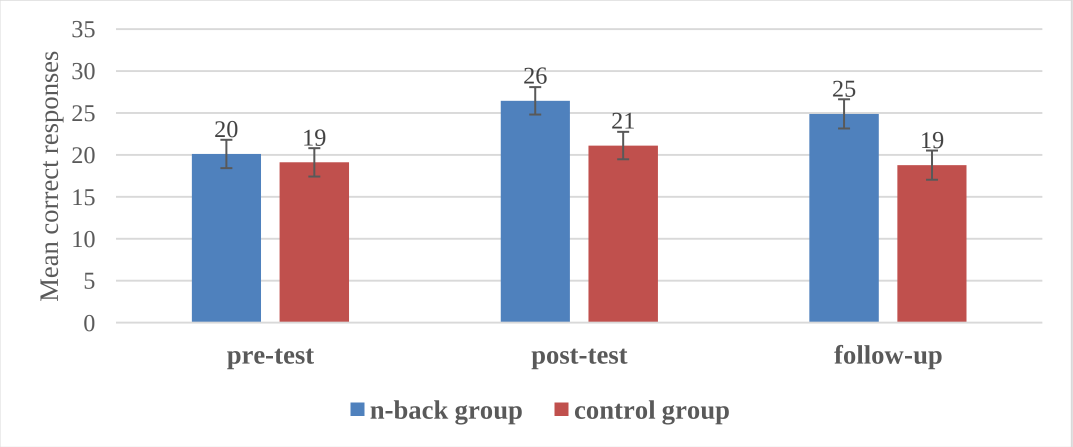

Figure 28: Mean correct responses of groups during 3-back task in pre- and post-tests and 3-month follow-up

Furthermore, a significant interaction effect between time and group was observed (*F*(2,32)=2.42, p<.05, ηp²=0,13). This indicates that performance gains in 3-back differed in *n*-back and control groups. For further analysis of the interaction, contrasts compared each level of correct responses in the tests across *n*-back and control groups. These contrasts revealed that *n*-back group had larger performance gains from pre-test to post-test than control group (*F*(1,16)=3.46, p<.05, ηp²=0.18). However, the performance gains from post-test to follow-up did not differ between the groups (*F*(1,16)=0.09, p=0.38, ηp²=0.006).

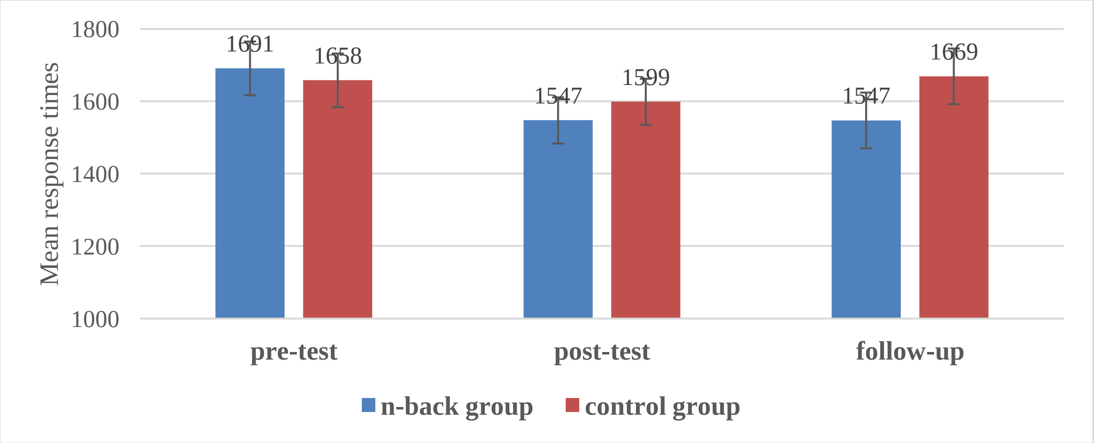

Figure 29: Mean response times of groups during 3-back task in pre- and post-tests and 3-month follow-up

When it comes to response times during 3-back task, there was a main effect of time on 3-back mean response times (*F*(2,32)=3.24, p<.05, ηp²=0.17), showing that response times for 3-back gradually decreased across time for both groups. According to planned repeated contrasts with Bonferroni correction, 3-back mean response times in the pre–test were higher than the post-test (*F*(1,16) = 5.06, p<.05, ηp²=0.24), but there was not a significant difference between the mean response times of post-test and follow-up (*F*(1,16)=1.12, p=.30, ηp²=0.06), indicating that the response times achieved after the training was maintained by both groups. Further analysis of interaction between time and group showed that there was not a significant interaction effect between time and group (*F*(2,32)=1.84, p=.08, ηp²=0.10), meaning that difference in response times from pre-test to post-test and from post-test to follow-up did not differ significantly between *n*-back and control groups.

4.3.1.3. 4-back Task

After preliminary analysis of pre-test behavioural data, it was realised that participants had almost complete scores for 1-back and they stated that it was too easy for them. Therefore, 1-back was not tested in post-test and follow-up; instead, 4-back was added in order to better understand the group differences when the task became more difficult and effortful.

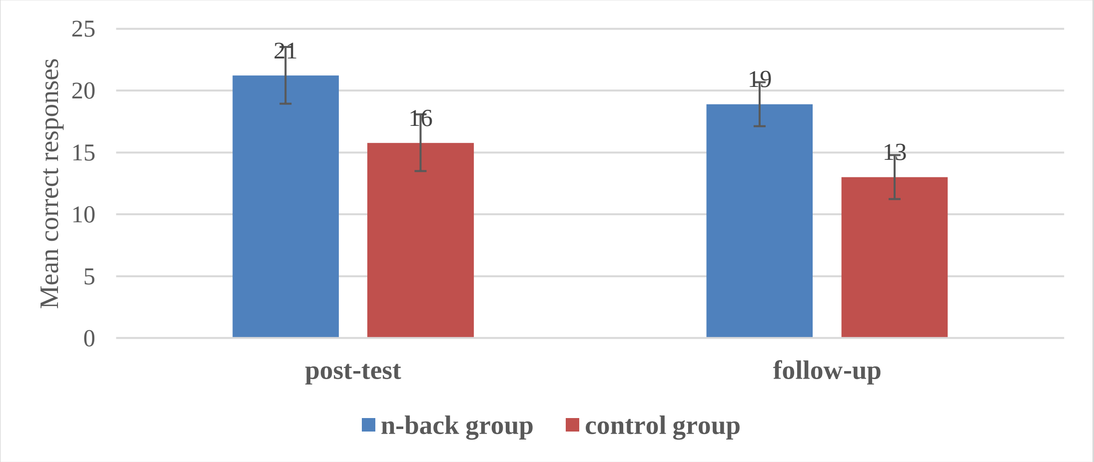

Figure 30: Mean correct responses of groups during 4-back task in pre- and post-tests and 3-month follow-up

Independent-samples t-test showed that in the post-test, when the participants were tested on 4-back for the first time, *n*-back group had significantly higher scores than control group (t(16)= 1.68 , p<.05, r=0.37). Similarly, the groups were compared in the follow-up, independent-samples t-test showed that *n*-back group performed better than control group in 4-back (t(16)= 2.34, p<.05, r=0.47). Moreover, a 2 (Time: post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) revealed that overall improvements by the groups were maintained over a 3-month period relative to post-test since there was not a significant main effect of time (*F*(1,16) = 3.80, p=.07, ηp²=0.19). However, the performance gains from post-test to follow-up did not differ between the groups (*F*(1,16)=0.03, p=0.86, ηp²=0.002).

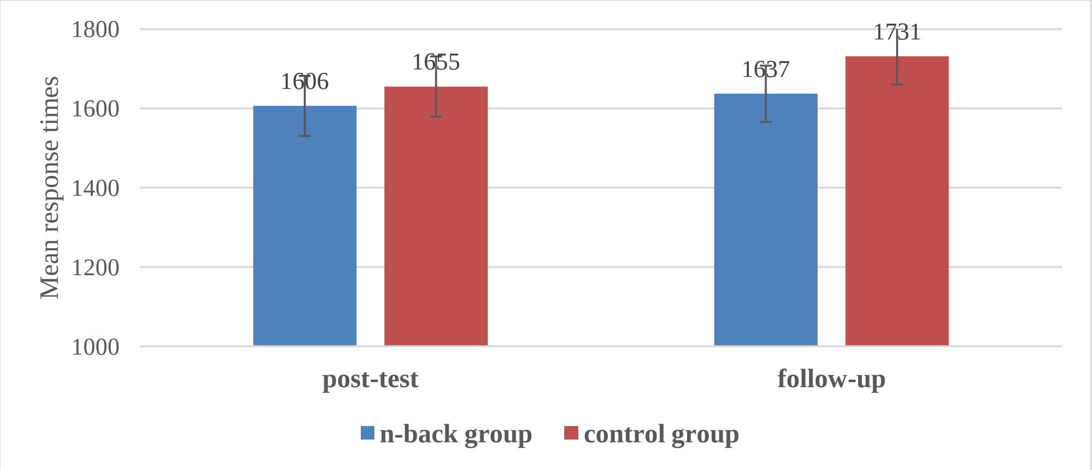

Figure 31: Mean response times of groups during 4-back task in pre- and post-tests and 3-month follow-up

A 2 (Time: post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was a main effect of time which indicates that overall mean response in follow-up were significantly higher than the post-test ($F(1,16)=5.27$, $p<.05$, $\eta p^2=0.25$). There was not a significant interaction effect between time and group ($F(1,16) = 0.94$, $p=.17$, $\eta p^2=0.05$). When the participants encountered with 4-back task for the first time in post-test, there was not a significant difference between the response times of the groups ($t(16)=-0.457$, $p=.65$). Similarly, when the groups' response times for 4-back were compared in the follow-up, there was not a significant difference between the response times of the groups ($t(16)=-0.940$, $p=.36$).

4.3.2. Simple Letter Span Task

Initially, the simple letter span task was composed of letter length ranging from 4 to 8 in the pre-test. The performance percentages of participants were collected in this task. Preliminary analyses showed that participants had almost 100% performance in 4 and 5 letter spans and the groups did not differ in terms of their performances. Therefore, they were excluded from statistical analyses while comparing the performances of the groups. Furthermore, 9-letter span was added in post-test and follow-up to observe whether it would reveal any significant differences between the groups. All statistical analyses were carried out for 6, 7, 8 and 9 letter-span tasks separately.

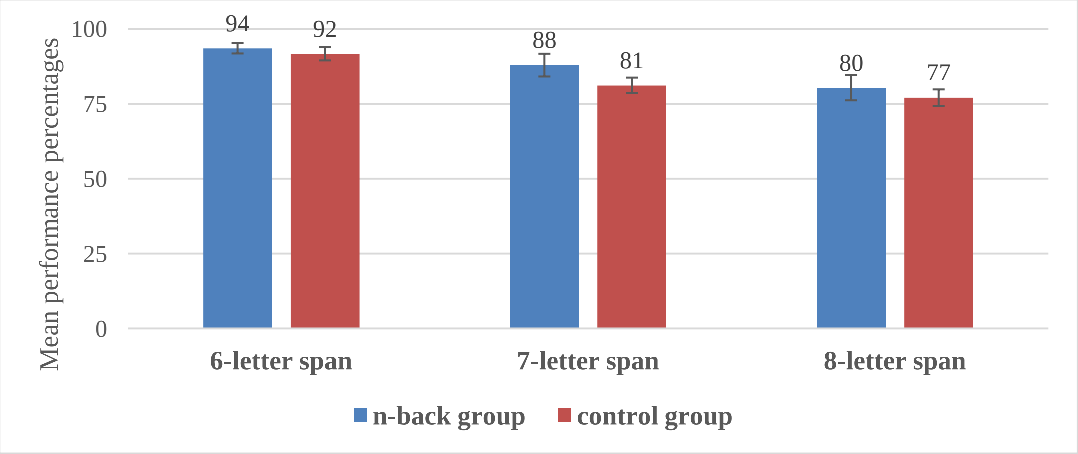

Figure 32: Mean performance percentages of groups for 6, 7 and 8 letter-span tasks in pre-test

In the **pre-test**, there was no statistically significant difference between the groups in each letter length of letter span task (6-letter span t(16)= 0.66, p =.52; 7-letter span t(16)=1.47, p=.16; 8-letter span t(16)= 0.66 , p=.52, 2-tailed). Both groups had very similar mean performance percentages during the task, showing that there was not any baseline difference between the groups in the pre-test. A repeated measures of ANOVA was performed for each group separately to test whether the task difficulty was present in both groups in similar direction at pre-test. For the ***n*-back group** there was a significant main effect of task difficulty on the mean performance percentages (F(2,16)=6.03, p<.05, ηp^2=0.43) and planned repeated contrast with Bonferroni correction showed that while performance percentages of 6-letter span and 7-letter span were in general the same (F(1,8)= 1.92, p=.10, ηp^2=0.19), performance percentages of 8-letter span were lower than 7-letter span (F(1,8)= 5.13, p<.05, ηp^2=0.39). In terms of task difficulty for the **control group,** there was a significant main effect of task difficulty on the mean performance percentages (F(2,16)= 41.90, p<.05, ηp^2=0,840) and planned contrast with Bonferroni correction revealed that performance percentages of 6-letter span were higher than 7-letter span (F(1,8)= 42.25, p<.05, ηp^2=0.84) and performance percentages of 7-letter span were higher than 8-letter span (F(1,8)=5.83, p<.05, ηp^2=0.42). All these results show that the task difficulty was present in both groups and both groups had lower percentage performances in 8-letter span task.

4.3.2.1. 6-Letter Span Task

When the performance percentages in 6-letter span task were analysed with a 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA), the results showed that there was a marginally significant main effect of time on mean performance percentages across time for both groups (F(2,32)=2.34, p<.05, ηp^2=0.13). Planned contrasts revealed that performances on 6-letter span in post-test was better than the performances in pre-test (F(1,16)=21.75, p<.05, ηp^2=0,58), and the difference between performance percentages in post-test and follow-up did not differ significantly (F(1,16)=3.01, p=.10, ηp^2=0.16).

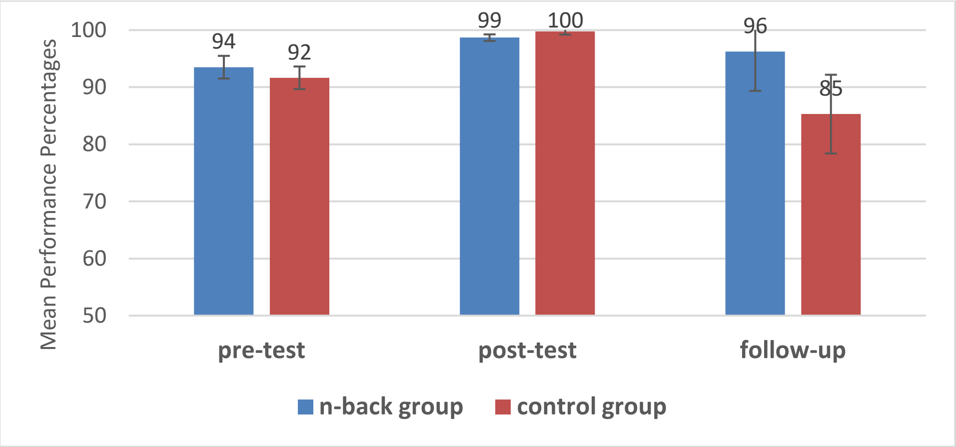

Figure 33: Mean performance percentages of groups during 6-letter span task in pre- and post-tests and 3-month follow-up

There was not any significant interaction effect between time and group (F(2,32)=1,16, p=.32, ηp²=0.07). While the general performance was increased from pre-test to post-test and was maintained in the follow-up by both groups, there was not a significant difference between the groups in terms of their performance gains from pre-test to post-test and from post-test to follow-up.

4.3.2.2. 7-Letter Span Task

In 7-letter span task, a 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was a main effect of time on mean performance percentages (*F*(2,32)=8.13, p<.05, ηp²=0.34). Planned repeated contrasts with Bonferroni correction revealed that performances on 7-letter span in post-test was better than the performances in pre-test (F(1,16)= 16.30, p<.05, ηp² =0.50), and performances in post-test and follow-up did not differ significantly (F(1,16)=1.54, p=.23, ηp²=0.09). Overall performance reached after the training by both groups was maintained in 3-month follow-up.

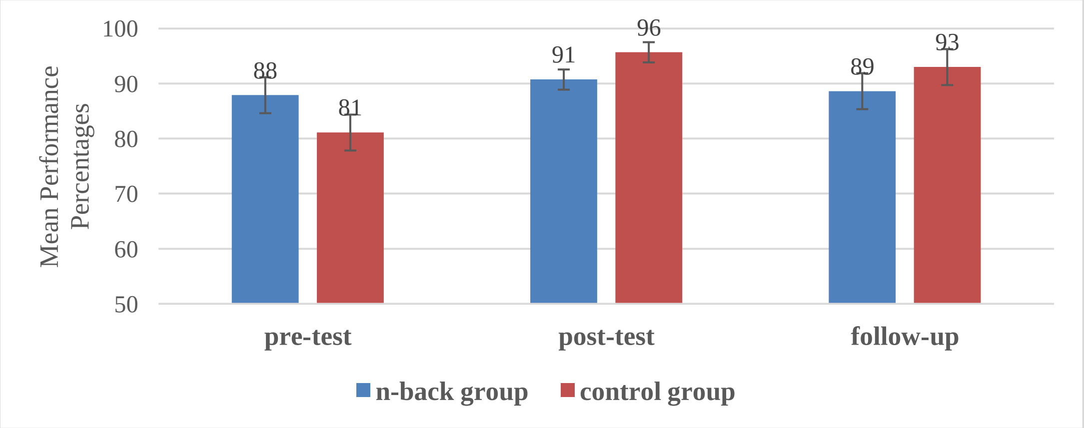

Figure 34: Mean performance percentages of groups during 7-letter span task in pre- and post-tests and 3-month follow-up

Furthermore, a significant interaction effect between time and group was observed (*F*(2,32)=4.39, p<.05, ηp²=0.22). This indicates that performance gains in 7-letter span differed in *n*-back and control groups across time. Further analysis of the contrasts revealed that control group had larger performance gains from pre-test to post-test than *n*-back group (*F*(1,16)=7.39, p<.05, ηp^2=0.32). However, the performance gains in 7-letter span task from post-test to follow-up did not differ between the groups (*F*(1,16)=0.02, p=0.88, ηp^2=0.001).

4.3.2.3. 8-Letter Span Task

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was a main effect of time on mean performance percentages in 8-letter span task (*F*(2,32) = 19.44, p<.05, ηp^2 = 0.549). Planned repeated contrasts with Bonferroni correction showed that performances on 8-letter span in post-test were better than the performances in pre-test (F(1,16)=34.29, p<.05, ηp^2=0.68), and performances in post-test were better than the performances in follow-up (F(1,16)=5.13, p<.05, ηp^2=0.24). Although performances on 8-letter span task increased when tested right after the training, there was generally a significant decline in performances in 3-month follow-up.

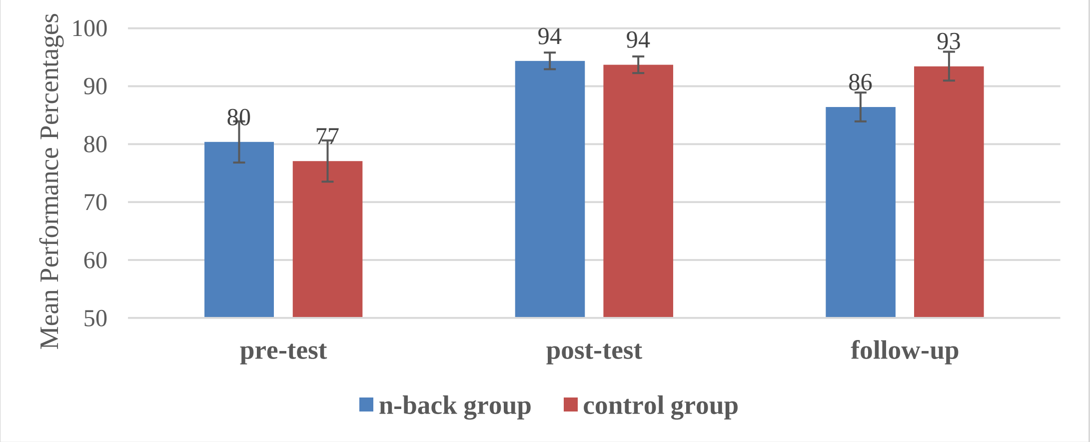

Figure 35: Mean performance percentages of groups during 8-letter span task in pre- and post-tests and 3-month follow-up

When interaction effect between time and group was evaluated, a significant effect was found (*F*(2,32)=2.23, p<.05, ηp^2=0.12). This indicates that performance gains in 8-letter span differed in *n*-back and control groups across time. Further analysis of the contrasts revealed that while there was not a significant difference between the groups in terms of their performance gains from pre-test to post-test (*F*(1,16)=0.26, p=0.62, ηp^2=0.02), *n*-back group' decline in performance from post-test to follow-up was larger than control group (*F*(1,16)=4.53, p<.05, ηp^2=0.22). This shows that while control group had similar performance in post-test and follow-up, *n*-back group's performance decreased from post-test to follow-up.

4.3.2.4. 9-Letter Span Task

When the performance percentages were analysed in 9-letter span task with a 2 (Time: post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA), the results showed that there was not a main effect of time on mean performance percentages across time (F(1,16)= 0.25, p=.62, $\eta p^2 = 0.01$) and there was not any significant interaction effect between time and group found (F(1,16)=0.05, p=.81, ηp^2=0.003). These results reflect that 9-letter span did not differentiate between groups as well as between post-test and follow-up.

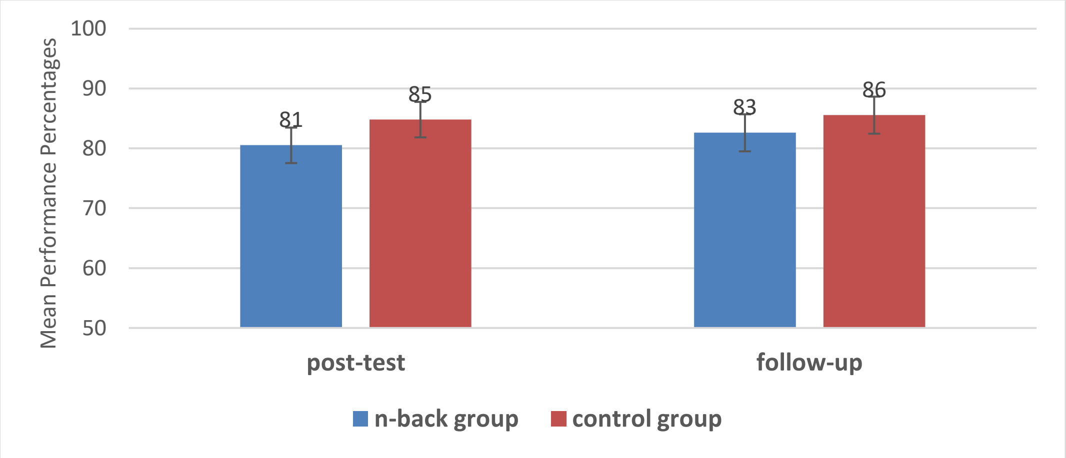

Figure 36: Mean performance percentages of groups during 9-letter span task in post-test and 3-month follow-up

4.4. Cognitive Performance in Near Transfer Tasks

Repeated measures analyses of variance (Mixed ANOVA) were conducted with time as within-subject factor and group as between-subject factor to evaluate near transfer gains across time. Changes from pre-test to post-test were analysed to see whether there was any significant difference in performance gains between *n*-back and control groups. In order to investigate whether the performance reached right after the training was maintained across 3-month interval, post-test and follow-up performances were compared between the groups for maintenance effects.

Independent variables: Group (*n*-back group, control group); Time (Pre-test, Post-test, Follow-up)
Dependent variables: 1) Performance Percentages (simple digit span);
2) Performance Percentages (dual *n*-back task)

4.4.1. Simple Digit Span Task

In simple digit span task, 4 and 5-digit span were excluded from statistical analyses because of the same reasons explained in 4.3.2. Furthermore, 9-digit span was added in post-test and follow-up to compare performances between the groups. While comparing the performances of the groups in terms near transfer gains, all statistical analyses were carried out for 6, 7, 8 and 9 digit-span tasks separately.

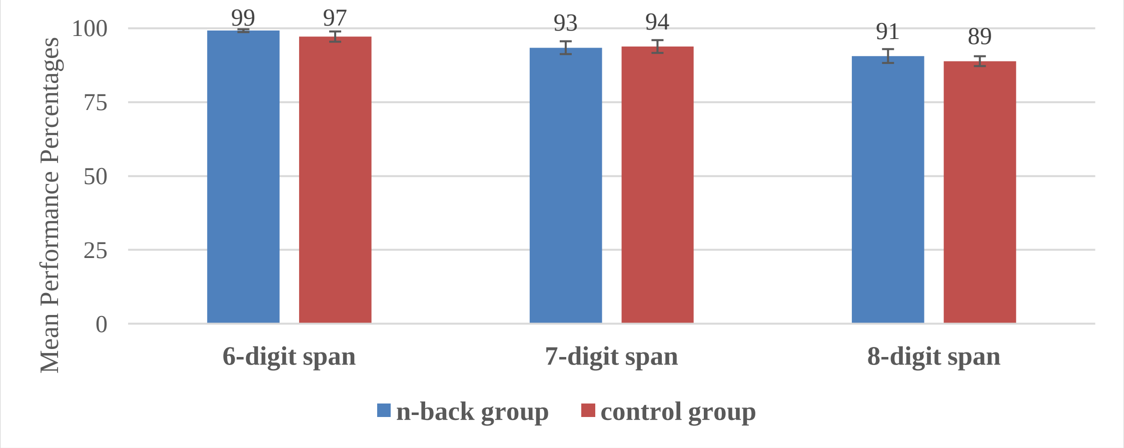

Figure 37: Mean performance percentages of groups for 6, 7 and 8 digit-span tasks in pre-test

In the **pre-test**, there was no statistically significant difference between the groups in each digit span level (6-digit span t(16)=1.11, p=.28; 7-digit span t(16)= -0.13, p=.89; 8-digit span t(16)=0.60 , p=.55, 2-tailed). Both groups had very similar mean performance percentages during the task, showing that there was not any baseline difference between the groups in the pre-test. A repeated measures of ANOVA was performed for each group separately to test whether the task difficulty was present in both groups in similar direction at pre-test. For the ***n*-back group** there was a significant main effect of task difficulty on the mean performance percentages (F(2,16)=7.18, ηp^2=0.47) and contrasts with Bonferroni correction showed that performance percentages of 6-digit span were higher than 7-digit span (F(1,8)=7.68, ηp^2=0.49), and there was not a significant difference between performance percentages of 7-digit and 8-digit spans (F(1,8)=1.36, p=.27, ηp^2=0.15).

In terms of task difficulty for the **control group,** there was a significant main effect of task difficulty on the mean performance percentages (F(2,16)=17.12, ηp^2=0.68) and contrasts with Bonferroni correction revealed that performance percentages of 6-digit span were higher than 7-digit span (F(1,8)=5.50, ηp^2=0.41) and performance percentages of 7-digit span were higher than 8-letter span (F(1,8)=11.63, ηp^2=0.59). These results show that the task difficulty was present in both groups and both groups had lower percentage performances in 8-digit span task.

4.4.1.1. 6-Digit Span Task

When the performance percentages in 6-digit span task were analysed with a 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA), the results showed that there was not a main effect of time on mean performance percentages across time for both groups (F(2,32)= 2.75, p=.07, ηp^2=0.15). Furthermore, a significant interaction effect between time and group was not found (F(2,32)=1.39, p=.26, ηp^2=0.08). Both *n*-back and control groups had in general the same performance in all three testing occasions (for *n*-back group pre-test mean=99.16, SD=1.47, post-test mean=99.82, SD=0.53, follow-up mean=99.38, SD=1.65; for control group pre-test mean=97.16, SD=5.2, post-test mean=99.67, SD=1.0, follow-up mean=99.71, SD=1.23); their performances were very close to 100%, indicating that they had ceiling performance in 6-digit span task already in the pre-test which may suggest that there was not enough space for performance improvement.

4.4.1.2. 7-Digit Span Task

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was a main effect of time on mean performance percentages in 7-digit span task (*F*(2,32)=3.11, p<.05, ηp^2=0.16). Planned repeated contrasts with Bonferroni correction showed that performances on 8-digit span in post-test was better than the performances in pre-test (F(1,16)= 6.53, p<.05, ηp^2=0.29), but performances in post-test were not significantly different than the performances in follow-up (F(1,16)= 1.27, p=.27, ηp^2=0.07).

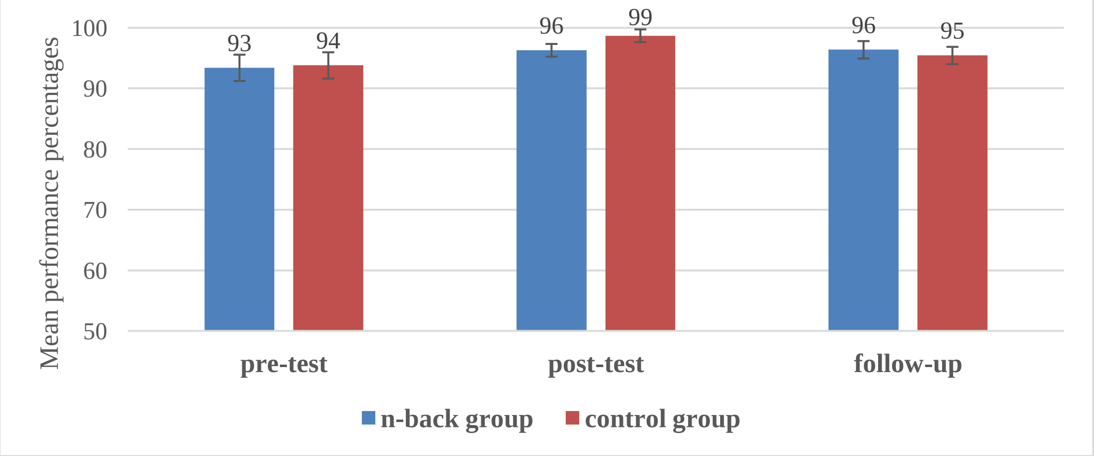

Figure 38: Mean performance percentages of groups during 7-digit span task in pre- and post-tests and 3-month follow-up

When interaction effect between time and group was evaluated, a significant effect was not found (*F*(2,32)=0.57, p=.56, ηp^2=0,03), indicating that there was not a significant difference between the groups in terms of their performance gains from pre-test to post-test and from post-test to follow-up.

4.4.1.3. 8-Digit Span Task

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) was performed to investigate near transfer gains across time. The analysis showed that there was a main effect of time on mean performance percentages in 8-digit span task (*F*(2,32)=5.07, $p<.05$, $\eta p^2=0.24$). Planned repeated contrasts with Bonferroni correction showed that performances on 8-digit span in post-test were better than the performances in pre-test (F(1,16)=2.56, p=.12, $\eta p^2=0.14$), and there was not any significant difference between 8-digit span performances in post-test and follow-up (F(1,16)=5.13, $p<.05$, $\eta p^2=0.24$). While general performance on 8-digit span increased from pre-test to post-test, both groups maintained their performances in follow-up even had the same performance.

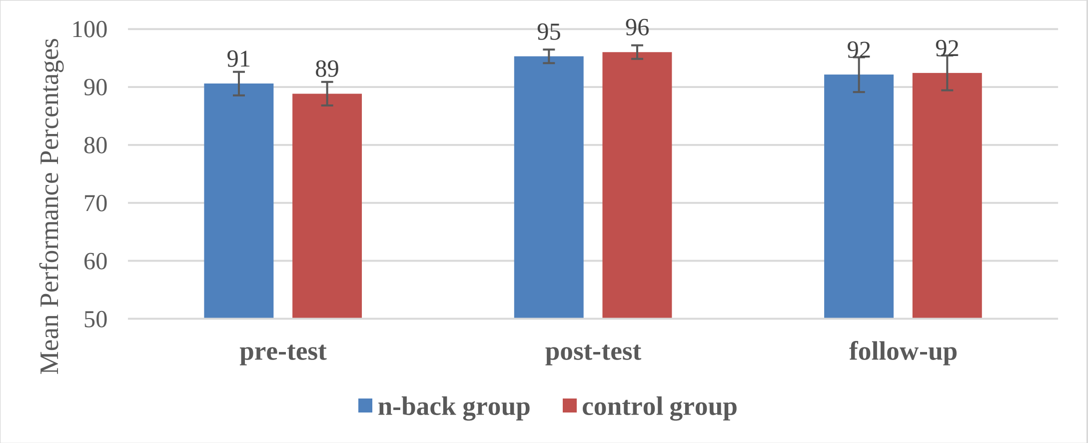

Figure 39: Mean performance percentages of groups during 8-digit span task in pre- and post-tests and 3-month follow-up

When interaction effect between time and group was evaluated to see whether there was any difference between the groups in terms of their performance gains, a significant interaction effect was not found (*F*(2,32)=0.24, p=.78, $\eta p^2=0{,}01$). This indicates that performance gains in 8-letter span did not differ in *n*-back and control groups across time.

4.4.1.4. 9-Digit Span Task

When the performance percentages were analysed in 9-digit span task with a 2 (Time: post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA), the results showed that there was not a main effect of time on mean performance percentages across time (F(1,16)=0.11, p=.74, $\eta p^2=0.007$). Mean performance percentage in post-test (M=91.12, SE=1.5) was almost the same with the follow-up (M=90.37, SE=1.7). In addition, a significant interaction effect between time and group was not found (F(1,16)= 0.44, p=.51, $\eta p^2=0.03$). These results reflect that performance in 9-digit span did not differentiate between groups as well as between post-test and follow-up.

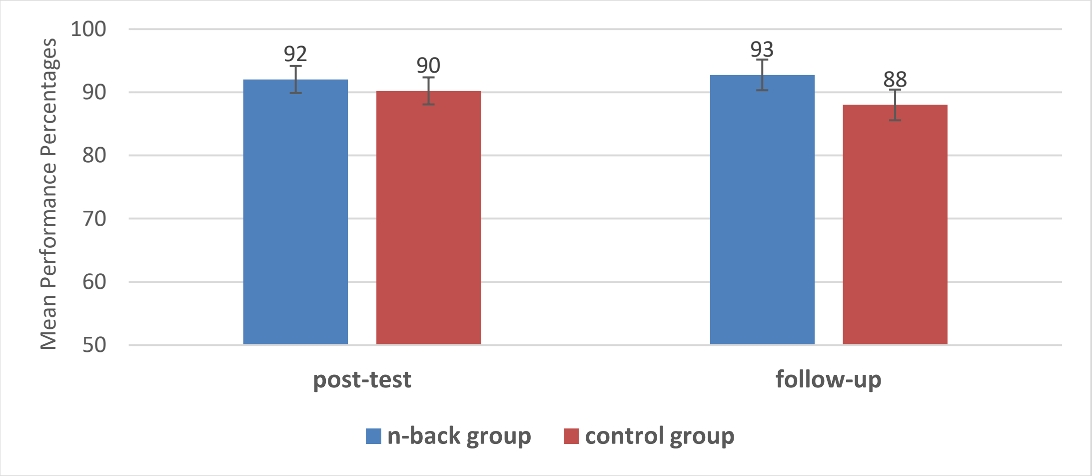

Figure 40: Mean performance percentages of groups during 9-digit span task in post-test and 3-month follow-up

4.4.2. Dual *n*-back Task

As explained in 5.3.1., the number of rounds for each dual *n*-back condition was decreased to 5. As a result, the total number of blocks decreased to 15; 5 rounds of each dual *n*-back condition. All analyses were carried out with performance percentages of participants during the task.

In **pre-test**, there was no statistically significant difference between the groups in each level of dual *n*-back task in the pre-test (dual 1-back t(16)= 0,136, p = .893; dual 2-back t(16)= 0,580, p = .570; dual 3-back t(16)= 0,283, p = .781, 2-tailed). Both groups had very similar performance during the tasks in pre-test. This shows that there was not any baseline difference between the groups in the pre-test.

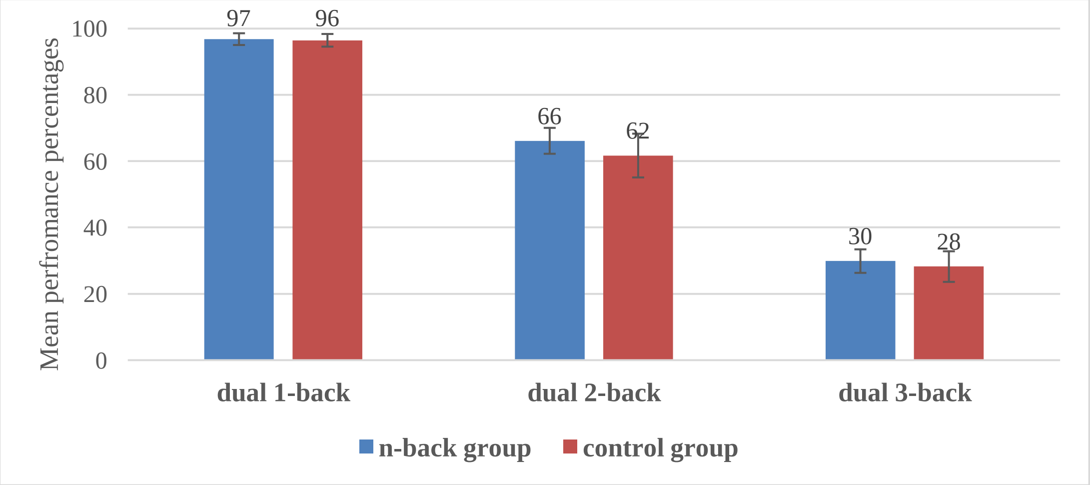

Figure 41: Mean performance percentages of groups during dual n-back task in pre-test

In order to assess the effect of task difficulty in pre-test, a repeated measures of ANOVA with three dual *n*-back levels was used for each group separately in order to investigate whether the task difficulty was present in both groups in similar direction at pre-test. For the ***n*-back group** there was a significant main effect of task difficulty on the mean performance percentages ($F(2,16)=161.52$, $p<.001$, $\eta p^2=0.953$) and planned contrasts with Bonferroni correction showed that performance significantly decreased from dual 1-back to dual 2-back (F(1,8)=62.96, p<.001, ηp^2=0.89) and from dual 2-back to dual 3-back (F(1,8)=64.04, p<.001, ηp^2=0.89). Similarly, for the **control group** there was a significant main effect of task difficulty on the mean performance percentages (F(2,16)=74.38, p<.001, ηp^2=0.90) and planned contrast with Bonferroni correction showed that performance significantly decreased from dual 1-back (F(1,8)=33.35, p<.001, ηp^2= 0.80) and as well as from dual 2-back to dual 3-back (F(1,8)=24.67, p<.001, ηp^2= 0.75). These results show that for both groups dual 1-back task was the easiest and they had ceiling performances which were close to 100% correct responses; dual 3-back task was the hardest as in the single 3-back, performances gradually deteriorated from dual 1-back to dual 3-back in pre-test.

4.4.2.1. Dual 2-back Task

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was a main effect of time on mean performance percentages of dual 2-back task (*F*(2,32) = 18.04, p<.05, ηp^2 = 0.530). Planned repeated contrasts with Bonferroni correction showed that performances on dual 2-back task in post-test was better than the performances in pre-test (F(1,16)=19.10, p<.05, ηp^2=0.54), but dual 2-back performances in post-test were not significantly different than the performances in follow-up (F(1,16)=0.006, p=.93, ηp^2=0.000). These indicate that overall mean performances in post-test (M=86.52, SE=3.34) and follow-up (M=86.31, SE=2.51) were almost the same. Overall improvements were maintained over a period of 3 months after the post-test.

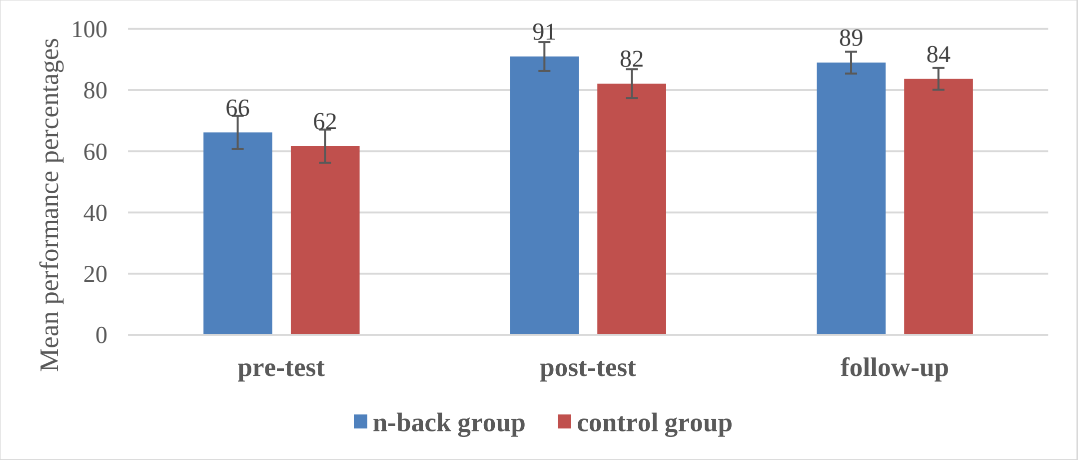

Figure 42: Mean performance percentages of groups during dual 2-back task in pre- and post-tests and 3-month follow-up

When interaction effect between time and group was evaluated, any significant interaction effect was not found (*F*(2,32)=0.15, p=.78, ηp^2=0.009). This indicates that performance gains in dual 2-back did not differ in *n*-back and control groups across time. Both groups similarly improved their performances in the task.

4.4.2.2. Dual 3-back Task

According to a 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA), there was a main effect of time on mean performance percentages of dual 3-back task (*F*(2,32)=18.02, p<.05, ηp²=0.53). Planned repeated contrasts with Bonferroni correction showed that performances on dual 3-back task in post-test was better than the performances in pre-test (F(1,16)=36.45, p<.05, ηp²=0.70), moreover dual 3-back performances in post-test were significantly higher than the performances in follow-up (F(1,16)=5.47, p<.05, ηp²=0.25).

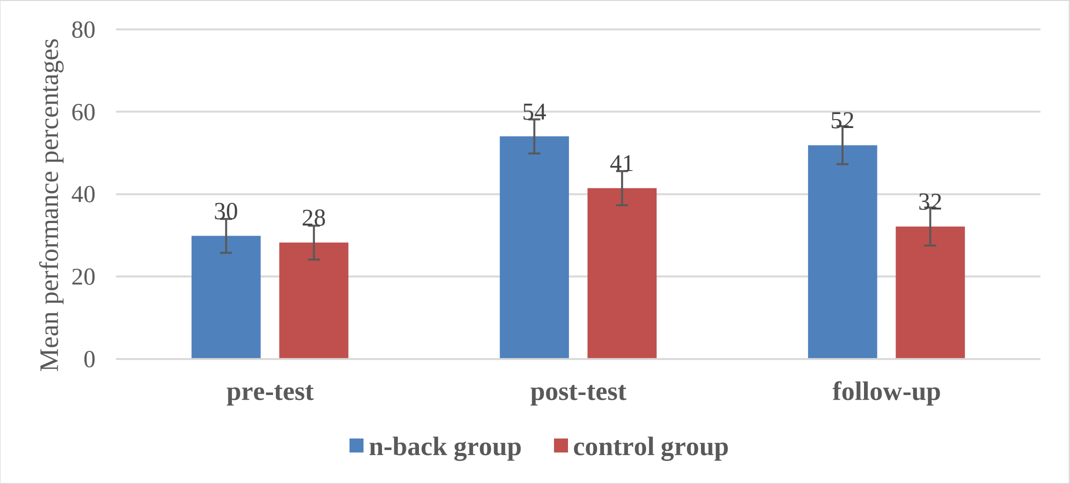

Figure 43: Mean performance percentages of groups during dual 3-back task in pre- and post-tests and 3-month follow-up

Furthermore, a significant interaction effect between time and group was observed (*F*(2,32)=4.05, p<.05, ηp²=0,20), indicating that performance gains in dual 3-back task differed between the groups across time. Further analysis of the contrasts revealed that *n*-back group had larger performance gains from pre-test to post-test than control group (*F*(1,16)=3.11, p<.05, ηp²=0.16), indicating that *n*-back group improved more than the control group. The performance gains in dual 3-back task from post-test to follow-up also differed between the groups in favour of *n*-back group (*F*(1,16)=2.16, p<.05, ηp²=0.12; one-tailed). While control group had significant decline in performance from post-test to follow-up, *n*-back group showed slightly similar performance to post-test, and still had better performance than pre-test. Furthermore, performance gains from pre-test to follow-up was significantly larger in *n*-back group than control group (*F*(1,16)=5.47, p<.05, ηp²=0.25). *n*-back group’s performance gains seem to be maintained over time based on both simple and repeated contrasts.

4.4.2.3. Dual 4-back Task

After preliminary analysis of pre-test behavioural data, dual 1-back task was excluded from post-test and follow-up. Instead, dual 4-back was added in order to better understand the group differences and how performances changed when the task became more difficult.

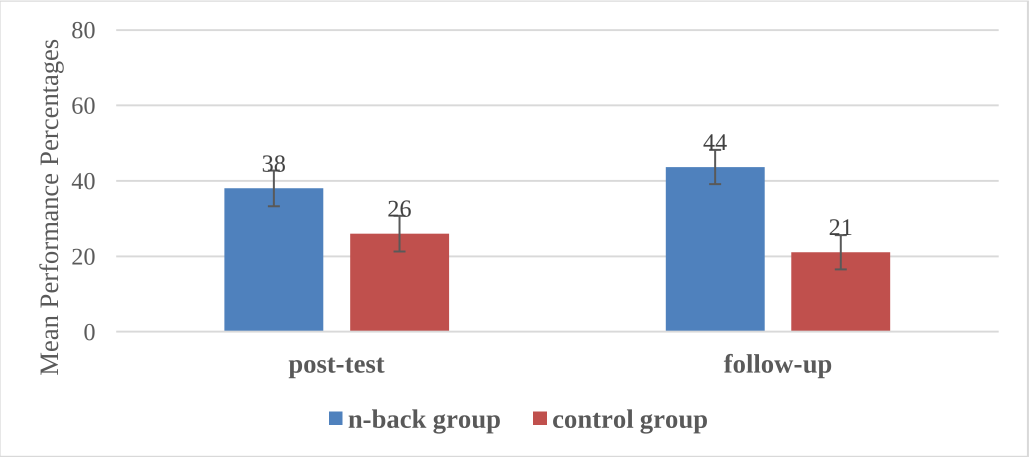

Figure 44: Mean performance percentages of groups during dual 4-back task in post-test and 3-month follow-up

A 2 (Time: post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) revealed that there was not a significant main effect of time ($F(1,16)=0.05$, $p=.81$, $\eta p^2=0,003$). However, a significant interaction effect between time and group was observed ($F(1,16)=11.18$, $p<.05$, $\eta p^2=0,41$). This interaction indicates that performance gains in dual 4-back task differed in *n*-back and control groups across time in other words *n*-back group improved more than the control group from post-test to follow-up. While there was a decrease in the control group's performance in follow-up, *n*-back group improved significantly from post-test to follow-up. Furthermore, independent-samples t-test showed that in the post-test, when the participants were tested on dual 4-back task for the first time, *n*-back group had significantly higher scores than control group ($t(16)=1.65$, $p<.05$, $r=0.37$). Similarly, when the groups were compared in the follow-up, independent-samples t-test showed that *n*-back group performed better than control group in dual 4-back task ($t(16)= 1.79$, $p<.05$, $r=0.33$).

4.5. Cognitive Performance in Moderate and Far Transfer Tasks

Repeated measures analyses of variance (Mixed ANOVA) were conducted with time as within-subject factor and group as between-subject factor to evaluate far transfer gains across time. Changes from pre-test to post-test were analysed to see whether there was any significant difference in performance gains between *n*-back and control groups. In order to investigate whether the performance reached right after the training was maintained across 3-month interval, post-test and follow-up performances were compared between the groups for maintenance effects. While reading span task was evaluated as a moderate transfer task, Bochum Matrices Test (BOMAT) was considered far transfer task.

Independent variables: Group (*n*-back group, control group); Time (Pre-test, Post-test, Follow-up)
Dependent variables: 1) Reading span scores 2) BOMAT scores

4.5.1. Reading Span Task as a Moderate Transfer Task

First of all, groups were compared in terms of their mean reading span scores in pre-test to see whether they differed from each other at baseline level. In **pre-test**, there was no statistically significant difference between the groups in their reading span scores (t(16)= 0,276, p=.79, r=0.06). Both *n*-back group (Mean=31.77, SD=16.07) and control group (Mean=29.66, SD=16.38) had similar mean reading span scores in the pre-test.

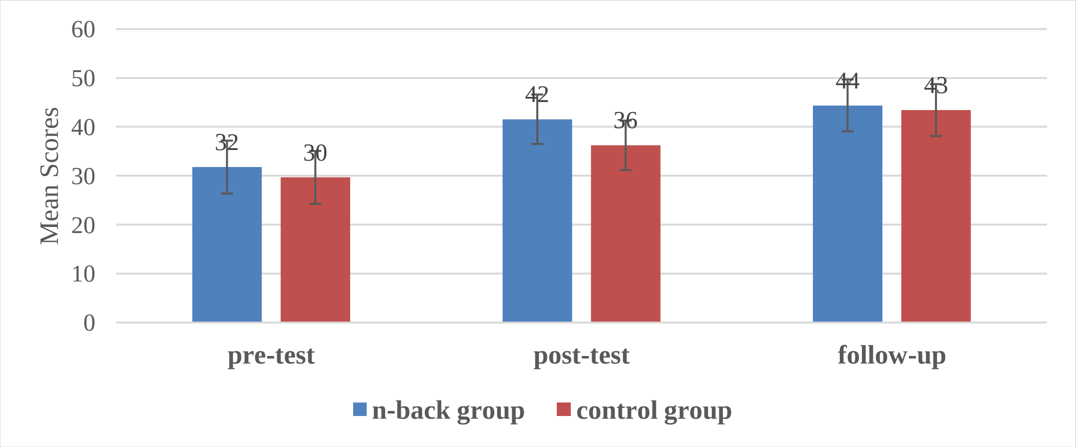

Figure 45: Mean reading span scores of groups in pre-test, post-test and post-tests and 3-month follow-up

Results of a 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was a significant main effect of time on reading span scores (*F*(2,32)=10.84, p<.05, ηp^2=0.40). According to planned contrasts with Bonferroni correction, reading span scores in post-test were significantly higher than those in pre-test (*F*(1,16)=12.89, p<.05, ηp^2=0.45), in addition, reading span scores in 3-month follow-up was significantly higher than pre-test (*F*(1,16)=16.87, p<.05, ηp^2=0.51). General performance in follow-up did not differ from the post-test (*F*(1,16)=2.78, p=.114, ηp^2=0.15), indicating that overall performance reached after the training was maintained by both groups. However, there was no significant interaction effect between time and group (*F*(2,32)=0.32, p=.73, ηp^2=0.02). The moderate transfer gains from pre-test to post-test (*F*(1,16)=0.50, p=.48, ηp^2=0.01) and from post-test to follow-up (*F*(1,16)=0.53, p=.47, ηp^2=0.01) did not differ significantly between *n*-back and control groups.

4.5.2. Bochum Matrices Test (BOMAT) as a Far Transfer Task

In Bochum Matrices Test (BOMAT), there were 29 items to complete and the number of correct items were regarded as BOMAT scores. When the groups were compared in terms of their mean BOMAT scores in pre-test, independent-samples t-test revealed that there was no statistically significant difference between the groups in their pre-test BOMAT scores (t(16)=0,16, p=.87, r=0.03), which indicates that *n*-back and control groups did not differ in their baseline performances in BOMAT.

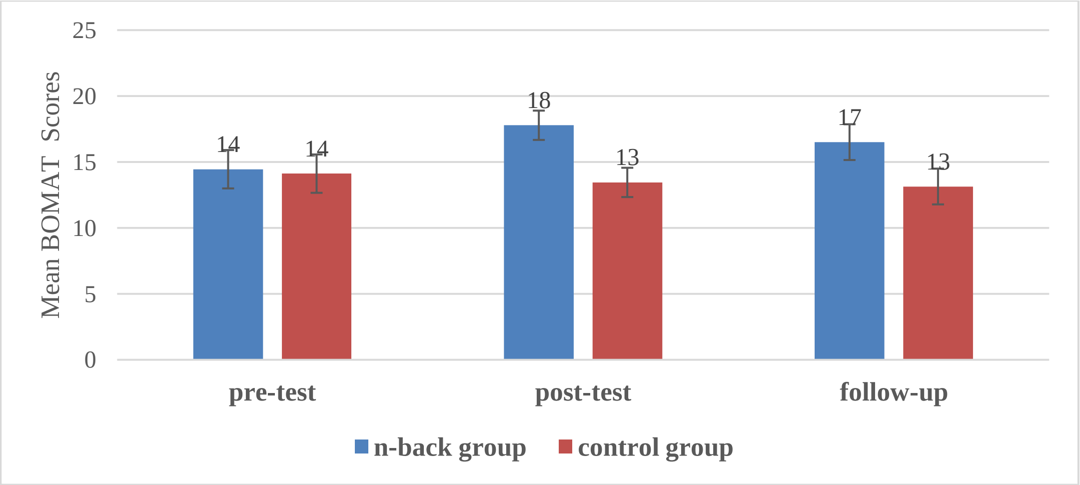

Figure 46: Mean BOMAT scores of groups in pre- and post-tests and 3-month follow-up

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) showed that there was not a significant main effect of time on BOMAT scores ($F(2,32)=1.014$, $p=0.18$, $\eta p^2=0.06$), showing that BOMAT scores did not improve across time for both groups. However, there was a significant interaction effect between time and group ($F(2,32)=2.45$, $p<.05$, $\eta p^2=0.13$). According to planned repeated contrasts with Bonferroni correction, far transfer gains from pre-test to post-test ($F(1,16)=4.60$, $p<.05$, $\eta p^2=0.22$) was larger in *n*-back group than the control group, but not between post-test and follow-up ($F(1,16)=0.27$, $p=.30$, $\eta p^2=0.02$). When changes from pre-test to follow-up was evaluated with simple contrast with Bonferroni correction, the change from pre-test to follow-up was marginally larger in *n*-back group compared to control group ($F(1,16)=2.44$, $p=.07$, $\eta p^2=0.13$). These results suggest that *n*-back group had better performance in both post-test and follow-up than control group.

4.6. Transfer Effect to Consecutive Interpreting

For consecutive interpreting, participants interpreted five different speeches in each test. Participants received interpreting scores for each speech based on correctly recalled and interpreted idea units in the speech. Since there were five speeches in each testing phase, the average of five speeches was regarded as the interpreting score for the test. Participants’ consecutive interpreting scores were calculated by taking an average of their scores in five speech. An external rater was asked to evaluate 20 percent of consecutive interpreting outputs of participants based on idea unit protocol. The external rater scored a total of 45 interpreting outputs out of 225. Each idea unit in a speech was given a point ranging from 0 to 2 (0=omitted; 1=partially recalled and interpreted; 2=fully recalled and interpreted). The sum of each speech's idea unit's score was considered the final score for that speech. Inter-rater reliability between external rater and the researcher herself was found to be 0.97 based on Krippendorff's alpha. The rest of all interpreting outputs were scored by the researcher herself. The highest score that a participant could get in each speech is presented in the table below:

Table 15: Possible highest interpreting scores in pre-test and post-test

Speeches used in Pre-test	**Highest score**	**Speeches used in Post-test & Follow-up**	**Highest score**
Alexander the Great	32	Uses of Money	36
Communication Theory	38	League of Nations	38
Benefits of Pets	38	Magna Carta	46
Poisonous Plants	50	Culture	38
The Invention of the Telescope	40	Genealogy	36
Mean	**39,6**	**Mean**	**38,8**

As can be seen in the figure, independent-samples t-test showed that *n*-back and control groups did not significantly differ from each other in terms of estimated means of consecutive interpreting scores (t(16)= -0,04, p =.97) in pre-test, indicating that the groups were almost identical in their content accuracy in consecutive interpreting at baseline level.

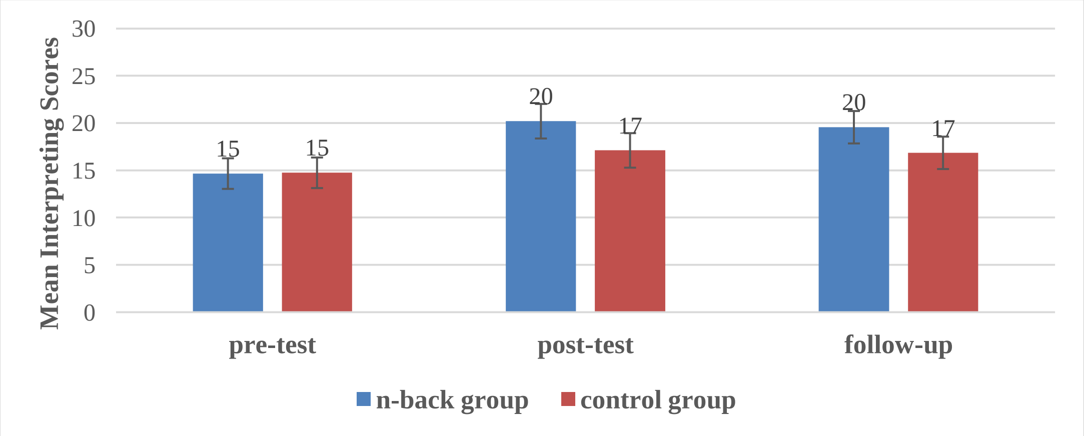

Figure 47: Adjusted mean consecutive interpreting scores of groups in pre- and post-tests and 3-month follow-up

A 3 (Time: pre-test, post-test, follow-up) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) was performed to investigate performance gains across time in groups. The results showed that there was a significant main effect of time on consecutive interpreting scores (*F*(2,32)=16.74, p<.05, ηp^2=0.51), reflecting a general improvement in consecutive interpreting performances across time for both groups. According to planned contrasts with Bonferroni correction, consecutive interpreting scores in post-test were higher than the scores in pre-test (*F*(1,16)=35.03, p<.05, ηp^2=0.69), on the other hand, there was not a significant difference between post-test and follow-up mean consecutive interpreting scores (*F*(1,16)=0.43, p=0.26, ηp^2=0.03), showing that the overall performance reached after the training was maintained even 3 months later. In terms of performance gain differences between the groups, a significant interaction effect between time and group was found (*F*(2,32)=2.67, p<.05, ηp^2=0.14). Repeated contrasts with Bonferroni correction suggest that *n*-back group's performance gains in consecutive interpreting from pre-test to post-test was larger than the control group's gains (*F*(1,16)=5.64, p<.05, ηp^2=0.261). This performance gain difference between the groups was not significant comparing post-test to follow-up (*F*(1,16)=0.08, p=0.39, ηp^2=0.005). Considering changes from pre-test to follow-up based on simple contrasts, it was found that *n*-back group's performance gains in consecutive interpreting from pre-test to follow-up was marginally larger than the control group's performance gains (*F*(1,16)=2.53, p=.06, ηp^2=0.136). Overall, these results suggest that *n*-back group showed larger performance gains after the training and seems to maintain this effect.

Furthermore, when we look at performance percentages of the groups which shows mean performance percentage in a speech with respect to the highest score that can be obtained in that speech (see Appendix K & L), it was found that *n*-back group also had larger increase in the performance percentage than the control group from pre-test to post-test (*F*(1,16)=5.08, p<.05, ηp^2=0.241). This shows that after the training, while *n*-back group increased their performance percentages from pre-test (Mean=37.64, SD=3.9) to post-test (Mean=52.23, SD=5.4), control group had lower increase from pre-test (Mean=35.80, SD=3.9) to post-test (Mean=41.58, SD=5.4).
In addition to quantitative differences in performance gains between the groups, consecutive interpreting outputs also showed differences qualitatively. The groups seemed to differ in terms of details provided in their interpreting outputs, fluency and coherence as well as sentence structures and language use. Below examples were taken from transcriptions of the best three participants in each group in the post-test (see Appendix H). It seems that even though the best participants of the groups were compared, while participants in *n*-back group provided more accurate content in the flow of information with respect to the structure of the original speech, participants in the control group showed a lot of repetitions and remarkable changes in the flow of the information. Furthermore, the sentence structures differed between the groups in terms of complexity and length. Details presented as list of information in the source speech seem to more missing in the outputs of participants in control group. Moreover, in terms of fluency, pauses and extra sounds such as "hıım" which indicates problems in recalling were present largely in the participants of control group (see Appendix H).

Example 1: …..Aside from strictly personal interest, the information they gather can lead to reunions of families who have been disrupted by *adoption, foster care or immigration*. This type of research could also lead to family reunions of distant relatives. (Excerpt taken from the speech "Genealogy" used in post-test)
Participant #3 (*n*-back group): …Soy bilimi sayesinde elde edilen bilgilerle *göç, evlat edinilme hatta koruyucu aile* gibi nedenlerle birbirinden ayrılmış aile üyeleri bir araya gelebiliyor ya da uzaktan akrabalarıyla iletişime geçebiliyorlar.
Participant #5 (*n*-back group): …Elde edilen sonuçlarla birçok ailenin uzak akrabaları bulunabiliyor ya da *göç veya evlatlık edinme* ya da *koruyucu aile sistemi* gibi sebeplerle birbirinden ayrılmış aile üyeleri bir araya gelebiliyorlar. Ayrıca bu yolla uzak akrabalara da ulaşılabiliyor.
Participant #7 (*n*-back group): …Bu tür çalışmaların kişisel ilginin dışında önemli yanlarından biri *göç, koruyucu aile ya da evlatlık edinme* gibi çeşitli sebeplerle parçalanmış ailelerin bir araya gelmesini sağlamasıdır. Bu sayede insanlar uzak akrabalarına erişme ve onlarla bir araya gelme şansına sahip olabilmektedirler.
Participant #6 (control group): …Böylece bir Figurede birbirinden ayrı düşmüş evlatlık yoluyla *evlatlık verilmiş* ya da evlatlık alınmış insanların aileleriyle tekrar

buluşmasına birleşmesine olanak sağlıyor. Ailelerin tekrar buluşmasına olanak sağlıyor.
Participant #11 (control group): …Bu sayede insanlar *göç* sebebiyle ayrı kaldıkları aile bireyleriyle tekrar bir araya gelebilme şansını yakalarlar. Ayrıca onlardan uzakta yaşayan akrabalarıyla da bir araya gelme şansını elde ederler.
Participant #14 (control group): …Soy bilimi uzak akrabalarınıza yeniden kavuşmanızı sağlar. *Göç* gibi çeşitli faktörler sonucu ayrı düşen insanların tekrar ailelerine kavuşması soy bilimle mümkündür.

As can be seen in the examples above, this segment of the speech was almost identically and completely interpreted by *n*-back group participants by providing all elements in the list, control group participants provided only one element of the list. In another speech about League of Nations on historical information about the organization, as can be seen the transcriptions presented in the appendix, control group showed remarkable comprehension mistakes and it seems that they could not recall the data specified in the speech while *n*-back group provided more details with correct date in a more coherent way. Another example showing the remarkable difference between the groups was taken from the speech on culture. In the speech, the definition of culture seems to be the most challenging part, which also indicates the high demand on WM even with a single part of the speech. Details provided by the groups seem to differ greatly, it also seems that grammar structures of participants in control group might have been affected by the difficulty encountered in recalling the parts of the sentence.

Example 2: ….“culture is the complex whole that includes knowledge, beliefs, arts, morals, laws, customs and any other habits and capabilities acquired by human beings as members of society.”
Participant #3 (*n*-back group): Kültür, insanların toplumun bir parçası olarak sahip oldukları her hangi davranış biçimi, inançları, düşünceleri vb. özelliklerini, örf ve adetlerini yansıtan her şeydir.
Participant #5 (*n*-back group): …kültür birden fazla şeyin birleşimden oluşur bunlar ise toplumu oluşturan insanların inançları, düşünceleri, alışkanlıkları, yetenekleri, dini inançları, örf ve adetleri olarak sıralanabilir.
Participant #7 (*n*-back group): …toplum içinde yaşayan insanların edindikleri bilgileri, davranışları, tepkileri, yaşayış Figureleri, alışkanlıkları gelenekleri ahlaki değerleri aslında toplum içindeki her şey kültür anlamına gelir.
Participant #6 (control group): …kültür herhangi bir toplumda bulunan insanların yaşadıkları birçok şey ahlak değerleri yaptıkları sanat ve her şeye…
Participant #11 (control group): …kültür sosyal, ahlaki, geleneksel, ahlaki, hukuksal konuların bazı inançların gelenek ve göreneklerinizin bir toplumun yaşayış şeklinin tümüdür
Participant #14 (control group): kültürün bir toplumu oluşturan etik değerler, kurallar, çeşitli gelenekler olduğunu görürüz.

Overall, when all interpreting outputs were considered, it is possible to say that as the demands of the tasks and load on WM capacity increase, repetitions, long pauses, corrections, lack of details especially in listed form seem to occur. Such factors inevitably have impacts of coherence and quality of the interpretation outputs, resulting in poor performance and less amount of correctly recalled and interpreted content.

4.7. Functional Near-Infrared Spectroscopy (fNIRS) Results

Functional Near-Infrared Spectroscopy (fNIRS) was utilized during single *n*-back task and consecutive interpreting in all testing occasions. Both behavioural and hemodynamic data were collected while participants were performing the tasks. *n*-back task consisted of 4 blocks which were 1-back, 2-back, 3-back and 4-back. These *n*-back blocks show the task difficulty and were analysed to assess to what extend task difficulty had an impact on oxygenation and whether it manifests itself differently between the groups after the training. Consecutive interpreting without note-taking is mainly composed of two phases; namely comprehension and analysis phase, and reformulation phase. Therefore, consecutive interpreting task had 2 blocks which were comprehension, and reformulation phases of consecutive interpreting. While comprehension and analysis phase of consecutive interpreting involves active and critical listening, and meaning presentation and construction, reformulation phase is related to expressing an equivalent message in a target language based on information processing at comprehension phase.

Changes in the relative ratios of deoxygenated hemoglobin (deoxy-Hb/HbR) and oxygenated hemoglobin (oxy-Hb/HbO) which were measured in micromolar/liter (µMolar/Lt) were computed for each block of both tasks across 16 optodes. Mean HbO values at each optode were calculated for each participant separately and used for statistical analyses of fNIR data.. Increase in oxygenation indicates increasing level of neural activity at the optode (Çakir et al., 2011, p. 307). This increase in neural activity at a specific optode can then be associated with the functions of the brain region related to that part covered by the optode. This enables us to gain a better understanding of underlying neural substrates of WM in these tasks. Following sections show mean HbO concentration changes in each task separately focusing on the optodes at which highest levels of activation were observed. As explained in Chapter 3, four participants were excluded from fNIR analysis in pre- and post-tests, and two participants did not attend the follow-up session. Therefore, the number of participants varied depending on the outlier and signal quality check in each analysis.

4.7.1. Oxygenation Changes During n-back Task in Pre-test

A 3 (*n*-back condition: 1-back, 2-back, 3-back) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) performed on the fNIR data revealed that a reliable change in oxygenation as a function of *n*-back condition (1-, 2-, 3-back conditions) occurred in pre-test at optodes which gather information on both left and right PFC. This finding is also supported by behavioural results indicating the task difficulty both in mean correct responses and mean response times.

The fNIR results showed that there were significant main effects of *n*-back condition on mean oxygenation changes at **optodes #2, #3** and **#4** corresponding to left dorsolateral PFC as well as **optode #9** corresponding to right fronto-polar cortex and

optodes #13 and **#15** which correspond to right dorsolateral PFC, indicating that oxygenation levels changed as the memory load increased at **optodes #2** (F(2,18)= 5,07, p<.05, ηp²=0.36), **#3** (F(2,24)=3.90, p<.05, ηp²=0,25), **#4** (F(2,20)=6.02, p<.05, ηp²=0.38), **#9** (F(2,20)=5.70, p<.05, ηp²=0,36), **#13** (F(2,24)=5,97, p <.05, ηp²=0,33), and **#15** (F(2,24)=8.45, p<.05, ηp²=0,41).

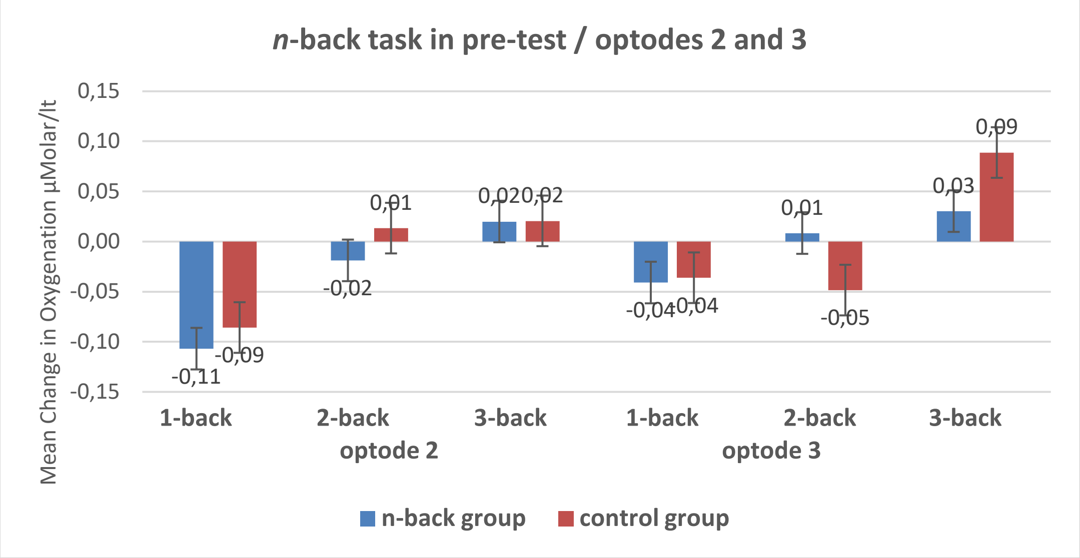

Figure 48: Changes in oxygenation observed during n-back conditions in pre-test at optodes 2 and 3 of the left hemisphere with respect to groups

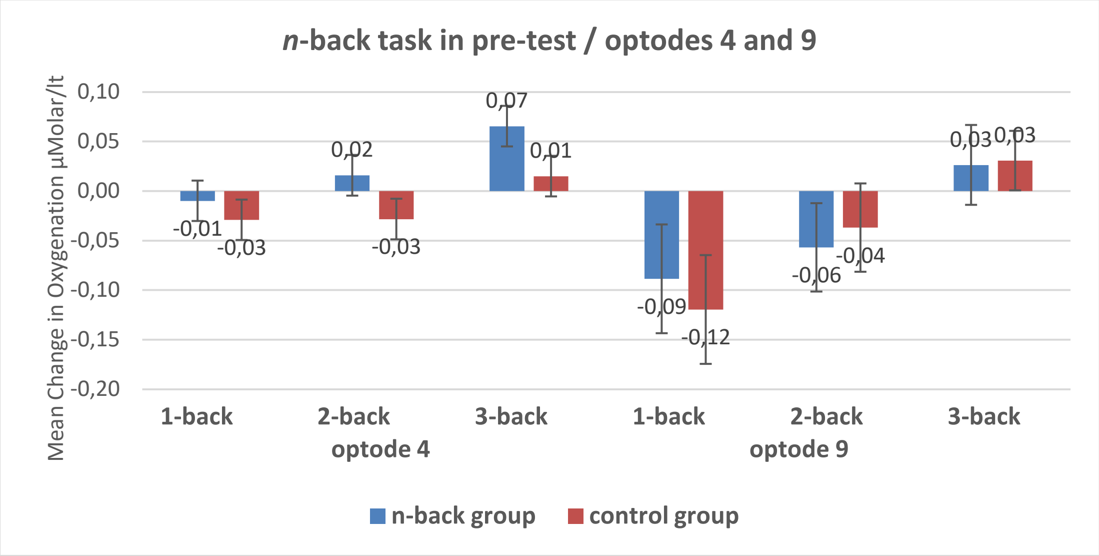

Figure 49: Changes in oxygenation observed during n-back conditions in pre-test at optodes 4 of the left hemisphere and 9 of the right hemisphere with respect to groups

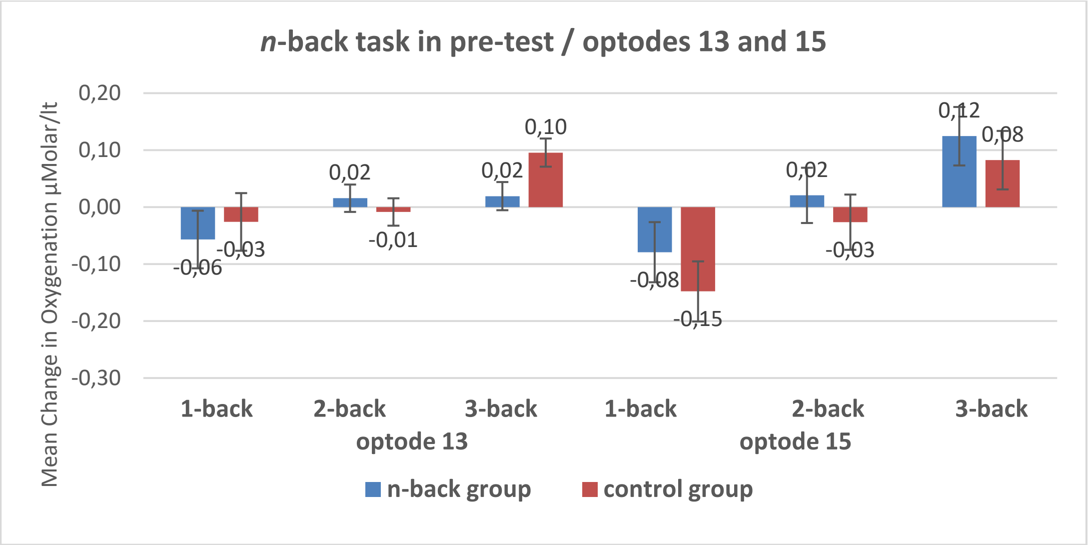

Figure 50: Changes in oxygenation observed during n-back conditions in pre-test at optodes 13 and 15 of the right hemisphere with respect to groups

Planned contrasts with Sidak correction indicated that as the *n*-back level increased and the task got difficult, higher oxygenation concentration occurred at these optodes. Contrasts revealed that 3-back condition induced higher levels of oxygenation as compared to 2-back condition at **optodes #3** (F(1,12)=4.74, p<.05, ηp²=0.28), **#4** (F(1,10)=13.04, p<.05, ηp²=0.57), **#9** (F(1,10)=9.83, p<.05, ηp²=0,50), **#13** (F(1,12)=9.83, p<.05, ηp²=0,45), and **#15** (F(1,12)=8,57, p<.05, ηp²=0,42) as well as compared to 1-back condition at **optodes**, **#4** (F(1,10)=8.63, p<.05, ηp²=0.46), **#9** (F(1,10)=6.92, p<.05, ηp²= 0.41), **#13** (F(1,12)=9.50, p<.05, ηp²=0.44), and **#15** (F(1,12)=13.74, p<.05, ηp²=0,53). At **optode #2**, 1-back condition induced significantly lower level of oxygenation as compared to 2-back condition (F(1,9)=5.99, p <.05, ηp² = 0.40), and 3-back condition (F(1,12)= 5.69, p<.05, ηp²=0.39), oxygenation concentration did not differ significantly between 2-back and 3-back conditions (F(1,9)=0.79, p=.39).

There was not any interaction effect between group and *n*-back task in terms of HbO values in pre-test since the participants in each group were naïve to the task and there was not any baseline difference between the groups in terms of performance based on behavioural analysis. It seems that all participants may have found the task challenging and cognitively demanding. During *n*-back task in pre-test, significant oxygenation increases were observed both in right and left DLPFC (BA9 and 46) as the *n*-back condition and load on memory increased. The association between increasing task difficulty and the increase in activation level was implicated in a number of previous studies on *n*-back task with Positron Emission Tomography (PET) (Reuter-Lorenz et al., 2000; Smith et al., 1996), fMRI (Cohen et al., 1997; Owen et al., 2005) and fNIR (Schreppel et al., 2008).

4.7.2. Training-induced Oxygenation Changes from Pre-test to Post-test during *n*-back Task

A 2 (*n*-back condition: 2-back, 3-back) x 2 (Group: *n*-back, control) x 2 (Time: pre-test, post-test) mixed-design analysis of variance (ANOVA) performed on the fNIR data revealed there was a marginally significant interaction between time and group only at **optode #1** ($F(1,11) = 2.48$, $p < .05$, $\eta p^2 = 0.25$), indicating that oxygenation levels during *n*-back task differed between the groups after receiving training.

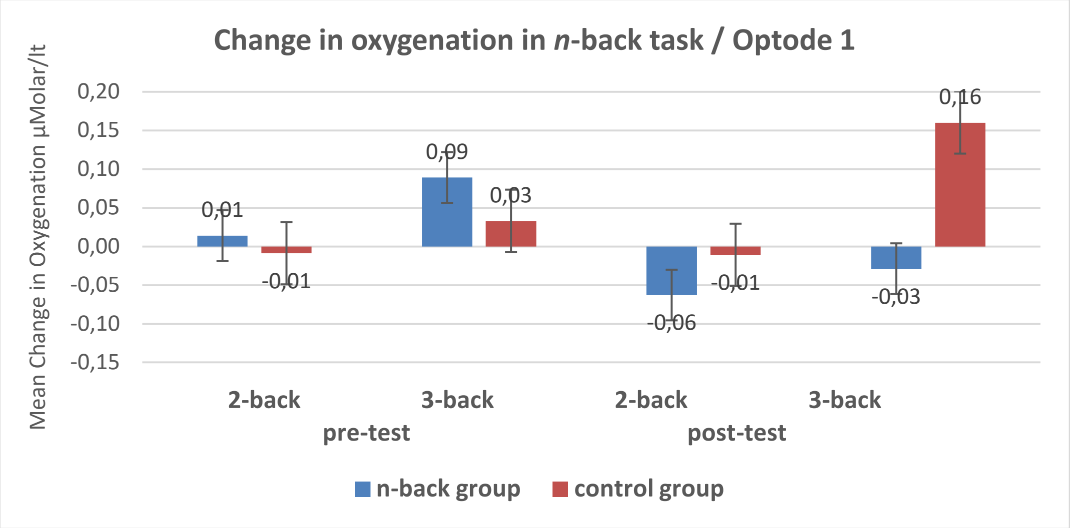

Figure 51: Changes in oxygenation observed at optode 1 of the left hemisphere with respect to groups, testing time and n-back conditions

At **optode #1**, while *n*-back group had a decrease in the level of oxygenation during *n*-back task from pre-test (M=.05, SE=.06) to post-test (M= -.05, SE=.05), control group had an increase in the level of oxygenation during *n*-back task from pre-test (M=.01 SE=.06) to post-test (M=.07 SE=.04). This results shows that the decrease in oxygenation during *n*-back task for *n*-back group is significantly larger than the increase in oxygenation during *n*-back task for control group, which may indicate the effect of training on neural plasticity. The analysis showed that a reliable change in oxygenation as a function of *n*-back condition (2-, 3-back conditions) occurred across time at optodes #1 of left hemisphere as well as #13, #14, #15 and #16, mainly corresponding to right PFC. The contrast revealed that 3-back condition induced higher levels of oxygenation as compared to 2-back condition at **optode #1** ($F(1,11)= 5.41$, $p<.05$, $\eta p^2=0.33$). Furthermore, at **optode #1**, there was a marginally significant interaction between time, group and *n*-back condition ($F(1,11) = 4.09$, $p < .05$, $\eta p^2=0.27$), suggesting that while *n*-back group had lower oxygenation level at post-test both during 2-back (M= -.06 SE=.03) and 3-back (M=-.03 SE=.08) tasks compared to pre-test, control group had higher oxygenation levels during 2-back (M=-.01, SE=.03) and 3-back (M=.16, SE=.07) tasks at post-test compared to pre-test. This interaction effect may suggest that control group had a higher level of oxygenation during *n*-back task as compared to *n*-back group after receiving training.

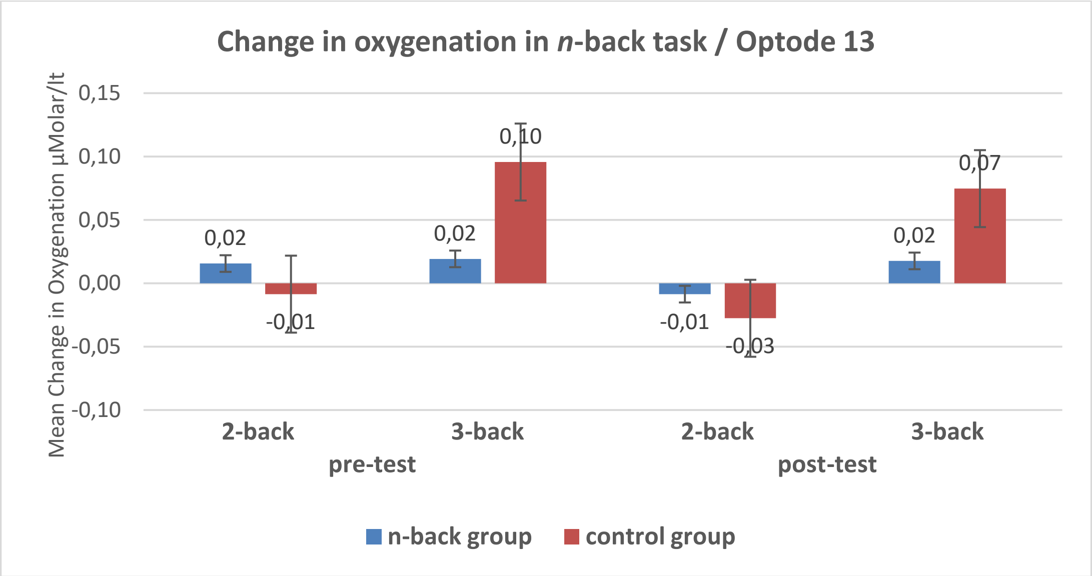

Figure 52: Changes in oxygenation observed at optode 13 of the right hemisphere with respect to groups, testing time and n-back conditions

Mixed-design analysis of variance (ANOVA) revealed main effect of *n*-back condition at **optode #13** (F(1,12)= 6.71, p<.05, ηp²=0,359), showing that 3-back condition elicited higher level of oxygenation compared to 2-back condition across time irrespective of groups. However, there was a marginally significant interaction between *n*-back condition and group at **optode #13** (*F*(1,12)=4.21, p<.05, ηp²=0.26), indicating that the difference in oxygenation levels between 2-back (M=-.02, SE=.02; control group) and 3-back (M=.08, SE=.03; control group) conditions was significantly larger in control group compared to the oxygenation difference between 2-back (M=.007, SE=.02; *n*-back group) and 3-back (M=.02, SE=.03; *n*-back group) conditions in *n*-back group.

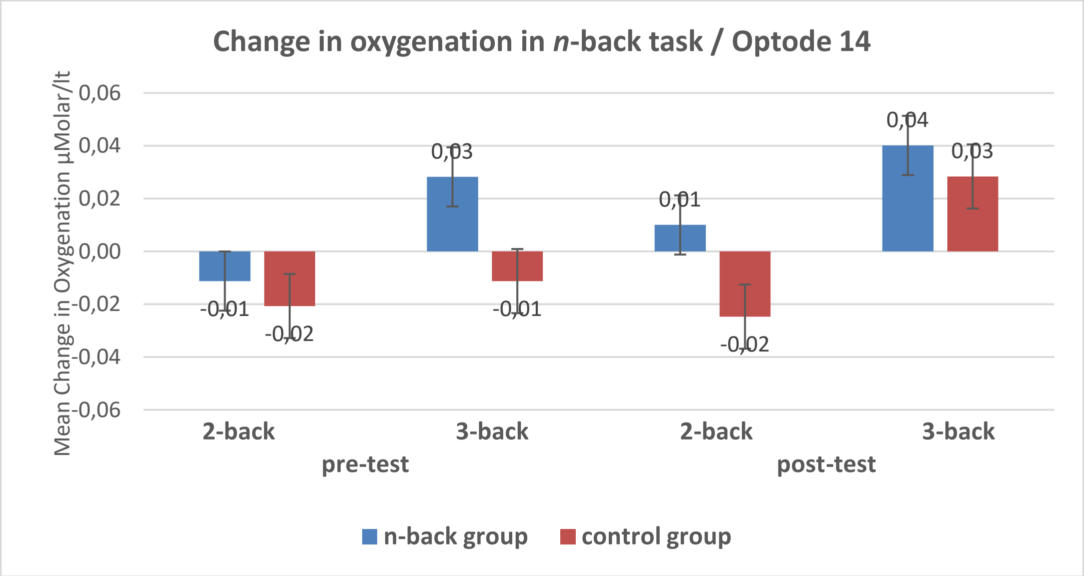

Figure 53: Changes in oxygenation observed at optode 14 of the right hemisphere with respect to groups, testing time and n-back conditions

Main effects of *n*-back condition were observed also at optodes **#14** (F(1,10)=7.42, p<.05, $\eta p^2=0.42$), **#15** (F(1,11)= 21.16, p.<.05, $\eta p^2=0.65$), and **#16** (F(1,12)= 7.38, p<.05, $\eta p^2=0.38$). Higher levels of oxygenation were observed in 3-back condition compared to 2-back condition at these optodes corresponding to right dlPFC, which provide more evidence for the increased neural activity during more demanding and difficult condition of the task. The behavioural data showing longer response times and lower correct responses for 3-back condition compared to 2-back condition also support the pattern of neural activity revealed by the analysis.

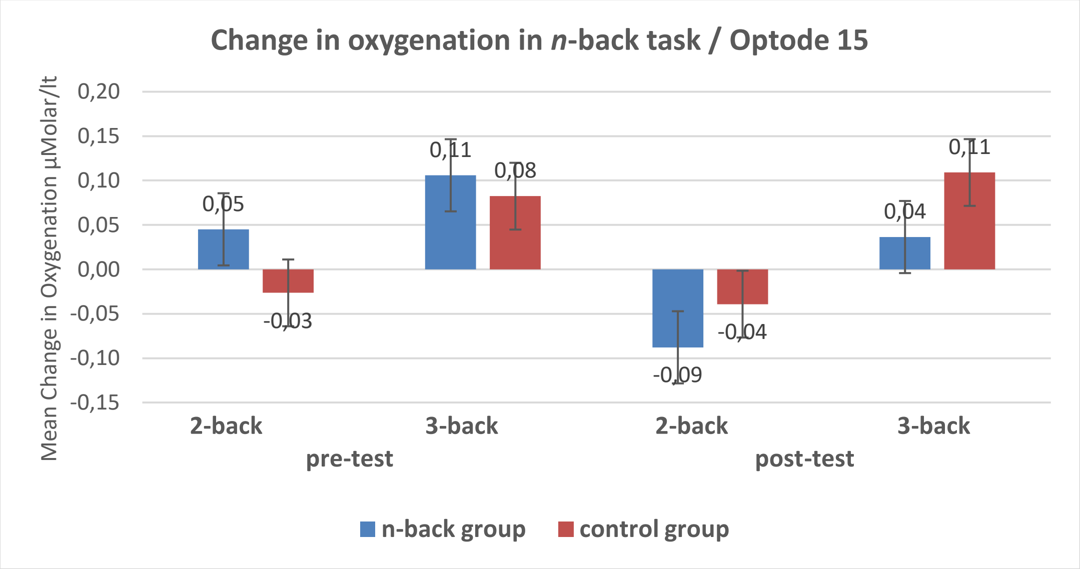

Figure 54: Changes in oxygenation observed at optode 15 of the right hemisphere with respect to groups, testing time and n-back conditions

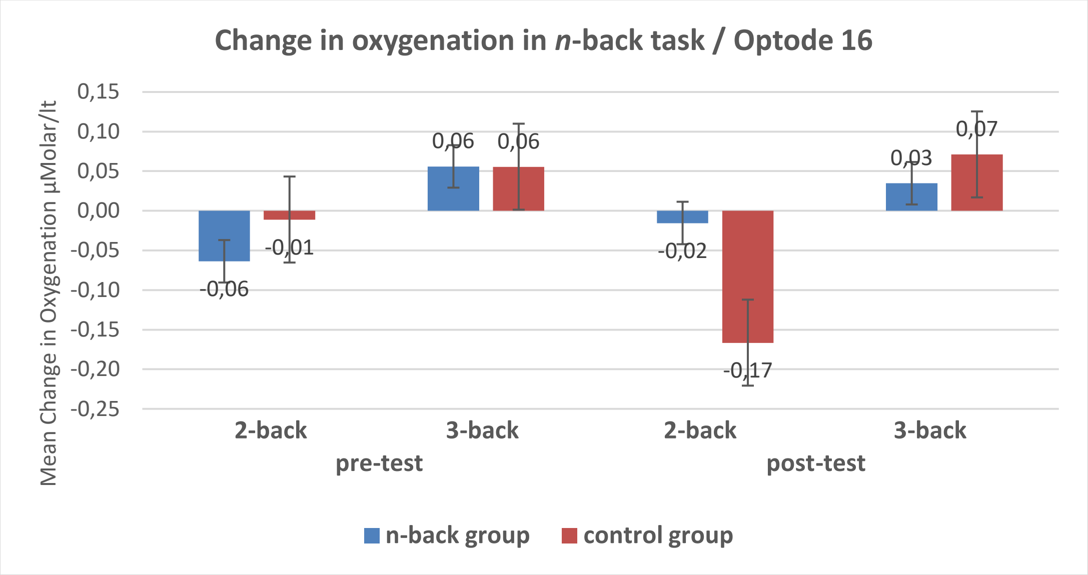

Figure 55: Changes in oxygenation observed at optode 16 of the right hemisphere with respect to groups, testing time and n-back conditions

4.7.3. Training-induced Oxygenation Changes from Post-test to Follow-up During *n*-back Task

A 3 (*n*-back condition: 2-back, 3-back, 4-back) x 2 (Group: *n*-back, control) x 2 (Time: post-test, follow-up) mixed-design analysis of variance (ANOVA) was performed on the fNIRS data to investigate the oxygenation changes from post-test to follow-up with respect to group, time and *n*-back conditions.

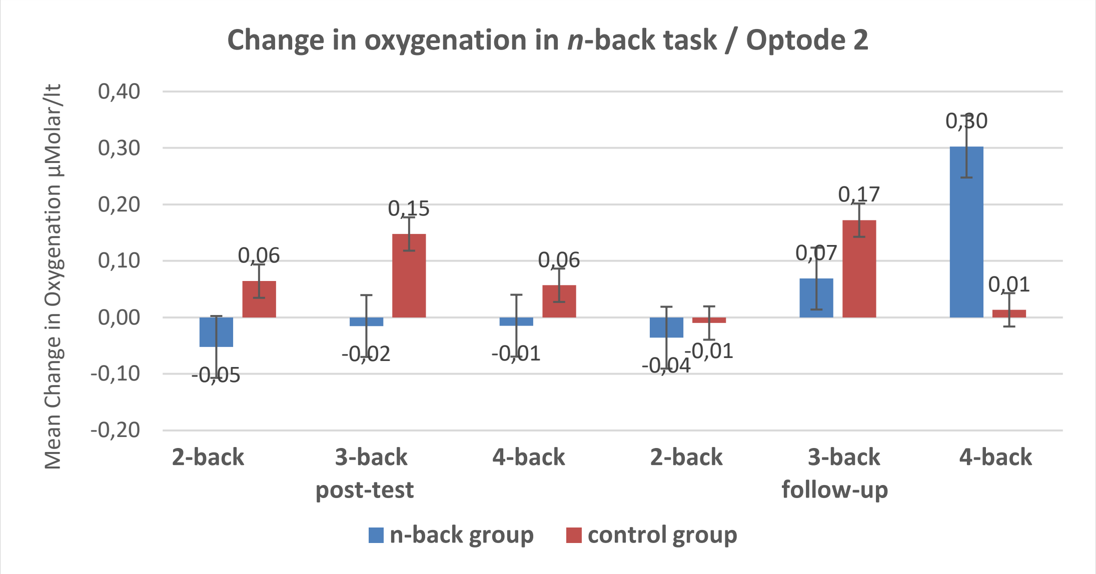

Figure 56: Changes in oxygenation observed at optode 2 of the left hemisphere with respect to groups, testing time and n-back conditions

The analyses revealed that there was a significant interaction between time and group as well as *n*-back condition and group at **optode 2** (*F*(1,9) =6.24, p<0.05, ηp²=0.40). The difference between mean oxygenation levels during *n*-back task in post-test (M=-.02, SE=.04) and follow-up (M=.11, SE=.05) was significantly larger in *n*-back group compared to the oxygenation difference between post-test (M=.09, SE=.04) and follow-up in control group (M=.06, SE=.04). There was also a significant interaction effect between *n*-back condition and group at **optode #2** (*F*(2,18) =4.19, p<0.05, ηp² =0.32), suggesting that the difference between mean oxygenation levels differed between the groups with respect to *n*-back condition.

The repeated contrasts with Sidak correction showed that the difference between oxygenation levels during 3-back (M=.16, SE=.06; control group) and 4-back (M=.06, SE=.04; control group) across time was larger for control group compared to overall oxygenation levels during 3-back (M=.03, SE=.08; *n*-back group) and 4-back (M=.14, SE=.04; *n*-back group) of *n*-back group at optode 2 (*F*(1,9) =5.60, p<0.05, ηp² =0.38). Considering behavioural results showing control group's overall performance in *n*-back task in post-test and follow-up and their lower correct responses especially in 3-back and 4-back conditions in follow-up, this may indicate that, control group might not have exhibited their full concentration and potential due to disengagement from the task.

Furthermore, there was a significant interaction between time, group and *n*-back conditions at **optode 16** (*F*(2,116) =3.54, $p<0.05$, ηp^2 =0.31). Planned contrast with Sidak correction revealed that the difference between 2-back and 3-back conditions was larger for control group compared to *n*-back group in post-test; however, in the follow-up it was the opposite. While the difference between oxygenation levels during 2-back and 3-back conditions increased from post-test to follow-up in *n*-back group, this difference decreased from post-test to follow-up in control group at optode 16 (*F*(1,9) =3.70, $p<0.05$, ηp^2 =0.32).

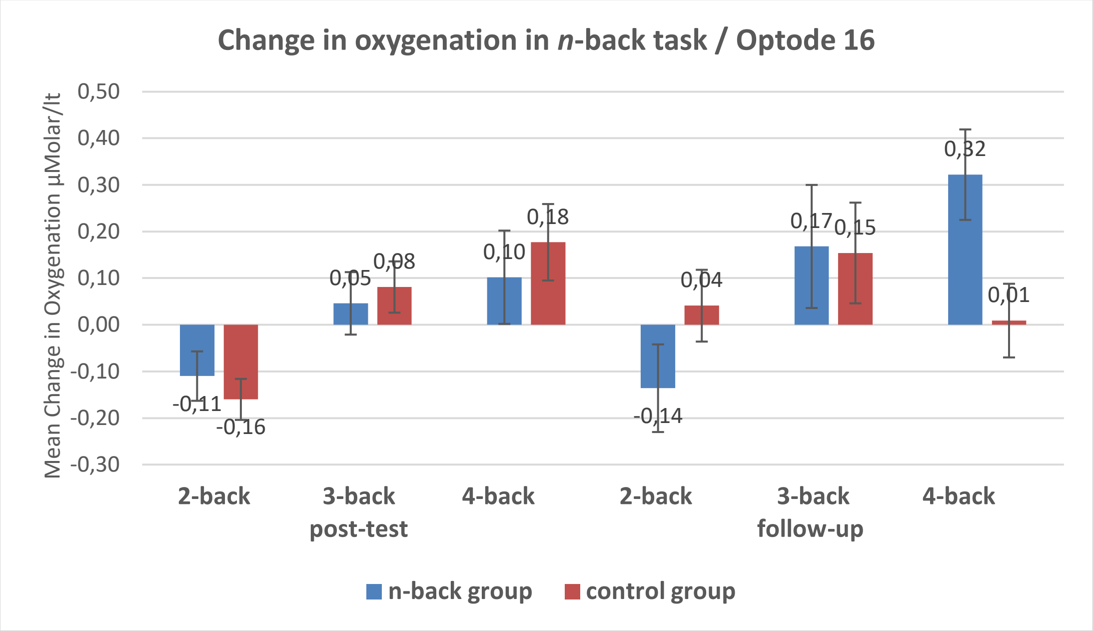

Figure 57: Changes in oxygenation observed at optode 16 of the right hemisphere with respect to groups, testing time and n-back conditions

In addition to interaction effects, there were also main effects of *n*-back condition and time considering the change from post-test to follow-up. The data showed that there were main effects of time at **optodes #5** (*F*(1,8)=8.42, $p<0.05$, ηp^2=0.51) corresponding to left dlPFC, **#7** (*F*(1,9)=11.06, $p<0.05$, ηp^2=0.55) and **#8** (*F*(1,7)=5.05, $p<0.05$, ηp^2=0.42) corresponding to left fronto polar region, as well as **#10** (*F*(1,7)=12.78, $p<0.05$, ηp^2=0.65) corresponding to right fronto polar region, indicating that *n*-back task elicited significantly higher levels of oxygenation in follow-up as compared to post-test.

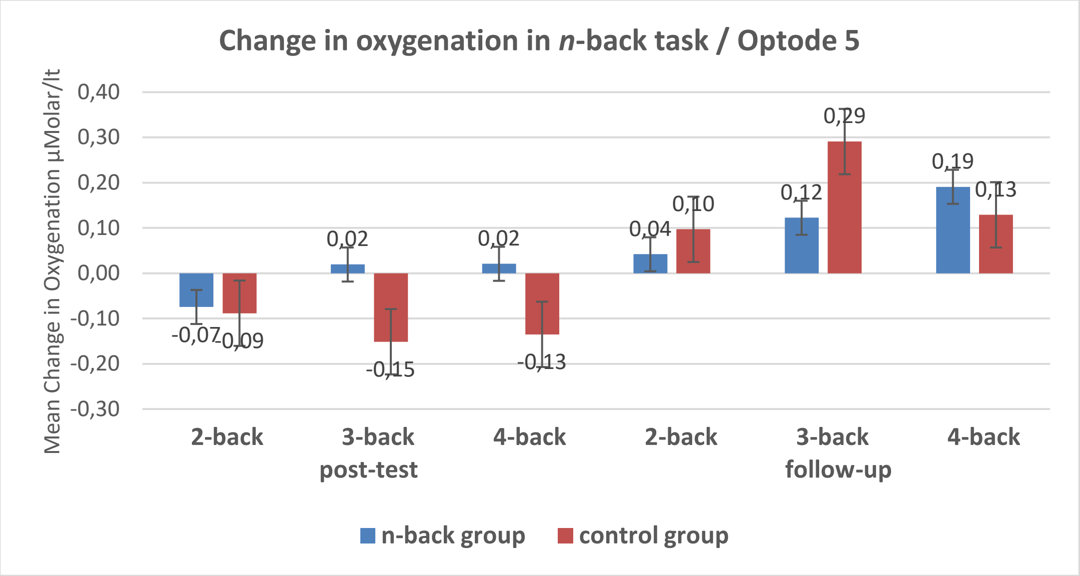

Figure 58: Changes in oxygenation observed at optode 5 of the left hemisphere with respect to groups, testing time and n-back conditions

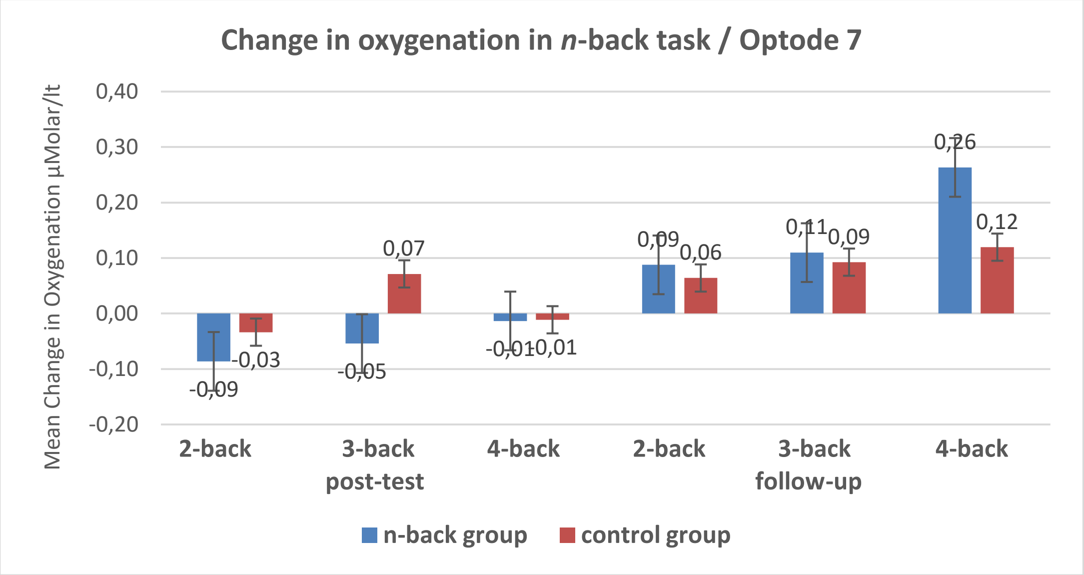

Figure 59: Changes in oxygenation observed at optode 7 of the left hemisphere with respect to groups, testing time and n-back conditions

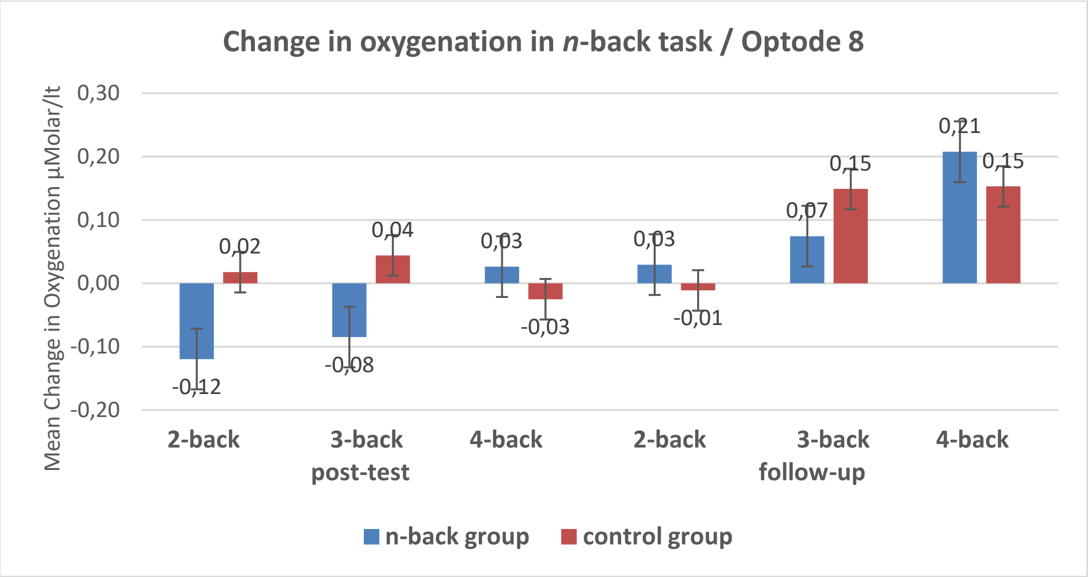

Figure 60: Changes in oxygenation observed at optode 8 of the left hemisphere with respect to groups, testing time and n-back conditions

Moreover, a reliable change in oxygenation as a function of *n*-back condition (2-back, 3-back, 4-back conditions) occurred at optode **#1** (*F*(2,16)=8.64, p<0.05, ηp²=0.52) corresponding to left dlPFC as well as optodes **#10** (*F*(2,14)=4.30, p<0.05, ηp²=0.38) corresponding to right fronto polar region and **#11** (*F*(2,16)=3.84, p<0.05, ηp²=0.32) mainly corresponding to right dmPFC, optodes **#13** (*F*(2,18) =4.95, p<0.05, ηp²=0.35)**, #15** (*F*(2,16)=5.83, p<0.05, ηp²=0.42) and **#16** (*F*(2,16)=10.62, p<0.05, ηp²=0.57) corresponding to right dlPFC.

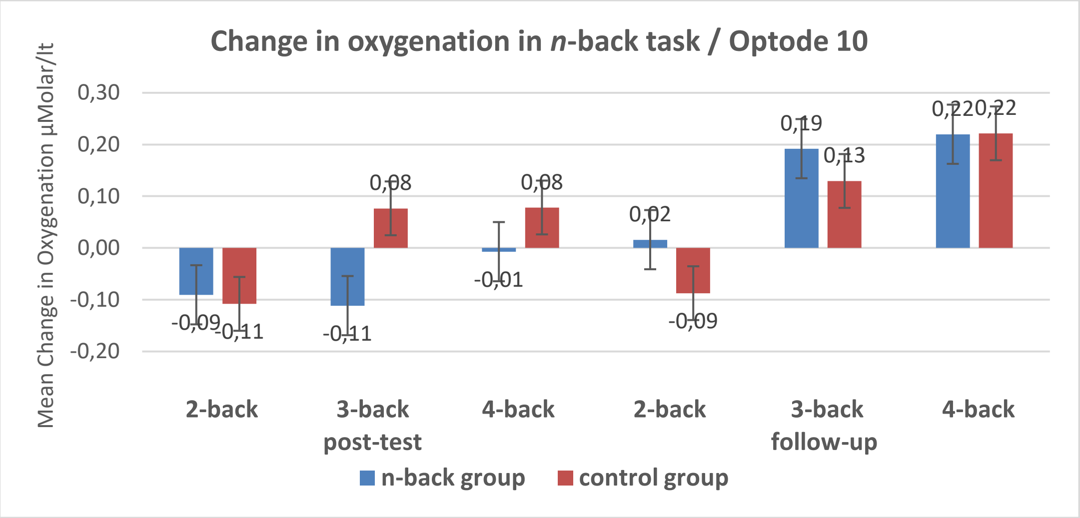

Figure 61: Changes in oxygenation observed at optode 10 of the left hemisphere with respect to groups, testing time and n-back conditions

The repeated contrasts with Sidak correction revealed that 3-back condition induced significantly higher levels of oxygenation as compared to 2-back condition at optodes **#1** (*F*(1,8)=13.06, p<0.05, ηp²=0,62), **#2** (*F*(1,9)=7.72, p<0.05, ηp²=0.46), **#10** (*F*(1,7)=6.74, p<0.05, ηp²=0.49), **#11** *F*(1,8)=5.53, p<0.05, ηp²=0.40), **#13** (*F*(1,9)=9.64, p<0.05, ηp²=0.52) **#15** (*F*(1,8)=7.99, p<0.05, ηp²=0.50) and **#16**

($F(1,8)=16.24$, $p<0.05$, $\eta p^2=0.67$). Moreover, further simple contrasts showed that 4-back condition also elicited significantly higher levels of oxygenation as compared to 2-back condition at optodes **#1** ($F(1,8)=10.94$, $p<0.05$, $\eta p^2 =0.58$), **#2** ($F(1,9) =5.08$, $p<0.05$, $\eta p^2 =0.36$), **#10** ($F(1,7)=5.50$, $p<0.05$, $\eta p^2=0.44$), **#15** ($F(1,8) =5.78$, $p<0.05$, $\eta p^2=0.42$) and **#16** ($F(1,8)=16.29$, $p<0.05$, $\eta p^2=0.67$). In terms of differences between the oxygenation levels of 3-back and 4-back, there was not any significant difference between the levels, which suggests that they both were similarly challenging and difficult levels of *n*-back.

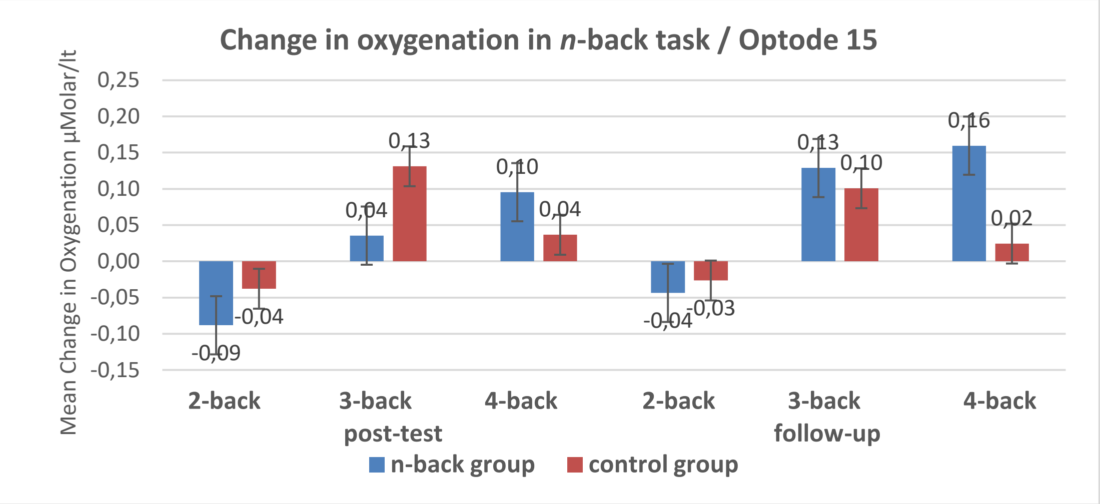

Figure 62: Changes in oxygenation observed at optode 15 of the left hemisphere with respect to groups, testing time and n-back conditions

4.7.4. Oxygenation Changes During Consecutive Interpreting in Pre-test

A 2 (consecutive interpreting: comprehension phase, reformulation phase) x 2 (Group: *n*-back, control) mixed-design analysis of variance (ANOVA) performed on the fNIR data revealed that comprehension and reformulation phases of consecutive interpreting showed significantly different oxygenation trends at **optodes #5** and **#7**.

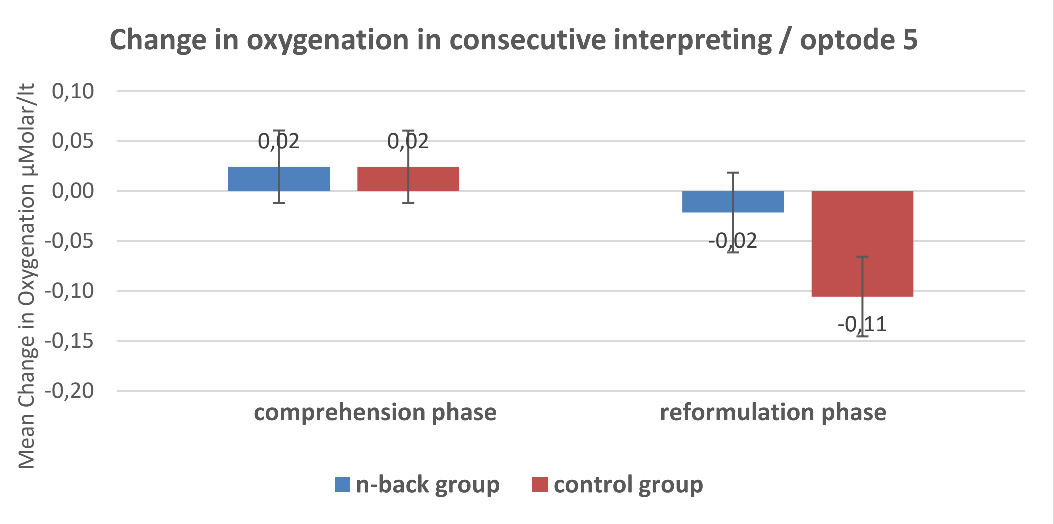

Figure 63: Changes in oxygenation observed during consecutive interpreting at optode 5 of the left hemisphere with respect to two phases of consecutive interpreting

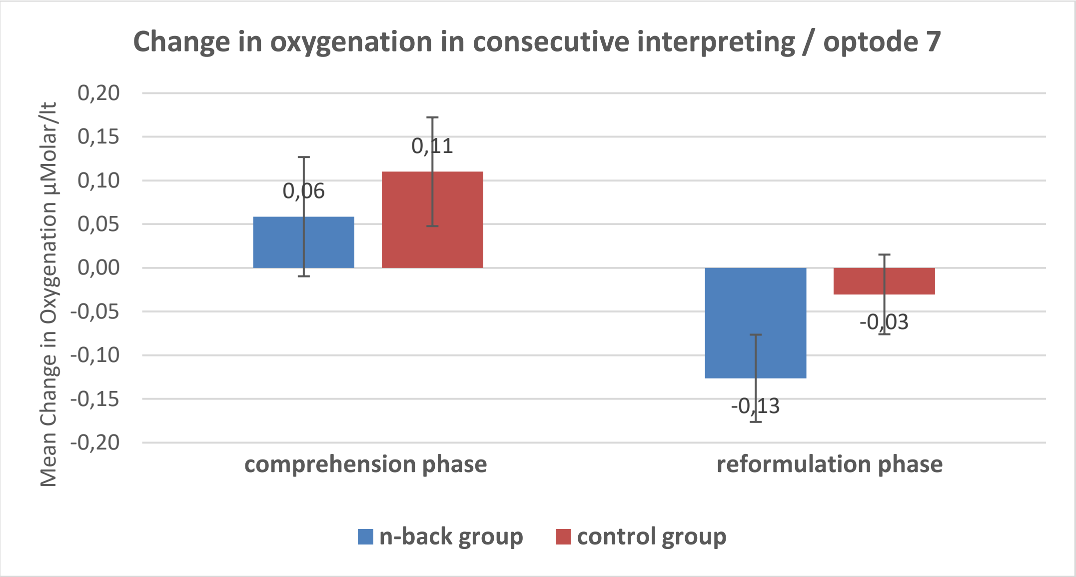

Figure 64: Changes in oxygenation observed during consecutive interpreting at optode 7 of the left hemisphere with respect to two phases of consecutive interpreting

As can be seen in the figures above, comprehension phase during consecutive interpreting induced higher level of oxygenation as compared to reformulation phase of consecutive interpreting at **optode #5** (F(1,11)=3.93, p <.05, ηp^2 = 0.26) and **optode #7** (F(1,9)=6.42, p <.05, ηp^2 = 0,42) across groups. There was not any interaction effect between group and consecutive interpreting phases in pre-test. All participants were assumed to perform similarly in the pre-test which was also concluded by behavioural results. Optode 5 corresponds to left dmPFC and Optode 7 is located in left fronto-polar, which is close to Brodmann Area (BA) 10.

4.7.5. Oxygenation Changes from Pre-test to Post-test During Consecutive Interpreting

A 2 (consecutive interpreting phases: comprehension, reformulation) x 2 (Group: *n*-back, control) x 2 (Time: pre-test, post-test) mixed-design analysis of variance (ANOVA) was performed on the fNIR data. The analysis revealed significant interactions and main effects mainly at optodes 3, 5 and 15 in addition to optodes 4, 7 and 13. The data showed that there were significant interaction effects between time and group at **optode 3** (*F*(1,12)=8.88, p<.05, ηp^2=0.42)corresponding to left DLPFC which is close to Broca's region (BA 44), and **optode 5** located in left DMPFC (*F*(1,11)=5.09, p<.05, ηp^2=0.31). These results indicate that overall oxygenation levels during consecutive interpreting irrespective of interpreting phases differed between the groups, and the change in mean oxygenation during consecutive interpreting from pre-test to post-test was significantly larger in control group compared to *n*-back group at both optodes.

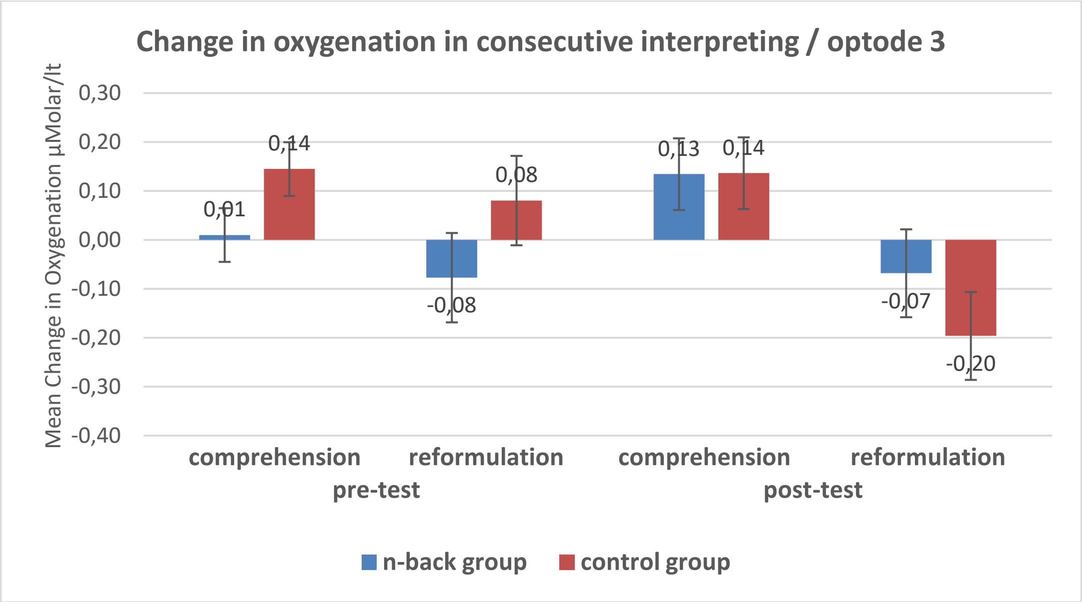

Figure 65: Changes in oxygenation observed at optode 3 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

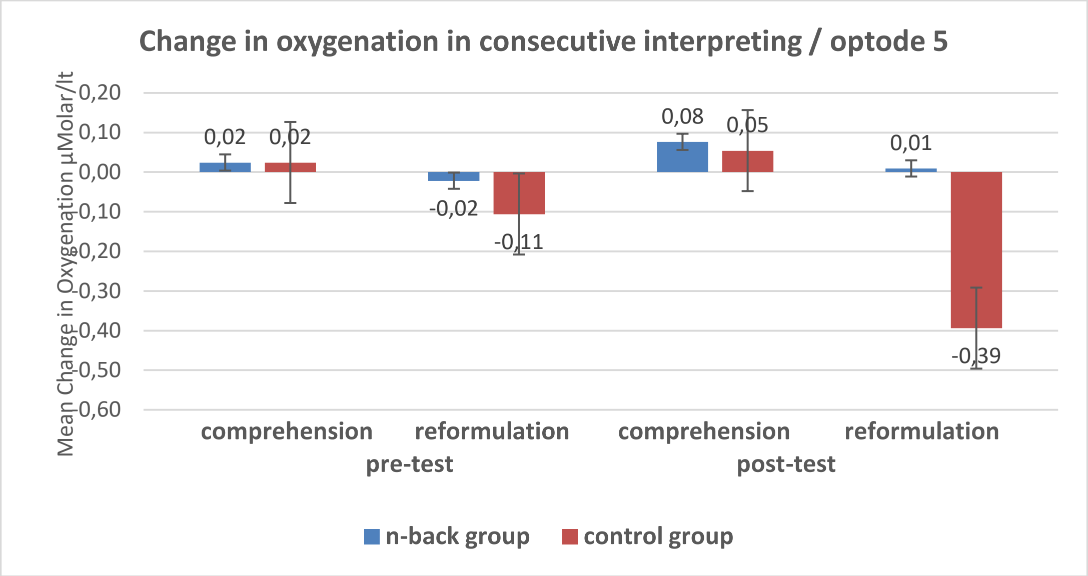

Figure 66: Changes in oxygenation observed at optode 5 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

While oxygenation level elicited by consecutive interpreting decreased significantly from pre-test (M=.11, SE=.04; control group) to post-test (M=-.03, SE=.04; control group) at optode 3 and pre-test (M=-.04, SE=.03; control group) to post-test (M=-.17, SE=.06; control group) optode 5 in control group, *n*-back group presented an opposite trend having a slight increase in oxygenation level from pre-test (M=-.03, SE=.04; optode 3; M=.001, SE=.02; optode 5) to post-test (M=.03, SE=.04; optode 3; M=.04, SE=.06; optode 5). Behavioural data also suggest that while both groups had almost 38% performance in consecutive interpreting in pre-test, when it comes to post-test, *n*-back group increased their performance to 51% and control group had a slight but nonsignificant increase in their consecutive interpreting performance (42%). This may show that *n*-back group's higher performance in behavioural analysis might have been also reflected in higher oxygenation levels during interpreting in *n*-back group.

Furthermore, there were significant interactions between consecutive interpreting phases and time at **optode 3** (*F*(1,12)=4.47, p<.05, ηp^2=0.27), and **optode 5** (*F*(1,11)=15.74, p<.05, ηp^2=0.59), suggesting that oxygenation levels during comprehension and reformulation phases exhibited significant differences between the testing times. The difference between mean oxygenation levels of comprehension and reformulation phases in post-test was significantly larger than the difference between the two phases in pre-test. Both in pre-test and post-test, it seems that comprehension phase elicited more oxygenation compared to reformulation at optodes 3 and 5.

Moreover, there was a significant interaction between time, group and two phases of consecutive interpreting at **optode 5** (*F*(1,11)=12.03, p<.05, ηp^2=0.52). In terms of difference between mean oxygenation levels of comprehension and reformulation, there was not any significant difference for both groups in pre-test. In post-test, the difference between mean oxygenation levels during comprehension and reformulation phases was larger for control group compared to *n*-back group. Furthermore, while mean oxygenation level during reformulation phase significantly decreased from pre-test to post-test in control group, such a trend was not observed in *n*-back group.

There was a significant interaction between consecutive interpreting phases and group at **optode 4** (*F*(1,9)=6.72, p<.05, ηp^2=0.43) corresponding to left dlPFC close to inferior frontal gyrus, indicating that oxygenation levels during comprehension and reformulation phases of consecutive interpreting exhibited significant differences between the groups. The difference in mean oxygenation between comprehension (M=.09, SE=.04; control group) and reformulation phases (M=-.07, SE=.05; control group) was significantly larger in control group compared to the difference between comprehension (M=.02, SE=.05; *n*-back group) and reformulation (M=.10, SE=.06; *n*-back group) phases in *n*-back group. Comprehension phase of consecutive interpreting resulted in significantly higher levels of oxygenation compared to reformulation phase at optodes 4 and 5 in both groups.

In addition to interactions, there were also main effects of consecutive interpreting phase at **optodes #3** (*F*(1,12)=4.06, p<.05, ηp^2=0.25 of dlPFC of left hemisphere, **#5** (*F*(1,11)=14.11, p<.05, ηp^2=0.56) of dorsomedial PFC of left hemisphere, **#7** (*F*(1,9)=9.29, p<0,05, ηp^2=0.50) corresponding to fronto polar cortex, indicating that comprehension phase induced significantly more oxygenation as compared to reformulation at **optodes 3, 5** and **7** of left hemisphere.

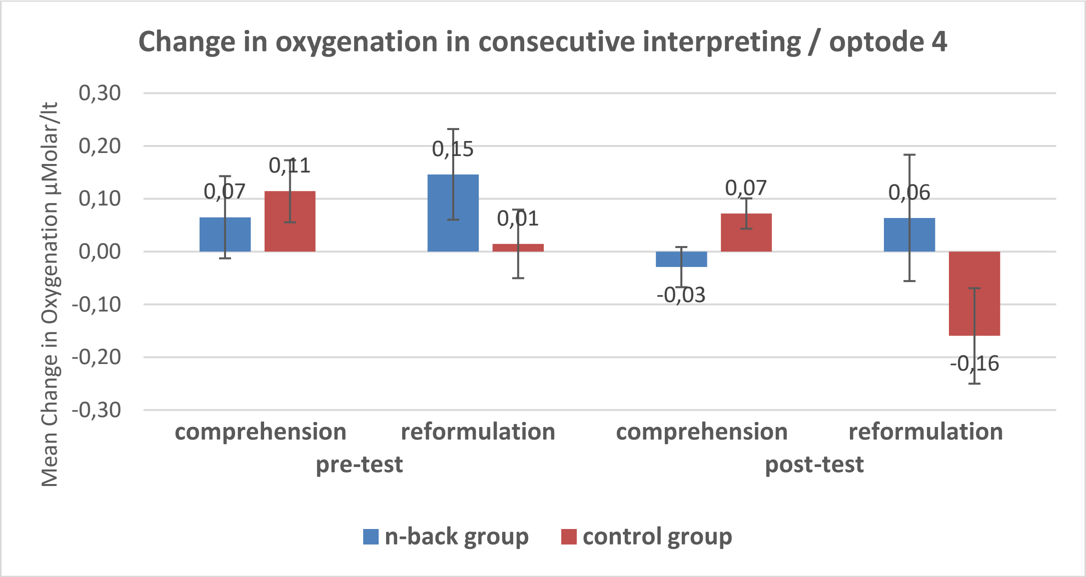

Figure 67: Changes in oxygenation observed at optode 4 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

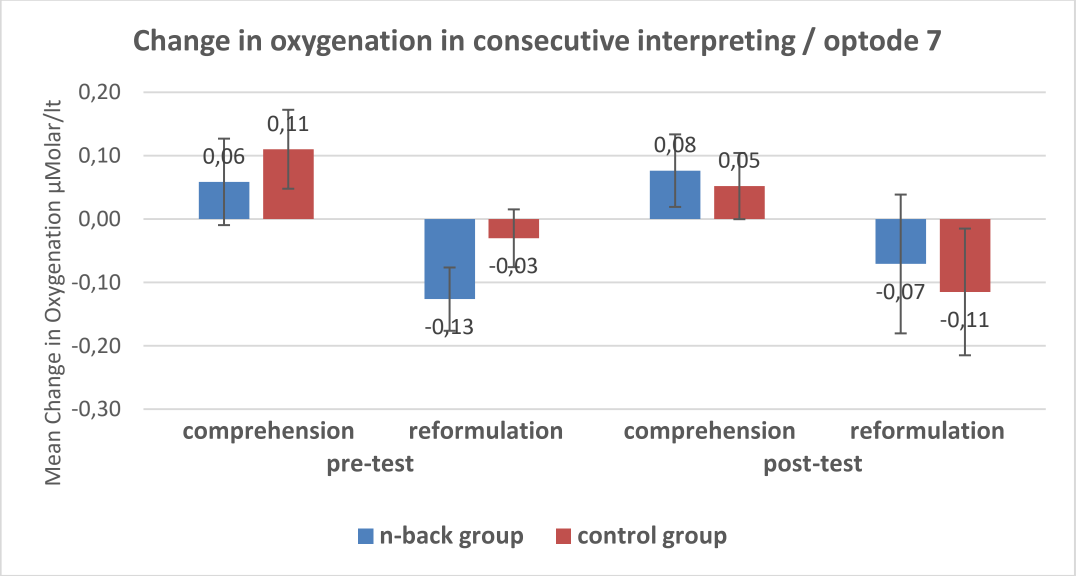

Figure 68: Changes in oxygenation observed at optode 7 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

4.7.6. Oxygenation Changes from Post-test to Follow-up During Consecutive Interpreting

Behavioural analysis showed that both *n*-back and control groups performed similarly in post-test and follow-up and the mean scores of both groups did not change from post-test to follow-up having almost identical scores without any decrease or increase. This may represent a re-test effect since the speeches used in post-test and 3-month follow-up were the same. A 2 (consecutive interpreting phases: comprehension, reformulation) x 2 (Group: *n*-back, control) x 2 (Time: post-test, follow-up) mixed-design analysis of variance (ANOVA) was performed on the fNIR data and the number of participants who were included in the analysis ranged between 8 and 11. The analysis revealed marginally significant interactions between time and group at **optode 2** (*F*(1,9)=4.49, p<.05, ηp²=0.33), corresponding to left dlPFC and at **optode 5** (*F*(1,6)=4.56, p<.05, ηp²=0.36) corresponding to dmPFC, indicating that oxygenation levels during consecutive interpreting in post-test and follow-up differed between the groups.

At **optode 2**, the change in oxygenation levels during consecutive interpreting from post-test to follow-up was slightly larger for control group as compared to *n*-back group. While *n*-back group showed a decreased pattern of oxygenation level during consecutive interpreting from post-test to follow-up, control group had an increase in oxygenation level during consecutive interpreting from post-test to follow-up. At **optode 5**, similarly, the change in oxygenation levels during consecutive interpreting from post-test to follow-up was larger for control group as compared to *n*-back group. While *n*-back group showed a decreased pattern of oxygenation level during consecutive interpreting from post-test to follow-up, control group had a significantly increased level in oxygenation concentration during consecutive interpreting from post-test to follow-up.

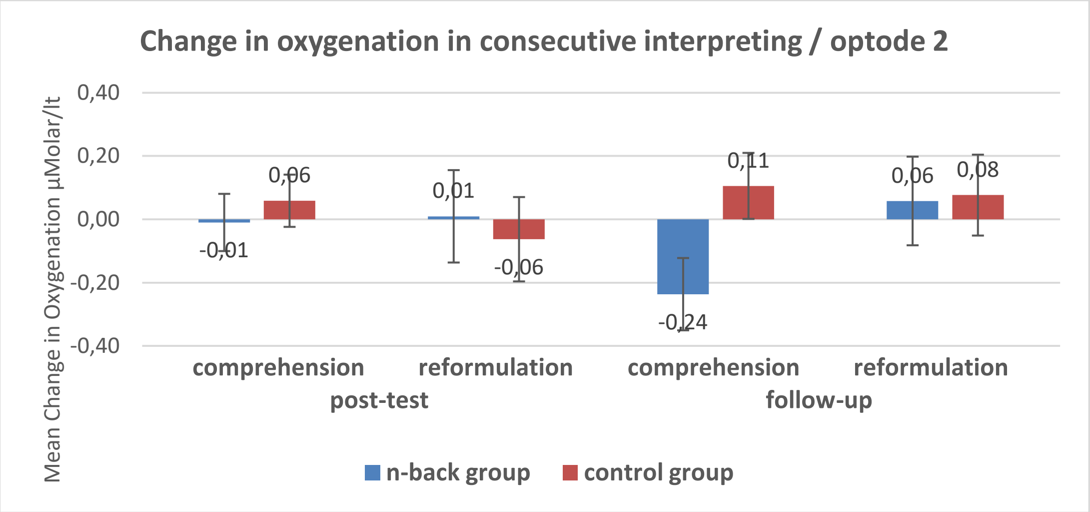

Figure 69: Changes in oxygenation observed at optode 2 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

Moreover, there were significant interactions between time and consecutive interpreting phases at **optode 3** (*F*(1,9)=14.14, p<.05, ηp²=0.61) and **optode 5** (*F*(1,6)=7.67, p<.05, ηp²=0.49). At **optode 5**, the difference between mean oxygenation levels of comprehension and reformulation phases of consecutive interpreting in follow-up was larger than the difference between the two phases in post-test. While comprehension phase seems to elicit more oxygenation concentration compared to reformulation phase in post-test, the opposite trend was observed in the follow-up; reformulation phase having higher level of oxygenation compared to comprehension phase. At **optode 3**, the difference between mean oxygenation levels of comprehension and reformulation phases in post-test was slightly larger than the difference between the two phases in follow-up. While comprehension phase seems to elicit more oxygenation concentration compared to reformulation in post-test, the opposite trend was observed in the follow-up; reformulation phase having higher level of oxygenation compared to comprehension phase.

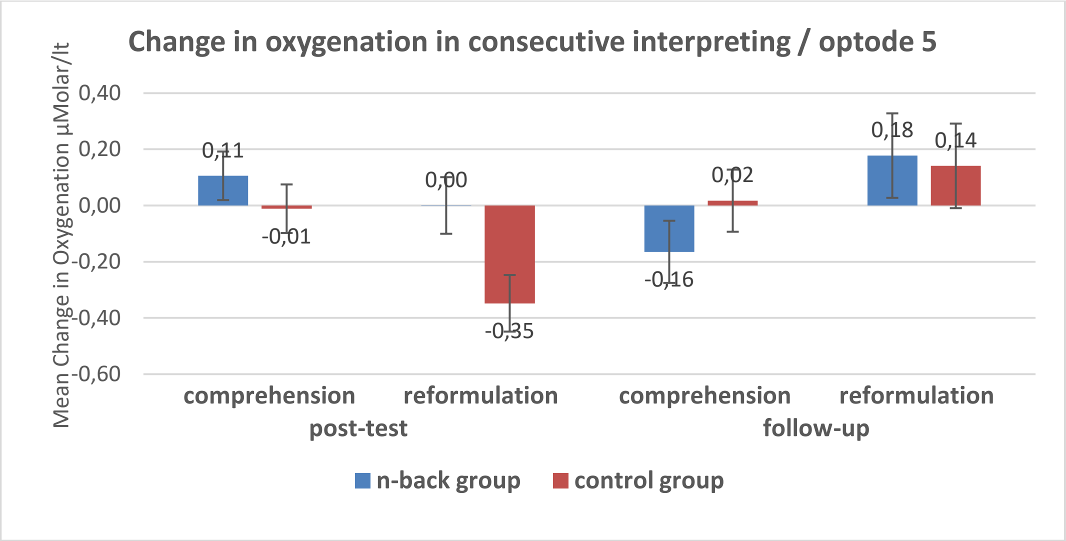

Figure 70: Changes in oxygenation observed at optode 5 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

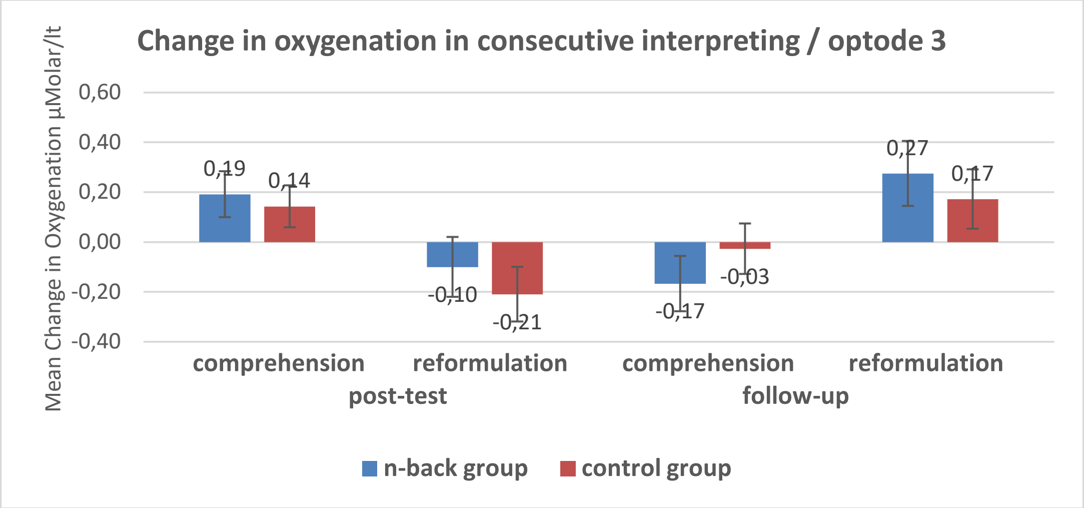

Figure 71: Changes in oxygenation observed at optode 3 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

There was also a significant interaction between consecutive interpreting phase and group only at **optode 15** of right hemisphere ($F(1,8)=12.50$, $p<.05$, $\eta p^2=0.61$), indicating that the difference in oxygenation levels between comprehension and reformulation phases was significantly larger for *n*-back group compared to the control group. This result suggests that while *n*-back group had higher level of oxygenation during reformulation, control group had reverse trend of oxygenation showing lower level of oxygenation during reformulation.

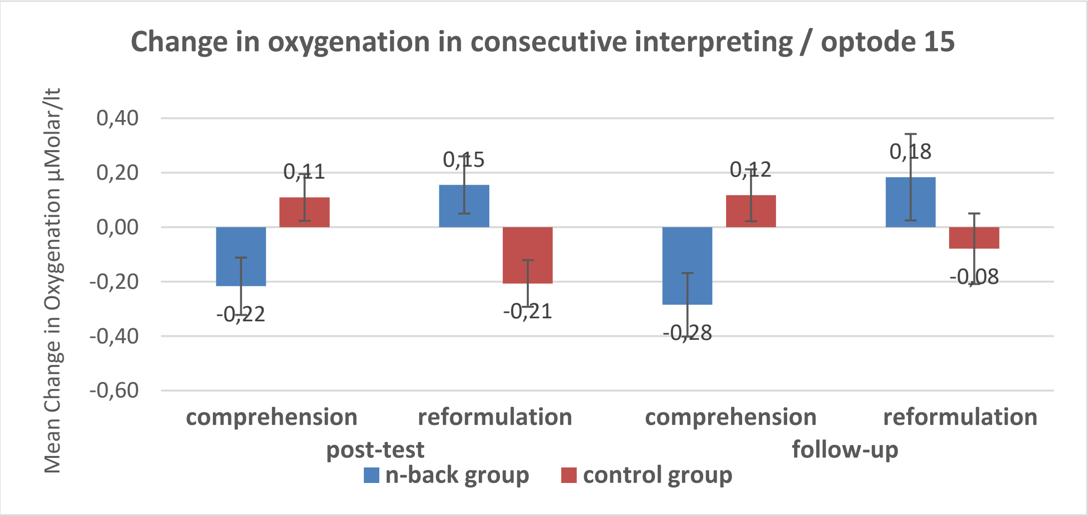

Figure 72: Changes in oxygenation observed at optode 15 of the right hemisphere during two phases of consecutive interpreting with respect to group and testing time

The analysis revealed a significant overall main effect of consecutive interpreting phase at **optode 8**, mainly corresponding to left fronto polar region of PFC ($F(1,6)=5.72$, $p<.05$, $\eta p^2=0.49$) and at **optode 16** of dlPFC in right hemisphere ($F(1,7)=5.27$, $p<.05$, $\eta p^2=0.43$). As shown in figures below, these results indicate that reformulation phase induced significantly more oxygenation as compared to comprehension phase during consecutive interpreting when post-test and follow-up mean HbO values were averaged irrespective of groups.

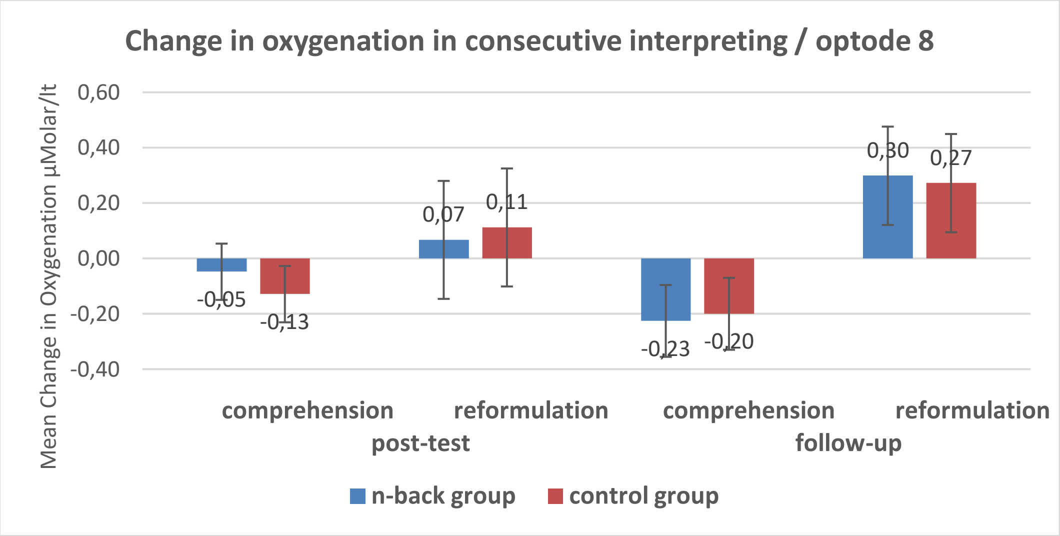

Figure 73: Changes in oxygenation observed at optode 8 of the left hemisphere during two phases of consecutive interpreting with respect to group and testing time

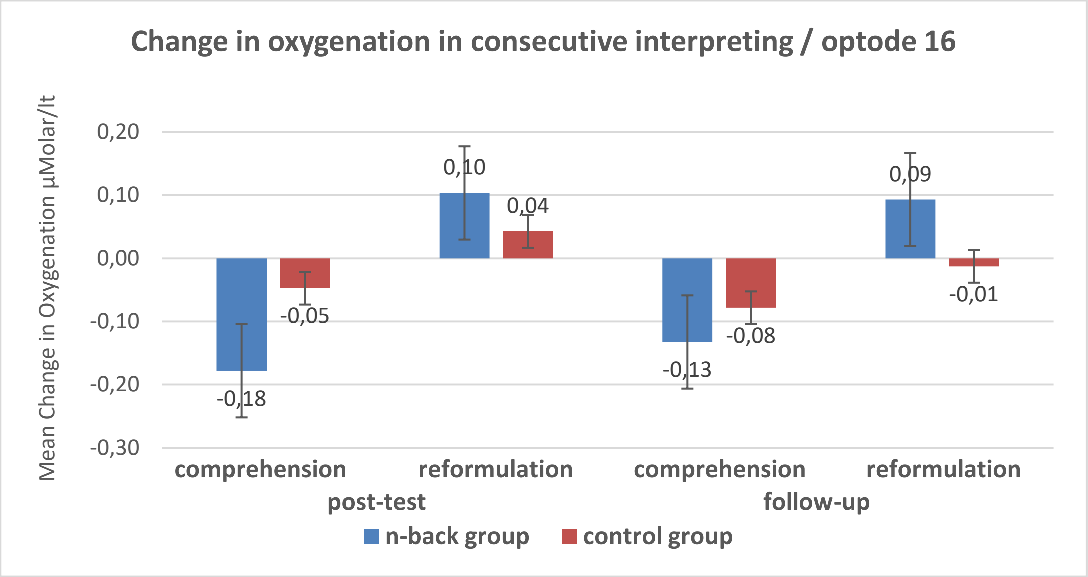

Figure 74: Changes in oxygenation observed at optode 16 of the right hemisphere during two phases of consecutive interpreting with respect to group and testing time

4.8. Summary of Chapter 4: Results

In this chapter, results of behavioural and optical brain imaging data (fNIRS) were presented separately. In terms of participants' motivation and beliefs about intelligence, it was found that both *n*-back and control groups were highly motivated and engaged throughout the study and showed a great tendency for the belief that intelligence in malleable and it can be changed with training or experience. Both groups gradually and significantly enhanced their performances in training sessions thanks to the adaptive nature of the training regimes. The highest levels of difficulty achieved in both n-back task and simple letter span were remarkable. When transfer effects were analysed with respect to the classification of near, moderate and far transfer, it was found that there was a near transfer to 3-back and 4-back conditions of dual *n*-back task, indicating that *n*-back group had larger performance gains compared to control group. In terms of moderate transfer which was measured with English reading span task, there was not any significant difference between the groups' changes in performance. When the groups were tested on Bochum Matrices Test (BOMAT) as a far transfer task, it was found that n-back group had larger performance gains than the control group. In addition to these measures of WM and intelligence, participants were also evaluated based on their consecutive interpreting performances, which was considered to represent the transfer to real world skills. Findings showed that *n*-back group had larger performance gains in idea-unit scores in consecutive interpreting task and the quality of their interpretation outputs were better considering the factors of fluency, information flow and coherence, etc.

fNIRS data collected during *n*-back task and consecutive interpreting in each testing phase provided valuable support for behavioural results. Neural findings of *n*-back task supported the task difficulty observed in behavioural data and showed that as the difficulty levels increased, the task elicited more oxygenation especially in bilateral dlPFC. Results also presented that oxygenation changes from pre-test to post-test significantly decreased in *n*-back group in left dlPFC, indicating increased neural efficiency as a result of intensive training. For the first time, neural correlates of consecutive interpreting were obtained via fNIRS and provided neural evidence for the assumption and demands and cognitive load of comprehension and reformulation phases of consecutive interpreting were different. It was found that comprehension phase elicited more oxygenation mainly in left dmPFC and left fronto polar region. Furthermore, it was revealed that after the training, comprehension phase elicited lower level of oxygenation in areas associated with mainly left dlPFC and dmPFC in *n*-back group, indicating that comprehension phase became effortless for *n*-back group and they allocated more resources for reformulation. This finding was also apparent in qualitative analysis of interpreting outputs showing that *n*-back group's interpretations were more structured and detailed with complex and elaborative sentences.

CHAPTER 5

DISCUSSION

The main of this thesis was to systematically investigate the transfer and maintenance effects of WM training on *n*-back task in consecutive interpreting students. Within this respect, near, moderate and far transfer effects of 7-week of intensive *n*-back WM training were evaluated in comparison to an active control group who were trained on simple letter span. Moreover, this thesis aimed at observing whether there could be any possible transfer to an applied domain of cognition; namely consecutive interpreting which is considered to a highly demanding task, and to what extent transfer effects of *n*-back WM training can be found in everyday skills, with a special focus on interpreting students. Performances on training and near, moderate and far transfer tasks as well as consecutive interpreting were evaluated before the training, right after the completion of the training, as well as after a 3-month interval. In addition to behavioural methods, this thesis incorporated an optical neuroimaging method (fNIRS), which enabled to gain a better insight into the neural mechanisms of WM training and consecutive interpreting. Behavioural and neuroimaging results were also supported with information on participants' motivation levels and their beliefs on intelligence and cognitive training.

5.1. Discussion of Questionnaires

It has been suggested in the literature that participants' motivation, openness to experience different things and personal beliefs about malleability of intelligence may have an impact on the amount of transfer because people who great motivation to complete the training or to improve their performance and cognitive capacity as well as people who believe that intelligence can be improved and enhanced seem to experience larger transfer gains after receiving training (Jaeggi, Buschkuehl, Shah, & Jonides, 2014d). Therefore, the scales of "need for cognition" and "Dweck's theories of cognitive abilities" were administered to participants in pre- and post-tests, and follow-up in order to see whether there was any individual differences between the groups in terms of their motivation and engagement. Both groups had high scores in Need for Cognition Scale at all testing times and they did not differ significantly from each other in terms of their scores. These scores indicate that participants in both groups enjoyed their trainings and the task, moreover, even after 3-month interval, when the scale was administered again in the follow-up, they were still highly motivated and showed favourable attitudes for engaging in such a cognitive study. Motivation of participants was not evaluated in each training session; therefore it is not possible to comment on their motivation levels throughout the 14 training sessions. However, the results of motivation levels in pre-test and post-test as well as follow-up may suggest that they were still motivated even a few months after the training. Moreover, there was not any drop-out from the study during training sessions and in the post-test, indicating that participants still enjoyed the study and were still interested in it.

Apart from motivation and engagement, it should be noted that even personal beliefs about cognition are major factors in participants' motivation to continue the training, thus may eventually impact the outcome of the training intervention (Katz, Jones, Shah, Buschkuehl, & Jaeggi, 2016). With this in mind, a second scale measuring participants' beliefs about intelligence and whether it is fixed or malleable was administered to participants together with Need for Cognition Scale. The scores of participants in Dweck's Theories of Cognitive Abilities Scale indicate that both groups had positive beliefs regarding intelligence and it seems that they believe that intelligence is not fixed and it can be changed. These results of scales are important in a way that they show that groups can be assumed equal in terms of their motivation and beliefs and the lack of any significant differences between the groups may suggest that performance outcomes and training gains were mainly the result of training intervention.

5.2. Discussion of Performance in the Trained Task

The adaptive nature of both training tasks; namely, *n*-back and simple letter span tasks enabled participants to challenge themselves in each session, thus, urging them increasing their performance gradually. The behavioural data showed that both *n*-back and control groups gained considerably from their training interventions and improved their performance in the course of 14 training sessions in seven weeks. However, both groups had participants with different performance in training sessions, while some participants were increasing their difficulty levels steadily, some participant kept a medium level performance without any big improvement changes. Both *n*-back and control group improved their performance gradually in their trained tasks.

In terms of cognitive performance in trained task, all *n*-back levels were evaluated separately in order to have a more detailed and elaborative perspective. Although *n*-back task included 1-, 2-, 3- and 4-back conditions, it would be useful to focus on improvements in 2-, 3- and 4-back tasks since nearly all participants performed tremendously well in 1-back task and had already excellent scores in the pre-test and there were not any group differences in 1-back condition, suggesting that there was not any place for further improvement. In terms of 2-back condition, both groups improved their performance similarly in the task without showing any significant difference, showing similar trend with 1-back condition. It should be noted that both groups had high mean correct responses in 2-back condition which is close to the highest number they can get. They even maintained their performance in the 3-

month follow-up without significant decrease in their responses. This high performance in 2-back condition was also reflected in response time showing an overall decreased pattern. As was expected, *n*-back group showed significant performance gains in 3-back and 4-back conditions as compared to control group, this finding clearly indicates although all participants found 3-back difficult initially in pre-test, the *n*-back group gained from their training more and participants in the *n*-back group became almost proficient in 3-back condition and even further showed successful performance in 4-back condition. The findings also revealed that *n*-back group maintained their higher performance in 3-back condition in the follow-up, as well. 4-back condition was evaluated only in post-test and follow-up and it was found that similar to 3-back condition, *n*-back group had larger training gains in 4-back compared to control group. These findings show that as the *n*-back condition increased, the performance gains of the *n*-back group became more apparent.

5.3. Discussion of Near and Moderate Transfer Effects of *n*-back WM Training

Near transfer effects of *n*-back WM training were measured with dual *n*-back and simple digit span tasks and moderate transfer effect was evaluated with reading span task. Findings of the thesis showed a task difficulty effect of dual *n*-back task, indicating task as the difficulty level of the task increases, performance on the task decreases from dual 1-back task to dual 3-back task which supports the previous results in the literature (Ayaz et al., 2012; Martin Buschkuehl et al., 2012; Jaeggi, Buschkuehl, Shah, & Jonides, 2014a). When we look at the near transfer effect of single *n*-back task to dual *n*-back task, dual 3-back and dual 4-back tasks seemed to be main determinant of near transfer effect, indicating performance gain differences between the groups. In the dual 2-back condition, although the *n*-back group seemed to have numerically higher performance than the control group at post-test, the interaction was not significant but *n*-back group maintained its higher performance at the follow-up as well. In dual 3-back condition *n*-back group had larger performance gains compared to control group from pre-test to post-test and maintained their high performance in the 3-month follow-up. In terms of dual 4-back condition which was measured in post-test and follow-up, *n*-back group had better performance than control group both in post-test and follow-up, more interestingly *n*-back group showed significant performance gain from post-test to follow-up, suggesting that near transfer effect was still strong and sustained and even increased in follow-up. Control group, on the other hand, had a decreasing pattern in their performance during dual 4-back task. The findings indicate that the increased improvement from pre-test to post-test in dual *n*-back task mainly stemmed from dual 3-back and 4-back conditions in favour of the *n*-back group, suggesting that the difficulty levels of these conditions were strong enough for revealing near-transfer effect. When the literature was reviewed in terms of transfer effects of WM training to other untrained WM tasks, there have been mixed results about modality specificity. Whether visuospatial WM training effects can transfer to untrained WM tasks in verbal domain and vice versa still remains controversial (Martin Buschkuehl et al., 2014; Jaeggi et al., 2014; Schneiders et al., 2011b). However, the finding of near transfer effect of verbal *n*-back task to dual *n*-back is in line with other studies reporting transfer effects of *n*-

back WM training to untrained WM tasks such as transfer of visuospatial *n*-back task to auditory *n*-back task (Pugin et al., 2014); transfer of dual *n*-back task to single *n*-back task or vice versa (Anguera et al., 2012; Jaeggi, Studer-Luethi, et al., 2010a; Li et al., 2008). This finding also supports previous conclusions that training on one type of *n*-back task has transfer effects to untrained versions of the *n*-back task regardless of the type of stimulus, suggesting that participants may have relied on similar processes in both tasks, and it was even proposed that single *n*-back training was as effective as dual *n*-back training (Blacker, Negoita, Ewen, & Courtney, 2017; Colom et al., 2013; Jaeggi, Studer-Luethi, et al., 2010a; Li et al., 2008). In their study on the role of individual differences in cognitive training and transfer, Jaeggi et al. (2014) showed that training on both dual *n*-back and single auditory *n*-back tasks exhibited near transfer effects to untrained tasks (Jaeggi et al., 2014). It should be also noted that near transfer effect was maintained 3 months after the completion of training session and even was improved in some conditions as a result of training on auditory verbal *n*-back task. Parallel to that finding, Pugin et al. (2014) suggested that long-term effects of auditory WM training can be due to more efficient use of WM not only in training sessions but also in daily life as a result of the training intervention, which also suggests the transfer to everyday skills and tasks. By including an active control group and having an adaptive training interventions for both groups, it is believed that potential impact of test-retest effect on observed larger performance gain in *n*-back group can be diminished, which was proposed in other studies stating that test-retest effects can be accounted for with adaptive WM training and proper control group (Brehmer, Westerberg, & Bäckman, 2012).

Concerning near transfer result in digit span task which is a simple STM task, both intervention groups had almost equally high performance in all levels of digit span task ranging from 6-digit span to 9-digit span at all testing times. The groups did not differentiate in their performance gains after the training, and their performance rates were almost the same; furthermore, even in pre-test before the training both groups performed considerably well in the task. This finding supports previous results of studies showing no effect to simple span tasks after *n*-back WM training, and these previous studies have shown that the correlation between simple span tasks especially digit span and *n*-back tasks is very low and weak, which suggests that digit span forward and *n*-back task tap on different processes (Kane, Conway, Miura, & Colflesh, 2007; Oberauer, 2005; Redick & Lindsey, 2013). While digit span is related to recalling of serial order; in other words free recall at the end of each list, without any binding or reordering function predominantly tapping WM storage, *n*-back task requires participants to change the serial position of items to be recalled and reorder and manipulate the current information based on temporal context, requiring quick recognition, suggesting that serial recall and recognition in principle do not correlate with each other (Pugin et al., 2014; Waris et al., 2017). It can be said that while *n*-back task mainly requires WM processing and cognitive control with higher demands on WM processing compared to complex and simple span tasks, simple digit span tasks, especially forward digit span tasks, mainly require WM storage, which was also supported by WM processing-load measured with EEG

(Scharinger, Soutschek, Schubert, & Gerjets, 2017). As explained by Conway et al.(2005), both domain-specific factors such as chunking and rehearsal, and domain-general factors such as cognitive control and executive attention are important for successful performance in WM task, however, STM tasks mainly rely on domain-specific storage (Conway, Kane, & Al, 2005)

With respect to reading span task in terms of moderate transfer, no transfer effects to another measure of WM capacity was found for *n*-back group although an overall improvement was observed in both groups. Moreover, both groups had almost equal scores in the 3-month follow-up, but the performance gains did not differ between the groups. The lack of any transfer effects to reading span task may seem unexpected however this finding is in accordance with various previous studies in which either single or dual *n*-back WM training was carried out, and no transfer effect was found for reading span task (Jaeggi, Studer-Luethi, et al., 2010a; Jaeggi et al., 2008; Kane et al., 2007). Both *n*-back and reading span tasks are considered to be WM tasks however, there is a weak correlation between complex span and *n*-back tasks and previous studies have shown that these two tasks do not share common variance although they both have strong power in predicting variance in matrix reasoning tasks (Jaeggi, Buschkuehl, et al., 2010a; Kane et al., 2007; Redick & Lindsey, 2013; Schmiedek, Lövdén, & Lindenberger, 2014a). While both complex span and *n*-back tasks seem to engage similar aspects of WM on surface, it has been proposed that these two tasks tap different processes of WM; while *n*-back tasks largely rely on discrimination processes based on familiarity and recognition, complex span tasks such as reading span or operation span tasks rely on serial recall processes (Jaeggi, Studer-Luethi, et al., 2010a; Oberauer, 2005; Redick & Lindsey, 2013a).

It should be acknowledged that there is small amount of shared variance between *n*-back and simple or complex span tasks; therefore, training on *n*-back task does not necessarily mean transfer effect to these types of WM tasks since the performance is not enhanced on such measures of WM after *n*-back WM training or vice versa (Redick & Lindsey, 2013). Based on latent factor analysis of *n*-back, simple and complex span tasks, Waris et al. (2017) have shown that although complex and simple span tasks predict Gf well because they represent the same construct of WM, *n*-back tasks load on a general WM factor rather than content-based WM division which reflects involvement of high level executive and attentional resources (Waris et al., 2017). It is important to note that WM is a multidimensional system which involves various processes such as encoding, maintenance, recall, recognition, familiarity, updating, temporal ordering, binding, attention and inhibition (Oberauer et al., 2007; Unsworth & Spillers, 2010). A significant difference between the processes involved in span tasks and *n*-back tasks is that in span tasks retrieval of items is based on recall however in *n*-back tasks retrieval is generally based on recognition since participants need to recognize the current item whether it was presented before in the required order (Redick & Lindsey, 2013). As the results of previous studies indicate, WM processes involved in simple and complex span tasks and *n*-back task are separate and distinctive which explains the lack of near transfer effect of *n*-back training on simple and complex WM tasks such as reading span or digit span (Jaeggi, Studer-Luethi, et al., 2010a; Jaeggi et al., 2008). This distinction between retrieval based on recall and recognition is also proved by fMRI studies, showing that medial temporal lobe is actively involved in complex span tasks but not typically activated in *n*-back tasks indicating that retrieval processes involved in search of correct items and recall of items differentiate the tasks (Chein, Moore, & Conway, 2011; Faraco et al., 2011). Hence, if two tasks tap considerably different and separate processes of WM system, then weak correlation is expected between the tasks and it may be less likely to observe any near transfer effect between the tasks.

5.4. Discussion of Far Transfer Effects of *n*-back WM Training

Fluid intelligence (*Gf*) can be considered a complex ability of individuals which enables them to adapt to new cognitive problems or situation. It is closely related to successful performance in professional and educational setting especially in which complex and demanding tasks are carried out (Deary, Strand, Smith, & Fernandes, 2007). This thesis aimed at investigating whether intensive *n*-back WM training transfer to fluid intelligence and reasoning skills measured with BOMAT. The results presented that while both groups had almost the same scores in the pre-test, *n*-back group significantly had larger performance gains from pre-test to post-test compared to control group, suggesting a far transfer effect of single *n*-back training to fluid intelligence. Moreover, this effect was maintained more than three months after the training. This finding seems to support the previous results of a number of studies on *n*-back WM training and the seminal study of Jaeggi et al. (2008), showing that WM training resulted in performance improvements on a measure of intelligence (*Gf*) generally on performance in RAVEN or BOMAT (Au et al., 2015; Jaeggi, Studer-Luethi, et al., 2010b, 2010a, Jaeggi et al., 2008, 2014; Jaušovec & Jaušovec, 2012; Rudebeck, Bor, Ormond, O'Reilly, & Lee, 2012). In their study on the relationship between *n*-back performance and matrix reasoning measured with both Raven Matrices and BOMAT, Jaeggi et al. (2010) reported far transfer to matrix reasoning was obtained by both dual *n*-back and single *n*-back training (Jaeggi, Studer-Luethi, et al., 2010a).

In a recent meta-analysis of 20 studies on *n*-back training investigation its relation to general intelligence, Au et al. (2015) showed small but significant positive effects of *n*-back training to fluid intelligence, concluding that short-term WM training may lead to beneficial effects on general intelligence. Far transfer effects of *n*-back task to intelligence relies on the assumption that there must be overlapping processes involved in both *n*-back task and intelligence, and share similar domains (Jaušovec & Pahor, 2017b). Binding processes and attentional control processes involved largely in both *n*-back tasks and reasoning tasks may explain this relation between WM training interventions and reasoning tasks (Jaeggi et al., 2008). It was also indicated that attentional control which is necessary for both tasks proves the strong relationship between WM and *Gf*; hence, Cowan et al. (2005) suggested that the scope of attention in WM which does not involve any processing component have high correlation with intelligence (Cowan et al., 2005). It was suggested that the adaptive nature of WM training minimizes the use of automatic processes and task-specific strategies, leading to engagement of executive processes more and making it possible for far transfer to matrix reasoning task (Jaeggi, Studer-Luethi, et al., 2010a). It should be also noted that far transfer from auditory-verbal single *n*-back task to visuo-spatial reasoning tasks (BOMAT) suggests that the observed effect is modality independent since the training tasks did not include any visuo-spatial stimuli and the underlying processes such as updating and manipulating may play fundamental role in both tasks (Jaeggi et al., 2014).

Engel de Abreu et al. (2011) also provides a similar explanation for the strong relationship between *n*-back and matrix reasoning, stating that both tasks require top-down cognitive control mechanisms and selective attention for better performance and indicate that stronger correlation between WM and fluid intelligence is observed when the demand for cognitive control is increased in a working memory task. Significant involvement of the scope and control of attention, updating and conflict monitoring and active maintenance in both tasks may provide evidence for such a strong correlation (Engel de Abreu, Conway, & Gathercole, 2011). Based on the multifaceted view of WM, Unsworth et al. (2014) suggest that capacity and attention control play significant role in understanding the relationship between WM and intelligence. In this view, capacity is believed to be the ability to maintain distinct abilities in a highly active state and attention control which is closely associated with capacity is the ability to select and actively maintain items when there is distraction. These factors mediate the relation between measures of WM capacity and processing such as span tasks and *n*-back tasks and intelligence, suggesting that multiple mechanisms are at play when it comes to the relation between WM and fluid intelligence taking into account that WM is a multifaceted system involving distinct and interacting processes (Unsworth, Fukuda, Awh, & Vogel, 2014). Far transfer effects might indicate that general strategies acquired during training can be transferred to different stimulus material resulting in enhanced WM efficiency (Layes, Lalonde, Bouakkaz, Rebai, 2018). In their study on latent factor analysis of WM measures four tasks; namely simple span, complex span, running memory and *n*-back, based on confirmatory and exploratory factor analysis, Waris et al. (2017) concluded that there might be a division for all tasks except *n*-back task according to content of the task (visuo-spatial, numerical-verbal). They have shown that *n*-back tasks are more related to general factor of WM reflecting high-level executive functioning and fluid intelligence, and suggested that this general factor is more involved in *n*-back task compared to all WM tasks (Waris, 2017).

Such findings of far transfer to different modalities might suggest different explanations for WM models. On one hand, it might suggest the enhancement of central executive which is involved in attention, cognitive control and strategy use as a modality or domain free subsystem in Baddeley's multicomponent model, it might suggest a unitary concept of WM as in Cowan's embedded model of WM indicating enhancement of capacity limitations of focus of attention. It should be noted that *n*-back tasks involves various operations such as active maintenance of items and their serial order in WM, repeatedly encoding current item and comparing it to *n*-trials back, constantly updating the list and rearranging the order irrespective of material type. Therefore, improvement in *n*-back performance suggests improvements in these operations, the control processes or efficient use of storage or attentional resources (Camos, 2017). Improvements in such operations which are involved in matrix reasoning tasks might be the driving force for observed far transfer effects. Taking into account unitary concept of WM representing a limited capacity system in which demands of processing and storage compete for a common limited pool of resources and resources are shared between processing and storage, *general capacity hypothesis* proposed by Engle, Cantor and Carullo (1992) reflects that WM performance is determined by efficiency of general processing capacity. If the processing system works efficiently, more resources are allocated for temporary storage, and effective use of strategies might lead to general processing efficiency (Dehn, 2008).

5.5. Discussion of Transfer Effect of *n*-back WM Training to Consecutive Interpreting

It is highly emphasized that WM training studies should include measures which are more close to real-life WM demands and everyday skills. Training-induced changes should also be investigated in such measures which are believed to tap similar processes and have shared overlaps (Soveri, Antfolk, Karlsson, Salo, & Laine, 2017). It has been stated that very few training studies have included measures which reflect real-world performances or can be “proxies” for everyday life (Jaeggi et al., 2017). It has been highlighted that implementation of measures with the perspective of real-world demands such as academic and education field can represent the complexity of everyday behaviour and potential benefits of cognitive training (Söderqvist & Nutley, 2017). Within this thesis, consecutive interpreting was regarded as a measure reflecting real-world performance demands of interpreting students. In consecutive interpreting, especially in the case of short consecutive interpreting in which note-taking is not required, the importance of memory operations for comprehending the speech in SL and for reformulating the speech in TL comes to the foreground. Therefore, one of the highlights of this thesis was to carry out the training with interpreting students and to investigate possible transfer effects of *n*-back training to increased content accuracy in short consecutive interpreting.

Participants interpreted five English speech in consecutive mode without note-taking in each testing phase and the content accuracy scores were evaluated based on idea-unit scoring protocol developed for this thesis. When interpreting scores of *n*-back group and control group were compared in the pre-test, there was not any significant difference between the groups and even their mean scores were almost identical. Considering overall improvement across time, both groups generally improved their scores and having numerically higher scores both in post-test and follow-up than the pre-test, which also suggests that overall performance was maintained in 3-month follow-up during which they did not receive any training. However, when the groups were compared in terms of performance gains from pre-test to post-test, the analyses revealed that *n*-back group improved significantly more than the control group, indicating that *n*-back WM training can yield transfer effects in other skills such as consecutive interpreting. This finding suggests that consecutive interpreting and n-back task might have overlapping processes, leading to transfer. It seems that the process of updating which is significantly tapped in both *n*-back task and consecutive interpreting might pave the way for observing such a transfer effect. There have been a few studies on language interpreting using different versions of *n*-back task (visuo-spatial or letter stimuli) which provided support for the relation between interpreting and updating. Timarova et al (2014) also presented a strong relation between better performance in letter 2-back task and interpretation of numbers by professional interpreters, suggesting that they both have close links. Furthermore, Morales et al. (2015) showed the role of updating in simultaneous interpreting and their results indicated that simultaneous interpreters had better updating ability than general bilinguals, suggesting that simultaneous interpreting employs the process of updating for a successful performance. Such studies have provided evidence for the argument that updating function of WM is closely linked to language interpreting.

In their longitudinal study on the relationship between consecutive interpreting and WM, Dong, Liu and Cai (2018) tested student interpreters on consecutive interpreting and non-verbal *n*-back task. They suggested that consecutive interpreting involves updating more than it involves verbal WM spans. They have proposed that updating and recalling during consecutive interpreting might share similar attentional control process. Updating the information and showing attentional control repeatedly seem to be involved greatly both in *n*-back task and consecutive interpreting. They concluded that updating which was measured by even a non-verbal *n*-back task was fundamental for consecutive interpreting even more than WM span which was measured by listening span. These findings might suggest dissociation between storing and updating skills in consecutive interpreting and indicate that executive control components might be more related to consecutive interpreting. The underlying and shared mechanism of updating in *n*-back task and consecutive interpreting involving similar attentional control process seem to be main source of link and even transfer of skills between the two tasks. In their study on the effect of WM training on mathematical performance of children with dyscalculia, Layes et al. (2018) suggested that a common, domain-general WM capacity enhanced by WM training might drive the transfer to unrelated tasks such as nonverbal reasoning and mathematical problem solving. Changes observed in performance as a result of WM training might indicate expanded capacity and also efficient WM. Such far transfer might suggest systematic changes in strategy use which might be related to other various cognitive domains associated with WM.

In her MA thesis, Sakallı (2016) carried out dual *n*-back training with interpreting students and tested the effect of training on simultaneous interpreting scores through single group pre-test versus post-test design. The findings of the thesis revealed that there was strong correlation between dual *n*-back training and simultaneous interpreting indicating enhanced WM capacity and interpreting performance. After an intensive WM training with dual *n*-back task, student interpreters showed better performance in different features of simultaneous interpreting. Positive correlations were found between dual *n*-back scores and simultaneous interpreting scores on sequential events, lexical items and figures which were specifically tested with different segments of the source speech. Moreover, the relation between dual *n*-back WM training and interpretation of subordinates was found to be stronger than the relation between dual *n*-back and interpretation of single words, indicating that improvements in WM capacity result in better performance on recalling and processing various kinds of linguistics components in subordinates.

Transfer effects of WM training was also presented in other professional disciplines and similar results showing transferable effects to different domains of cognition such as reading or mathematical skills can be found in the literature. In their study on effect of short-term WM training on risk taking in adolescents, Rosenbaum et al. (2017) showed the potential transfer effect of WM training on everyday behaviour. In the study, near transfer to STM tasks was observed although transfer was not found to cognitive control tasks such as Stroop and Go/No go tasks (Rosenbaum, Botdorf, Patrianakos, Steinberg, & Chein, 2017). In their study on the effect of WM training on WM, arithmetic and following instructions, Bergman-Nutley and Klingberg (2014) showed the potential of WM in the field of education. They reported both training-induced improvements in non-trained WM tasks and transfer to arithmetic skills (Bergman-Nutley & Klingberg, 2014).

In terms of interpreter training and improved and enhanced skills in professional life, such a transfer of intensive *n*-back WM training also suggests the potential of cognitive training in interpreter training and professional development, and shows the need for further studies investigating the role of cognitive training in professional life, which was also suggested by Blacker et al. (2018) in their review on cognitive training in military applications (Blacker et al., 2018). It would be beneficial to integrate the results of such studies on the effects of WM training in language interpreting either in simultaneous or consecutive mode into training programs of interpreters, thus offering different perspective for both student interpreters and professionals. Such an effective WM training on *n*-back task involving various operations but most importantly updating can boost the performance of especially student interpreters.

5.6. Discussion of Oxygenation Changes in *n*-back Task

In this thesis, participants performed auditory *n*-back task with alphabet letters at each testing phase and in the pre-test before participants began their training interventions, reliable change in mean oxygenation level was found as a function of *n*-back condition at optodes 1, 2, 3 and 4 corresponding to left dlPFC (BA9/46), optode 9 located in right frontopolar cortex and optodes 13 and 15 corresponding to right dlPFC. Optodes 1 and 3 are closely related to Broca's area (BA44) and optodes 13 and 15 can be considered its right homologue region of Broca's area, optodes 2 and 4 are mainly located in region within left inferior frontal gyrus.

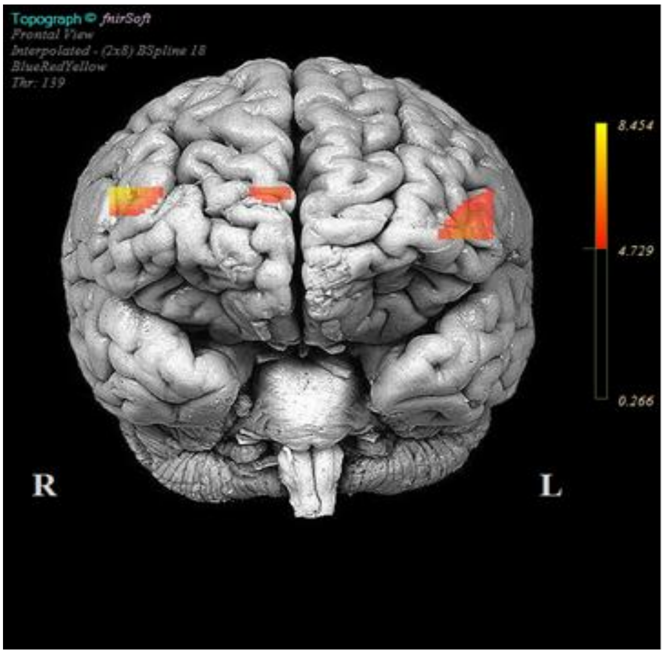

Figure 75: Topograph maps for oxygenation during n-back task in pre-test

As can be seen in Figure 76, during *n*-back task in pre-test, significant oxygenation increases were observed both in right and left dlPFC as the *n*-back condition and load on memory increased. The data revealed that oxygenation levels changed as the memory load increased with respect to *n*-back condition, it was found that 3-back condition induced higher levels of oxygenation than 2-back condition in these regions as well as mean oxygenation level in 1-back condition was always lower than 2-back and 3-back conditions, showing the presence of task difficulty especially in bilateral dlPFC in pre-test. The association between increasing task difficulty and the increase in activation level with respect to *n*-back condition was implicated in previous studies of *n*-back task with Positron Emission Tomography (PET) (Reuter-Lorenz et al., 2000; Smith et al., 1996), fMRI (Cohen et al., 1997; Owen et al., 2005). More importantly, these results are consistent with earlier studies measuring neural activity by means of fNIRS showing increased activation in PFC with respect to increased difficulty *n*-back task especially in regions located in dlPFC (Ayaz et al., 2010; Ayaz, Shewokis, Bunce, Schultheis, & Onaral, 2009; Herff et al., 2014).

In their study investigation mental workload during visual *n*-back task, Herff et al. (2013) showed that different activation patterns were observed when 1-back, 2-back and 3-back conditions were compared, 3-back condition inducing more workload measured via fNIRS. In a study on verbal *n*-back task including alphabet letters with auditory or visual stimuli, larger bilateral activation of dlPFC was found in auditory *n*-back task, suggesting that auditory version of *n*-back elicits more functions of central executive than the visual version. Furthermore left dlPFC and superior temporal gyrus indicated greater activation in auditory *n*-back task compared to visual n-back task based on fMRI results (Rodriguez-Jimenez et al., 2009). In a similar study which investigates modality effects in *n*-back working memory task comparing auditory and visual stimuli with respect to prefrontal and parietal activation with fMRI, it was reported that there was greater activation in left dlPFC during auditory *n*-back task (Crottaz-Herbette, Anagnoson, & Menon, 2004). Furthermore, in a study of neuropsychological assessment of WM in classic and modified *n*-back task using fNIRS, Dominguez et al. showed that left dlPFC regions were mainly activated during *n*-back task as the task difficulty increased (León-Domínguez, Martín-Rodríguez, & León-Carrión, 2015).

Studies which used fNIRS for measurement of cerebral blood flow during WM dependent tasks such as *n*-back and Luria’s Memory Word-Task suggest that learning of auditory and verbal information is dependent on WM capacity for both holding information temporarily and manipulating the information. The increased load on WM in manipulation of verbal information is closely associated with increased cerebral activity in related regions which are mostly located in left hemisphere (Leon-Carrion & Leon-Dominguez, 2012). Similar to the findings of this thesis revealing increased neural activity observed in task-relevant regions of PFC such as Broca’s area and dlPFC based on fNIRS analysis, studies on *n*-back task using fMRI have commonly shown activation patterns in Broca’s area (BA44), posterior parietal area (BA40) and dlPFC (BA9/46), which indicates the use of executive control processes as well as information maintenance in *n*-back task. It was suggested that BA44 indicates articulatory rehearsal; BA40 indicates short-term storage; BA9/46 indicates excitatory or inhibitory activation (Juvina & Taatgen, 2007). Moreover, in a study on WM using spatial *n*-back task, findings based on event related fMRI results have indicated the significant role of dlPFC in attentional selection, including selection and attention within working memory (Rowe & Passingham, 2001)**.**

Furthermore, the meta-analysis of neuroimaging studies on *n*-back task carried out by Owen at al. (2005) has shown that while *n*-back generally taps six cortical regions, namely lateral premotor cortex, dorsal cingulate and medial premotor cortex, dorsolateral and ventrolateral PFC, frontal pole and bilateral and medial posterior parietal cortex, which also supports the main findings of this thesis. Significant activation in dlPFC in *n*-back task provides evidence for subtasks such as processing incoming information; maintaining relevant information; avoiding irrelevant information which are crucial for task performance because dlPFC is associated with cognitive processes such as actively maintaining information in WM, changing behaviour according to the task demands, and representing current goals (Siddiqui, Chatterjee, Kumar, Siddiqui, & Goyal, 2008).

5.7. Discussion of Neural Mechanisms of Transfer Effects of *n*-back WM Training

One of the main aims of the thesis was to investigate neural mechanisms of *n*-back WM training and an optical brain imaging method, fNIRS was used for that purpose, and data were collected from the participants before the training, right at the end of the training and three months after the training. fNIRS analysis demonstrated that 7-week of *n*-back training showed a decreased pattern of oxygenation for *n*-back group compared to control group from pre-test to post-test at optode 1 which corresponds to dlPFC of left hemisphere. This decreased pattern of activation may indicate that some processes become more automated causing less brain activation due to training which is explained by neural efficiency. The increased neural efficiency as a result of training may indicate enhanced interactions between related brain regions and faster neural processing during the task (Jonides, 2004). In terms of neural mechanisms of WM training, frontal brain areas related to attentional control (prefrontal cortex) become less involved in task performance, activation in areas supporting task specific functions increases (Martin Buschkuehl et al., 2012). This finding shows that prolonged and intensive training results in more automatic and less effortful processing during a task which initially requires more effort and attention, adaptive training may result in a change in processing from effortful to automatic. This may show that task-relevant brain regions and networks become more efficient as a consequence of cognitive training and thus decreasing the activation in relevant regions (Martin Buschkuehl et al., 2014; Rypma et al., 2006). This result of increased neural efficiency in *n*-back training is consistent with previous studies on *n*-back WM training reporting a decreased activation after training (Buschkuehl et al., 2014; Hempel et al., 2004; J. Schneiders et al., 2012; Schneiders, Opitz, Krick, & Mecklinger, 2011; Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013).

In a visual and auditory *n*-back training study, activation decreases were observed in both modalities after two weeks of training in BA6 and BA 40 areas within middle frontal gyrus and posterior parietal regions (Schneiders, Opitz, Krick, & Mecklinger, 2011). In their fMRI study in which they used adaptive *n*-back training, Schneiders et al. (2012) showed that cognitive training can result in improvements only in the tasks which share similar or overlapping brain regions. They found decreases in activation after auditory WM training using *n*-back task in the right inferior frontal gyrus related to maintaining auditory information as well as decreased activation in right inferior parietal lobule and right middle frontal gyrus indicating general attentional control processes. Moreover, Schweizer et al. (2013) also reported decreased activation in left dlPFC together with right superior frontal gyrus, left and right supramarginal gyrus and left and right temporal gyrus, left and right middle occipital lobe. In another *n*-back training study conducted by Hempel et al. (2004) in which activation patterns were measured before training, within training period (in two weeks of training) and at the end of the training, inverted U-shaped activation pattern was found suggesting an increase in activation during in the first part of training and then activation decrease at the end of the training (Hempel et al., 2004). According to a review of 10 neuroimaging studies of WM training, while increases in brain activity in prefrontal and parietal areas have been reported in terms of fMRI results, in verbal WM tasks, decreased brain activity was found in dlPFC in addition to fronto polar region (Klingberg, 2010). However, it should be stated that the previous studies investigating neural correlates of *n*-back training measured activation patterns only before and after the training; in the case of Hempel et al. (2004), they also measured the activation at an intermediate point of the training, but none of them used pre-, post-test and follow-up design. One of the profound finding of this thesis was related to oxygenation changes in 3-month follow-up and analysing the changes from post-test to follow-up. The results indicated that at optode 2 corresponding to dlPFC of left hemisphere located within left inferior frontal gyrus, mean oxygenation levels increased from post-test to follow-up during *n*-back task in *n*-back group. This may suggest that the increased neural efficiency achieved right after the training may not be maintained for a long period of time. This may indicate that neural efficiency is more obtainable right after the training and increased neural efficiency does not seem last long, suggesting that occasional or booster training sessions may be necessary for consolidating the effect of training in order to sustain long-term neural efficiency, which was also suggested by other researchers (Ball et al., 2002; Jaeggi et al., 2014).

WM training generally affects neural activity in functional fronto-parietal control network including executive control network and dorsal attention network. “Executive control network” involves mainly dorsolateral and dorsomedial frontal nodes and “dorsal attention network” is comprised of the intraparietal sulcus and the frontal eye fields (Thompson, Waskom, & Gabrieli, 2016). Training-related activation observed especially in dlPFC may suggest that training may lead to less demand on selective attention and executive control processes tapped during *n*-back task in terms of executive control network. Observed changes on oxygenation levels may suggest training-induced plasticity underlying WM processes. It is significant to note that different brain structures function when learning takes place regardless of content or mode of information. In this process, dlPFC plays an important role in temporal integration of information which is considered to be related to WM. Therefore, capacity for learning and remembering indicates the plasticity of brain and changes in neural system as a result of experience (Leon-Carrion & Leon-Dominguez, 2012). This was also supported by the results of this thesis that activation patterns during *n*-back task after WM training were observed in dlPFC closely related to BA 9/46 which has been identified as a vital region for WM function (Rypma & D’Esposito, 1999). It has been also proposed that lateral PFC is organized by both content (right/left) and process (dorsal/ventral), indicating that both maintenance and manipulation of information which are two different cognitive operations, may tap dlPFC although apparently not to the same extend (D’Esposito & Postle, 2002).

dlPFC which is closely related to WM functions receives sensory, motor, motivational and emotional information from other cortical and subcortical areas. Therefore, it is believed that dlPFC can operate in visuospatial and linguistic information processing as well as any multimodal information processing. The role of dlPFC in information maintenance and processing in WM seems to be more crucial for especially performing the current task (Funahashi, 2017). Various neurophysiological studies have established the relationship between WM and dlPFC and how active maintenance of information in WM is achieved in dlPFC. dlPFC is considered to be critical in utilizing WM to maintain information for a short period of time (Funahashi, 2006; Goldman-Rakic & Leung, 2002). It has been shown that maintenance-related processes regardless of stimulus type are distributed across both hemispheres of PFC. However, it seems that maintenance of verbal information is strongly linked to left posteroinferior PFC, maintenance of spatial and non-spatial information has weak lateralization. If manipulation of this stored information is required while performing a task, dlPFC is significantly involved to a greater extend (D’Esposito & Postle, 2002).

When oxygenation changes from pre-test to post-test were analysed in terms of *n*-back condition, the analyses revealed that as the difficulty level of the task increased, oxygenation level increased mainly in the right hemisphere at optodes 13, 14, 15 and 16 corresponding to dlPFC region. This difference in oxygenation from pre-test to post-test with respect to *n*-back condition was mainly driven from 3-back condition. In terms of oxygenation changes from post-test to follow-up including 2-back, 3-back and 4-back conditions, 3-back and 4-back condition seemed to elicit higher levels of oxygenation than 2-back condition at optodes corresponding to left dlPFC regions as well as optodes corresponding to right frontopolar, right dmPFC and right dlPFC regions. In terms of oxygenation changes from pre-test to post-test, oxygenation levels elicited by 3-back condition differed between the groups, control group showing higher levels of oxygenation than *n*-back group at optode 13 corresponding to right dlPFC. This result may indicate that participants in control group spent more mental effort to complete the task and perform well as revealed by increased oxygenation levels, which is also evidenced with longer response times and lower accuracy and performance in the task. A similar results was reported in a study investigating task performance in visual *n*-back task with letter stimuli with respect to activation in prefrontal cortex measured with fNIRS. It was shown that there was a significant difference between high performance and normal groups in terms of mental effort during the task and accuracy in the task (Hani, Feng, & Tang, 2016).

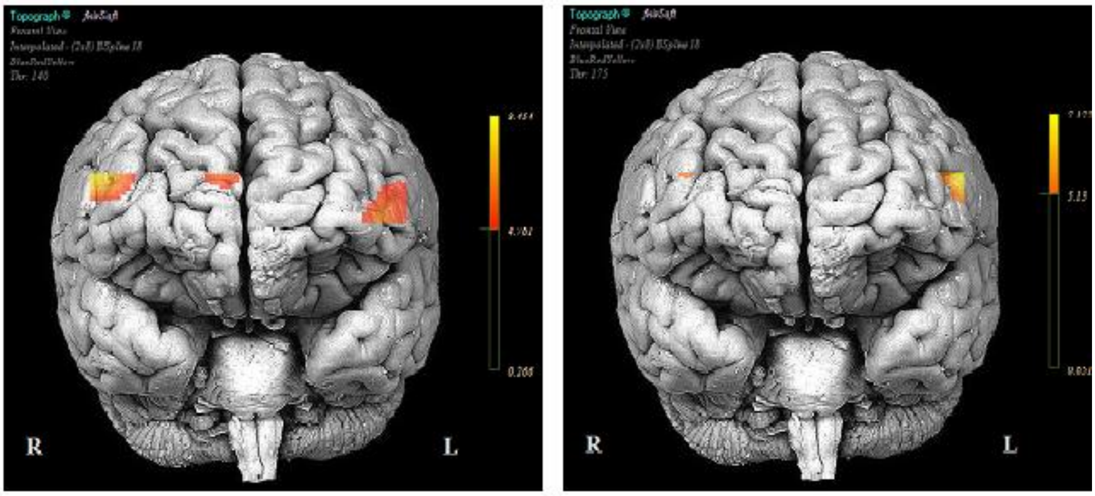

Figure 76: Topograph maps for oxygenation during n-back task in post-test (left) and follow-up (right)

In terms of changes from post-test to follow-up, while 3-back condition elicited higher level of oxygenation in control group, in 4-back condition oxygenation level of control group was significantly lower than *n*-back group at optode 2 corresponding to left dlPFC. This lower oxygenation level of control group is also supported by the behavioural data showing that participants in control group had very low scores in 4-back condition and seemed to disengage from the task while *n*-back group still performed numerically better. It seems that while task-relevant regions in both hemispheres were activated during *n*-back task in the pre-test, after training a shift towards right hemisphere was observed, which may suggest that attentional networks were more recruited or tapped during the task with respect to task difficulty. A similar result of right hemisphere activation during *n*-back task with letter stimuli was also shown by Smith et al. (1996) suggesting the functional recruitment of contralateral mechanisms of response inhibition and cognitive control while performing under highly demanding conditions (Braver et al., 1997). Considering the difference in oxygenation levels with respect to *n*-back conditions between the groups in task-relevant regions, the findings may suggest that intensive *n*-back WM training may enable the participants to improve their skills in executive control processing for updating and inhibiting operations which are crucial for task performance especially in 3-back and 4-back conditions, which was also shown in a study investigation neural mechanisms of transfer effects of *n*-back WM training with older adults by measuring blood-oxygenation-level-dependent (BOLD) signal changes (Heinzel et al., 2016). Taken together all neural activation patterns revealed by the findings, it is possible to suggest that as a result of intensive training and practice, increased efficiency in neural processes can be observed both in fMRI and fNIRS studies. The findings may provide evidence for neural plasticity and demonstrate the strong relation between WM processes and *n*-back task as a result of observed activation patterns in PFC especially dlPFC.

5.8. Discussion of Oxygenation Changes in Consecutive Interpreting

Consecutive interpreting without note-taking consists of two phases; namely comprehension and analysis phase and reformulation phase. The fNIRS results revealed that comprehension and reformulation phases of consecutive interpreting showed different oxygenation patterns, showing that comprehension phase induced higher level of oxygenation as compared to reformulation phase at optode 5 which corresponds to left dmPFC and optode 7 which is located in left fronto-polar region, which is close to Brodmann Area (BA) 10. The frontal polar PFC, BA 10, is a region positioned above Orbito Frontal Cortex (OFC) and serves as a junction between the OFC and dlPFC. These areas are closely linked to WM processes and executive control (León-Domínguez et al., 2015). BA 10 is also assumed to have a significant role in multitasking especially in selecting and maintaining higher order goals (Roca et al., 2011), which seem to be involved in consecutive interpreting. Using fNIRS, Kovelman et al. (2008) found that bilinguals activated the dlPFC and the inferior frontal cortex in a semantic judgment task more strongly than did monolinguals, even though both groups had equally good performance in the task (Wong, Yin, & O'Brien, 2016). Furthermore, in their study on cerebral activation during simultaneous interpreting, Rinne et al. (2000) reported predominant activation in left hemisphere especially in left frontal lobe, BA 6 and 46 during simultaneous interpreting, which indicates processes related to lexical search, semantic processing, verbal encoding and verbal WM. Increased activation in left PFC especially in dlPFC has been associated with retrieval, maintenance or control of semantic information (Rinne et al., 2000). In a recent review of anatomic distribution of language network and functions of these networks in language processing, it has been presented that dmPFC which is associated with BA8/9 is located medial and dorsal to dlPFC and is generally considered to be involved in semantic processing and also it is highly activated in phonological tasks, goal-directed processes and attention. On the other hand, dlPFC which is largely related to verbal WM in semantic processing has cortical and subcortical connections which are crucial for information integration (Middlebrooks, Yagmurlu, Szaflarski, Rahman, & Bozkurt, 2017). It has been shown in various studies that medial PFC plays important role in recent and remote memory. It has also been revealed that medial PFC is involved in WM especially when a delayed response is required due to its relation to short-term maintenance of information in memory for action and errors. It has been suggested that medial PFC is largely involved in maintaining responses over short periods of time, indicating a top-down control over motor cortex (Euston, Gruber, & Mcnaughton, 2013).

Higher oxygenation level during comprehension phase is also in line with the Gile's Effort Model indicating that comprehension phase has higher risk of capacity overload and reformulation phase seems relatively easier compared to comprehension phase since the message has already been processed. As argued by Gile in his effort model, efficient use of WM and processes employed during comprehension lead to better and quality interpreting performances (Gile, 1995). It has been argued that successful performance in consecutive interpreting mainly relies on performance in listening and analysis phase because well comprehension of the speech and efficient use of memory during this phase may provide more support for delivery of the speech in TL (Setton & Dawrant, 2016). Efficient use of WM is vital for especially comprehension processes in interpreting, it has been postulated that while at least 80% cognitive resources are allocated to listening and comprehension of the speech, only 20% cognitive resources are devoted to speech production. WM is a fundamental component of comprehension in interpreting in which semantic and syntactic relations are computed for a proper representation of discourse, and integration of new information with the previously processed one is carried out. Therefore, successful and better performance in comprehension relies heavily on efficient use of WM resources, which allows quicker access to lexical and semantic information in LTM as well as easier temporary storage and integration of information. (Bajo, Padilla, & Padilla, 2000).

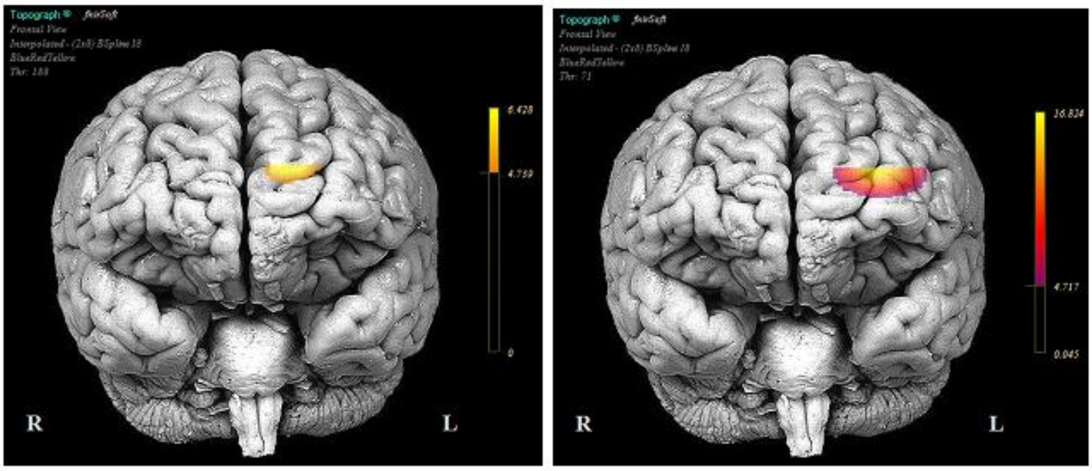

Figure 77: Topograph maps for oxygenation during consecutive interpreting in pre-test (left) and post-test (right)

Moreover, when we look at the oxygenation changes from pre-test to post-test, we observe that the change in oxygenation is closely related to engagement and motivation levels of individuals in the groups. Compared to increased oxygenation level during consecutive interpreting from pre-test to post-test in *n*-back group, the decreased oxygenation during consecutive interpreting from pre-test to post-test in control group at optode 3 corresponding to dlPFC (BA 44, close to Broca’s region) and optode 5 located in dmPFC may indicate that control group engaged less in the post-test which is also supported their lower performance rate (42%). In terms of changes in functional activations in a task-relevant region, increased neural activity may indicate either practice-related expansions in cortical representations or increased strength of activations. It also refers to recruitment of additional cortical units as a result of practice (Kelly & Garavan, 2005). Therefore, increased oxygenation in *n*-back group may suggest redistribution of cognitive resources during the task as well as involvement of more attentional and control areas considering the functions associated with dmPFC. Interestingly, the findings also revealed that oxygenation levels during consecutive interpreting phases differed between the groups considering overall changes from pre-test to post-test at optode 4 in dlPFC region closely related to left inferior frontal gyrus. It seems that as *n*-back group began to use WM resources efficiently in comprehension phase, they may rearrange their cognitive resources allocating more to reformulation phase. This may suggest that chunking and attending in comprehension phase may take less effort for them so that they can focus more on reformulation phase and its components suggesting that cognitive workload may have increased in reformulation phase. This is also consistent with previous explanations in consecutive interpreting literature indicating that if interpreters have ease in comprehension phase, they can focus on reformulation more and take into account features of production such as prosody, sentence structure, pronunciation, etc. more (Setton & Dawrant, 2016). This may also show that after *n*-back WM training, these student interpreters become more efficient at retrieving lexical and semantic information and lexical processing during comprehension phase (Padilla & Bajo, 2015). Considering significant difference between comprehension and reformulation in control group, it also seems that control group still relies heavily on comprehension and have high cognitive workload in this phase, and decreased oxygenation level in reformulation suggests that they tend to reformulate overall message without much details and specifications, which was also observed in behavioural data.

In terms of oxygenation changes from post-test to follow-up, due to decline in participants’ data and data point loss as a result of prior check of signals, it is not likely to come to conclusions regarding the changes. Taking into account that the same five speeches were used both in post-test and follow-up, in overall reformulation phase elicited more oxygenation than comprehension phase at optodes 8 corresponding to left frontopolar region and 16 of dlPFC in right hemisphere, suggesting that there may be a re-test effect which may have eased the comprehension phase so that participants allocated more resources to reformulation. Furthermore, at optode 15 corresponding to right dlPFC, oxygenation levels during comprehension and reformulation differed between the groups. Similar to oxygenation changes observed from pre-test to post-test, while reformulation induced higher oxygenation in *n*-back group, control group still had higher levels of oxygenation in comprehension phase.

As can be seen from these findings, consecutive interpreting activates specific regions of PFC (dlPFC, dmPFC, fronto polar cortex) which have been shown to be functionally related language processing and switching as well as cognitive control, attention and multitasking. Specific areas of PFC such as left middle and inferior frontal gyrus have fundamental functions for bilinguals and are considered to be involved in language control network and interference control in the case of irrelevant information (Abutalebi & Green, 2016). More importantly, Rinne et al. (2000) have shown that left dlPFC has a crucial role in simultaneous interpreting, which is in line with the findings of this thesis showing great oxygenation changes mainly in left dlPFC (Rinne et al., 2000). A longitudinal study on interpreting students revealed increases in gray matter volume in those students compared to a not multilingual control group in left lateral PFC structures (Hervais-Adelman, Moser-Mercer, & Golestani, 2011). In a recent study which compared simultaneous interpreters and professional multilingual controls, Becker et al. (2016) showed more gray matter volume in simultaneous interpreters especially in left fronto pole (BA 10) and left inferior frontal gyrus and middle temporal gyrus (Becker, Schubert, Strobach, Gallinat, & Kühn, 2016). These findings also support the observed activation patterns in dlPFC, dmPFC and fronto polar region of left hemisphere during consecutive interpreting with student interpreters. It has been shown in a meta-analysis that fronto polar cortex (BA 10) is generally associated with multitasking and damage to this region leads to decreased performance in dual-tasking and managing multiple goals (Dreher, Koechlin, Tierney, & Grafman, 2008; Gilbert et al., 2006). Furthermore, in WM tasks, this region is specifically tapped for monitoring and integrating subgoals (Braver & Bongiolatti, 2002).

Activations in left dlPFC close to Broca's area are generally observed in verbal encoding and WM tasks, this region is specially associated with language processing features such as lexical search and semantic processing and retrieval, maintenance and control of semantic information in verbal tasks (Buckner, Kelley, & Petersen, 1999; Shallice et al., 1994). In terms of language processing in, left dlPFC is strongly related to cognitive control and WM operations required in language comprehension and production (Klaus & Schutter, 2018). The findings of this thesis showing higher oxygenation in dlPFC during consecutive interpreting are consistent with studies on simultaneous interpreting, which reinforces the pivotal role employed by dlPFC during interpreting (Hervais-Adelman, Moser-Mercer, Michel, & Golestani, 2015; Rinne et al., 2000). It should be also noted that activation in dlPFC is strongly associated with efficient response selection and suppression of interfering information especially in bilingual language control (Abutalebi & Green, 2016). Medial PFC, on the other hand, has been shown to play a significant role in decision making and information retrieval from LTM as well as metacognitive processes (Schnyer, Nicholls & Verfaellie, 2005). Mid-dorsolateral PFC (areas 9 and 46) which is close to anterior middle frontal gyrus has been shown to be involved in monitoring and manipulation of information held in WM with animal and human studies. It has been shown that lesions to this area have adverse effect on response selection if manipulation and maintenance of information in the task rely on temporal order or ordering processes (Moscovitch & Winocur, 2002).

Studies have shown that complex control processes activate more anterior regions within dmPFC suggesting that decision-related control processes are largely associated dmPFC (Purves, et al., 2013). Moreover, it has been proposed that area 46 within dmPFC is specifically activated in WM tasks requiring "attentional selection" between items in memory in other words response selection and response inhibition (Passinghham & Rowe, 2002). Considering overall neural basis of language comprehension, different brain areas are activated for semantic and syntactic information processing. While syntactic processing generally involves anterior superior temporal frontal gyrus and posterior portion of Broca’s area (area 44), semantic processing mainly involves middle temporal gyrus, anterior temporal lobe and anterior portion of Broca’s area (BA 45) (Friederici, 2017). This shows the predominant involvement of dlPFC in language processing and may provide evidence for language processing during consecutive interpreting as a highly demanding language comprehension and production task which requires efficient language switching and language control for better performance.

CHAPTER 6

CONCLUSION

The main role of cognitive science is to understand cognitive processes and provide an elaborated view of processing restrictions and their impacts on limitations in performances. Therefore, capacity limitation of WM is one of the most studied topics in the field because performance on various cognitive tasks is directly correlated with WM (Luck & Vogel, 1998). Cognitive science endeavours providing a common account of cognition integrating all different disciplines with different levels of explanation using a variety of tools and techniques (Bermúdez, 2014). As a "mental engine" which is required in complex and demanding cognitive activities involving controlled and effortful processing, WM has significant implications in general cognition such as fluid intelligence and reasoning, multitasking, language comprehension and production, etc. as well as social cognition such as metalizing, stereotyping, self-regulation, etc. (Gruszka & Nęcka, 2017). Therefore, there is no doubt that WM as well as limitations in WM capacity have fundamental consequences in everyday cognition and skills, and affect individual's day-to-day practices and actions. The design of this thesis allowed to conduct an interdisciplinary study bringing together different explanations and approaches mainly from the fields of psychology, linguistics and interpreting and neuroscience. In this thesis, different levels of cognitive domains, explanations and organization have been integrated in order to present an elaborated framework of transfer of cognitive skills especially in an applied domain of cognition; namely, interpreting based on behavioural with fNIRS data.

The main aim of the thesis was to investigate transfer effects of *n*-back WM training at various levels and possible transfer effect to consecutive interpreting which is a highly demanding and WM-dependent cognitive task based on the assumptions that WM is crucial for cognitive processing and limitations in WM capacity can affect performance in cognitive tasks. With behavioural and optical brain imaging methods, this thesis incorporated a longitudinal study approach in order to carry out a systematical analysis of short- and long-term effects of WM training. As for main research questions and investigation areas, the thesis aimed at providing explanations for following points:

6.1. Transfer Effects of *n*-back WM Training

The main aim of this thesis was to investigate transfer effects of *n*-back WM training and to reveal the relationship between WM training and untrained tasks which have been assumed to depend on similar WM processes. Therefore, transfer effects were investigated in four dimensions:

(1) near transfer to dual *n*-back and digit span tasks
(2) moderate transfer to reading span task
(3) far transfer to matrix reasoning task (BOMAT)
(4) transfer effect to real-life/everyday skills with respect to consecutive interpreting

The results of the thesis have shown that *n*-back WM training might lead to improved WM especially improved processing capacity of WM which has been proven with changes in both WM measures and matrix reasoning and consecutive interpreting. Positive findings of near and far transfer as well as transfer to consecutive interpreting suggest generalized domain-general cognitive improvement following an intensive 14-week WM training. These improvements can be fundamental for interpreting students in their training. Considering that WM capacity has a capacity of information storing and capacity of information processing as stated by Juffs and Harrington (2011), observed near and far transfer effects of *n*-back WM training might suggest that *n*-back training can improve especially processing capacity of WM which is crucial for complex tasks requiring both storage and processing components of WM. If storing capacity would be enough to observe transfer effects, control group who were trained on simple letter span would also show similar improvements in near and far transfer tasks. This suggests that *n*-back WM training share overlapping and similar processes with other untrained tasks which was also supported by fNIRS results indicating oxygenation changes in especially lateral areas of PFC which have been associated with processing and attentional operations in WM. Near transfer to dual *n*-back task and far transfer to BOMAT indicate that manipulation of information and efficient allocation of attention can drive the observed transfer effects, leading to capacity improvement in WM.

The findings of this thesis seem to be beneficial to find a way for an effective use of WM training in interpreter training programs by combining formal training programs and cognitive training interventions because it seems that with *n*-back WM training, central structure of WM are targeted. In addition, if enough time is dedicated to such a training, it might be possible even to observe that WM training has a potential to induce plastic effects in specific brain regions which are associated with WM processing. These findings show that such a special group of individuals can benefit from cognitive training throughout their training and active work life and effects of training can be found far outside of the training context and benefit real-world cognition and skills employed in real-life settings. It has been even shown that transfer effects of cognitive training are crucial for some professions such as baseball players and it can enhance their performance in their baseball field (Deveau, Ozer, et al., 2014). Furthermore, it has been concluded in a study on the relationship between WM capacity and interpreting that interpreter training should also include components related to the efficient use of WM through training which might have useful reflections on eventual interpreting performance (Bajo, Padilla & Padilla, 2000).

6.2. Maintenance of Transfer Effects of *n*-back WM Training

In terms of investigation of maintenance effects, the results showed that post-training and 3-month follow-up performances did not change significantly in near and far transfer tasks as well as consecutive interpreting scores. This suggests that performance level that was reached following an intensive training was maintained across time. Furthermore, the lack of significant group and time interaction between post-test and follow-up indicate that the difference between the groups was also maintained. Larger performance gains in *n*-back group from pre-test to post-test as well as from pre-test to follow-up in dual *n*-back, BOMAT and consecutive interpreting tasks might suggest that near and far transfer effects can be maintained over time. Few studies on WM training have reported long term effects of training but Dahlin et al. found improvements even 18 months after the training and Schmiedek et al. presented that intensive cognitive training intervention can yield long-term effects on cognitive functions of younger adults even over 2 years (Dahlin, Nyberg, et al., 2008; Li et al., 2008; Schmiedek, Lövdén, & Lindenberger, 2014b). Therefore, it seems that observed long-term effects of *n*-back WM training on cognitive skills of interpreting students support earlier findings of maintenance of effects in various groups. It should also be stated that it might be possible to enhance the long-term maintenance of transfer effects through occasional practice or booster sessions after the end of training sessions (Jaeggi et al., 2011).

6.3. Neural Mechanisms of Transfer of *n*-back WM Training

The fNIR results revealed decreased neural activation in dlPFC as a result of training, indicating an increased neural efficient in *n*-back group following an intensive WM training. Increased neural efficient indicates that processes employed in a certain task may become more automatic as a result of practice and training thus becoming les effortful. The observed neural efficiency stemming from decreased activation in PFC suggests that brain regions and neural networks required for the task get more efficient thanks to cognitive training. The findings of the thesis supported the argument that WM training impacts neural activity in executive control network involving mainly dlPFC and dmPFC. Training-induced changes observed in dlPFC show efficient selective attention and executive control processes during *n*-back task following the training. All these results shows neural mechanism of *n*-back training as well as training-related neural plasticity underlying WM processes.

6.4. Neural Activity Patterns During *n*-back Task and Consecutive Interpreting

The fNIRS results showed that while bilateral dlPFC was mainly activated during *n*-back in pre-test, indicating active use of WM, and it was observed oxygenation levels changed depending on task difficulty and difficult *n*-back conditions induced more oxygenation. Reliable oxygenation changes observed during *n*-back task in optodes mainly corresponding to bilateral dlPFC were associated with processes such as information processing; maintaining relevant information; and avoiding irrelevant information. As it was shown by Rodrigues-Jimenez et al. (2009), bilateral activation of dlPFC especially in in auditory *n*-back task suggests that functions of central executive are employed heavily in the task. These results were consistent with a number of previous studies showing similar neural activation patterns in PFC which is closely related to WM processes.

In terms of consecutive interpreting, it was found that comprehension and reformulation phases elicited different levels of oxygenation. The results revealed that comprehension phase had higher levels of oxygenation in dmPFC which is close to Broca's area and fronto polar cortex, suggesting that comprehension processes tapped more cognitive load and required more allocation of WM resources. Observed differences between the groups in terms of oxygenation changes from pre-test to post-test have been associated with attention modulation and efficient resource management of *n*-back group. While cognitive, linguistics and social factors play diverse roles in consecutive interpreting, the challenge of establishing a cognitive process model of the consecutive interpreting still remains unresolved because of the complexity of the task itself, small sample sizes, and high inter-subject variability. Therefore, models of interpreting with an emphasis on mental operations have not been fully elaborated (Andres, 2015). Therefore, it is believed that this thesis might contribute to gaining a better insight into neural underpinnings of consecutive interpreting by elaborating on functions of WM in such a complex cognitive task which has never been shown before.

To conclude, main results of the thesis replicated previous results of near and far transfer effects of *n*-back WM training. Moreover, the results showed that WM training leads to improvements in not only trained tasks but also non-trained and everyday tasks such as consecutive interpreting. It should be pointed out that these improvements were accompanied by neural findings suggesting an increased neural efficiency in *n*-back training group, and overlapping WM processes between *n*-back task and consecutive interpreting presented by activations in similar areas of PFC. The findings are consistent with the assumptions of neural plasticity that through experience and practice, synaptic strength can be increased in task relevant regions of brain and functional changes can be observed. Therefore, it seems that such effective and intensive WM training interventions might promote plasticity and neural efficiency, indicating a more efficient allocation of neural resources and result in improved WM capacity, a more efficient use of attentional and WM resources. The results also indicate that underlying processes of *n*-back training can be domain-general and modality-independent because the findings revealed that verbal *n*-back training had a near transfer to dual *n*-back task including both auditory and visuospatial stimuli and far transfer to a visuospatial matrix reasoning task.

To our best knowledge, this is the first study to tackle transfer effects of WM training at different levels including transfer to everyday skills on student interpreters by providing both behavioural and neuroimaging evidences. Based on the findings showing that intensive WM training can be an effective tool for improving WM capacity, it can be concluded that transfer into daily life skills, better academic performance in school or performance enhancement in individuals' profession is likely to be achieved. The transfer from test settings to performance in daily life seems to a reasonable explanation for applying WM training in education and training settings to enhance performance in daily life but also in specific professions and training programs. Taken altogether, it is hoped that this thesis can contribute to a better understanding of the notion of transfer and how it relates to cognition and neural plasticity not only in laboratory settings but also in real-world.

6.5. Limitations

Randomization, sample size, having active control group, using adaptive training interventions, administering multiple tests, including outcome measures of real-world cognition, evaluating moderating and mediating factors, assessing short-term and long-term transfer effects, and continuous evaluation of performance during training are main issues that are discussed in cognitive training studies regarding limitations (Seitz, 2017). It seems that the method of this thesis meet most of these requirements such as randomization, active control group, adaptive training interventions in both groups, longitudinal study design, measures of real-world cognition. However, the sample size can be considered small but it should be noted that as a representative of a special group of bilinguals pursuing formal interpreter training, it is believed that the sample of the thesis would not be a great challenge on the contrary can be considered appropriate considering that the same participants attended three testing sessions over a course of almost 10 months. But it would be nice to replicate the same design with a larger sample and compare the results.

Another limitation could be related to use of fNIRS. EEG or fMRI can be recommended because of their advantages in spatial resolution. However, considering the nature of tasks accompanied by fNIRS, it would be rather difficult to run the same tests with EEG under the same conditions. But a follow-up study with fMRI which enables measuring activations in parietal cortex as a more elaborative method can provide a valuable contribution to the observed findings since fNIRS results are consistent with results of fMRI.

6.6. Future Work

In most of the cognitive training studies, "one-size-fit-all" approach is followed without taking into account individual differences in terms of motivation, baseline performance or educational backgrounds and such an approach in cognitive training programs do not seem to be useful because cognitive training can be made more efficient if it is tailored or personalized according to interindividual differences (Colzato & Hommel, 2016; Katz et al., 2016). Therefore, a follow-up study that has a personalized training intervention taking into account individual differences in skills and competences will be a great contribution to the field. Such a research design can also be supported by collecting brain imaging data not only during testing times but also at specific intervals during training sessions.

Similarly, extrinsic and intrinsic motivational factors in WM training can be addressed with proper measures throughout training sessions and the relation between motivation and performance gains can be better understood. Furthermore, after initial assessment of motivation and beliefs about intelligence, group attribution of participants can be made according to these assessment so that the effect of motivation and engagement can be properly investigated.

Consecutive interpreting task of the thesis was carried out from English into Turkish. It should be noted that these two languages belong to different language families and their syntaxes are significantly different, which makes interpreting even harder. It would be very useful to have a similar study with different language pairs and compare the results in order to have a better insight into whether languages involved in the task play role in observed effects. Furthermore, the directionality which refers to the direction of interpreting whether it is into native language or second language might have some implications in terms of cognitive load during the task. It seems that a follow-up study focusing on detailed linguistics factors such as prosody, coherence, etc. together with directionality would have great contributions to these findings.

A valuable follow-up study can be carried out with again interpreting students with simultaneous interpreting measures which can provide a good opportunity to investigate whether two separate modes of interpreting benefit from *n*-back WM training in the same way. As it has been mentioned highly in the literature that direction of interpreting has a huge impact on cognitive load and WM capacity, direction can be added as a variable to a follow-up study.

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APPENDICES

APPENDIX A

SHORT FORM OF THE NEED FOR COGNITION SCALE

Instructions: For each of the statements below, please indicate to what extent the statement is characteristic of you. If the statement is extremely uncharacteristic of you (not at all like you) please write a "1" to the left of the question; if the statement is extremely characteristic of you (very much like you) please write a "5" next to the question. Of course, a statement may be neither extremely uncharacteristic nor extremely characteristic of you; if so, please use the number in the middle of the scale that describes the best fit. Please keep the following scale in mind as you rate each of the statements below: 1 = extremely uncharacteristic; 2 = somewhat uncharacteristic; 3 = uncertain; 4 = somewhat characteristic; 5 = extremely characteristic.

1. I would prefer complex to simple problems.
2. I like to have the responsibility of handling a situation that requires a lot of thinking.
3. Thinking is not my idea of fun.
4. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.
5. I try to anticipate and avoid situations where there is a likely chance I will have to think in depth about something.
6. I find satisfaction in deliberating hard and for long hours.
7. I only think as hard as 1 have to.
8. I prefer to think about small, daily projects to long-term ones.
9. I like tasks that require little thought once I've learned them.
10. The idea of relying on thought to make my way to the top appeals to me.
11. I really enjoy a task that involves coming up with new solutions to problems.
12. Learning new ways to think doesn't excite me very much.
13. I prefer my life to be filled with puzzles that I must solve.
14. The notion of thinking abstractly is appealing to me.
15. I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.
16. I feel relief rather than satisfaction after completing a task that required a lot of mental effort.
17. It is enough for me that something gets the job done; I don't care how or why it works.
18. I usually end up deliberating about issues even when they do not affect me personally.

APPENDIX B

DWECK'S THEORIES OF COGNITIVE ABILITIES SCALE

Read each sentence below and then circle the one number that shows how much you agree with it. There are no right or wrong answers.

1. You have a certain amount of intelligence, and you really can't do much to change it

    1. Strongly agree
    2. Agree
    3. Mostly agree
    4. Mostly disagree
    5. Disagree
    6. Strongly disagree

2. Your intelligence is something about you that you can't change very much

    1. Strongly agree
    2. Agree
    3. Mostly agree
    4. Mostly disagree
    5. Disagree
    6. Strongly disagree

3. You can learn new things, but you can't really change your basic intelligence

    1. Strongly agree
    2. Agree
    3. Mostly agree
    4. Mostly disagree
    5. Disagree
    6. Strongly disagree

APPENDIX C

SPEECHES USED IN PRE-TEST

Alexander the Great

Alexander the Great began his quest to conquer the world at the age of 20, when he became the king of Macedonia. That is probably the same age as many of you here. He and his army defeated the then-powerful Persian Empire and continued to acquire vast amounts of territory. At the time of his death, he ruled the largest Western Empire of ancient times. Some remember him as a charismatic leader whose purpose was to foster East-West relations. Others say he was a brutal killer who was only interested in personal glory. Most historians, though, do agree on one point: he was a brilliant military strategist and leader.

Communication theory

The most important element in communication theory is input. Input includes all of the information we receive from the external world. People have the ability to filter this information if there is too much of it. There are biological and psychological filters. Biological means a person can only process and retain so much information at a time. For instance, a student cannot remember everything said in a lecture, so he or she takes notes on key points. The psychological filter is like selective attention, or "you hear what you want to hear." So, information a person is not interested in does not ever get processed.

Benefits of Pets

Pets actually bestow many benefits upon their owners. For example, studies have shown that with elderly people, having a pet nearby lowers their blood pressure and raises their spirits. So, for all of you with grandmothers or grandfathers living alone, maybe your next gift to them should be a puppy.

Another pertinent study from Britain showed that pets seemed to help fight disease. The study found that people cohabiting with pets had a lower risk of heart disease and recovered more quickly from heart attacks than those who did not live with pets. The study also found that pet owners suffered fewer colds, headaches, and fevers than people who didn't own pets.

Poisonous plants

Have you ever wondered how we know which plants are good to eat and which ones are poisonous? Well, it was simply a very long and drawn-out process of trial and error. Throughout history, people ate what they could find, kill or otherwise get a hold of. When there was a lack of a traditional food source, people had to try new things. Over time, they started to figure out which plants made them sick and which didn't.

Now, I am not just talking about ancient times before farming became established. This trial and error with plants was going on well into the 18th and 19th centuries! In fact, historical records indicate that in the 1800s plant poisoning had become a serious issue. Since food was not as readily available then as it is today, people were forced to take more chances with what they ate. Rather than drop by the market at the end of the street, people would have to wander out into the fields or forests and find whatever looked edible. Today, because the food supply is rather ample and stable, we rarely have to go find our lunch or dinner out in the woods.

The Invention of the Telescope

The invention of the telescope had a huge impact on our understanding of not only the universe, but also of our place in it. It changed the way that people viewed our world, and our world’s place in the universe. Before the telescope allowed us to get a closer look at what was up in the sky, people believed that the Earth was the center of the universe, and everything else revolved around it. You can imagine why. The sun rises in the east and sets in the west. Why would not people think that the sun was moving? It was not until the early 17th century, when Galileo invented the telescope and looked into the sky, that we found out this idea was wrong.

APPENDIX D

SPEECHES USED IN POST-TEST AND FOLLOW-UP

Use of Money

Money is something that can be exchanged for goods and services. It has several uses. One is that it is a medium of exchange. It is a lot easier to do business in a money-based economy than a barter-based one. Currency, or money, gives people a lot more flexibility in spending than trying to buy things with chickens or bags of grain. Money is also a way to measure value. When things are given a monetary value, we can compare their costs and values. Thirdly, money is an asset. We can put aside some money and use it at a later date.

League of Nations

After the First World War, the League of Nations was established for the purpose of settling conflicts between countries peacefully. As we know from the outbreak of World War II, they ultimately failed in their objective. The League lacked strength because it did not have an army. It relied on its most powerful members to enforce its resolutions, but these countries were reluctant to do so. Britain and France, after World War I were largely pacifist and therefore reluctant to use force against Hitler's growing military regime. In the 1930s, the fascist powers left the League, and eventually World War II brought an end to the League of Nations.

Magna Carta

I would like to discuss some of the historical events that led to the signing of the Magna Carta. The Magna Carta is the most famous document of British constitutional history and is widely considered to be the first step in what was a long process leading to the establishment of a constitutional monarchy. The Magna Carta required the King to give up a number of rights. As a result, the king had to follow certain legal procedures and to accept that the will of the king was not absolute. Let's take a look at the background to all this. By the end of the 12th century, that is the late 1100s, the English King had become the most powerful monarch ever seen in Europe. At that time, the king of England even controlled part of northern France, Normandy.

Culture

What exactly is culture? A definition that comes straight out of a textbook would be this: "culture is the complex whole that includes knowledge, beliefs, arts, morals, laws, customs and any other habits and capabilities acquired by human beings as members of society. Culture refers to all those ways of thinking, feeling and behaving that are socially transmitted from one generation to the next." A bit long-winded, but a definition of culture really has to be. It is a big idea to cram into just a few words. In case you are having trouble grasping the idea of what our textbook definition actually means, I will give you a paraphrased version. Culture is basically any aspect of human life that is learned and taught and then passed on to younger generations.

Genealogy

There certainly seems to be a lot more interest in history these days, especially personal or family history. That’s why I wanted to take some time in class to talk about non-academic historical research. You probably know this type of research better as genealogy. Genealogy is the investigation of family histories. Professional genealogists use written records and stories people tell in order to learn about where and when people lived and about their lifestyles. Aside from strictly personal interest, the information they gather can lead to reunions of families who have been disrupted by adoption, foster care or immigration. This type of research could also lead to family reunions of distant relatives.

APPENDIX E

SPEECH EVALUATION QUESTIONNAIRE

They were asked to evaluate the speeches on specific criteria which were difficulty, familiarity, and speed on a 5-point Likert Scale, and were asked to comment on the structure, appropriateness and content of the speeches qualitatively

The following questions are about the speeches that will be used in pre-test and post-test for consecutive interpreting without note-taking. The study will carried out with 3rd and 4th year interpreting students. Please circle one number that best describes your opinion.

1. Please rate your FAMILIARITY with the general content covered in each speech of pre-test on a scale from 1 to 5, with 1: not familiar and 5: very familiar.
   Alexander the Great : 1 2 3 4 5
   Communication Theory : 1 2 3 4 5
   Benefits of Pets : 1 2 3 4 5
   Poisonous Plants : 1 2 3 4 5
   Invention of Telescope : 1 2 3 4 5

2. Please rate your FAMILIARITY with the general content covered in each speech of post-test on a scale from 1 to 5, with 1: not familiar and 5: very familiar.
   Uses of Money : 1 2 3 4 5
   League of Nations : 1 2 3 4 5
   Magna Carta : 1 2 3 4 5
   Culture : 1 2 3 4 5
   Genealogy : 1 2 3 4 5

3. Please rate the DIFFICULTY of each speech of pre-test on a scale from 1 to 5, with 1: easy and 5: difficult.
   Alexander the Great : 1 2 3 4 5
   Communication Theory : 1 2 3 4 5
   Benefits of Pets : 1 2 3 4 5
   Poisonous Plants : 1 2 3 4 5
   Invention of Telescope : 1 2 3 4 5

4. Please rate the DIFFICULTY of each speech of post-test on a scale from 1 to 5, with 1: easy and 5: difficult.
   Alexander the Great : 1 2 3 4 5
   Communication Theory : 1 2 3 4 5
   Benefits of Pets : 1 2 3 4 5
   Poisonous Plants : 1 2 3 4 5

Invention of Telescope : 1 2 3 4 5

5. Please rate the SPEED at which each speech of pre-test was presented on a scale from 1 to 5, with 1: very slow and 5: very fast.
   Alexander the Great : 1 2 3 4 5
   Communication Theory : 1 2 3 4 5
   Benefits of Pets : 1 2 3 4 5
   Poisonous Plants : 1 2 3 4 5
   Invention of Telescope : 1 2 3 4 5

6. Please rate the SPEED at which each speech of post-test was presented on a scale from 1 to 5, with 1: very slow and 5: very fast.
   Uses of Money : 1 2 3 4 5
   League of Nations : 1 2 3 4 5
   Magna Carta : 1 2 3 4 5
   Culture : 1 2 3 4 5
   Genealogy : 1 2 3 4 5

7. Please write your general opinion about the speeches in terms of their structure and language use, content and terminology use and appropriateness for short consecutive interpreting.

APPENDIX F

IDEA UNIT QUESTIONNAIRE

In this PhD research which investigates the effect of working memory training on content accuracy of consecutive interpreting, 3rd and 4th year students of Translation and Interpreting Department were asked to carry out consecutive interpretation of short English speeches which didn't require any note-taking. Interpreting outputs will be evaluated based on content accuracy through scoring correctly recalled and interpreted idea units. Features of delivery such as pronunciation, intonation, etc. are not included in this research. In order to develop an idea unit scoring protocol for this research, you are kindly asked to participate in a survey. You are expected to determine idea units of the speeches attached based on the definition and example provided below. The mean number of correctly interpreted idea units will constitute consecutive interpreting scores of student interpreters.

Idea unit is an idea, proposition, or constituent structure. Individual words or chunks of words within a text or speech which have a high information value and add meaning to the text or speech can be classified as an idea unit.

Example of Idea Units: First impressions / are the initial judgments / we make about people /, and they play an important role / in social perceptions /. We are more likely to form opinions / of others quickly / based on first impressions /, than to refrain from forming opinions / until we have more information /. These first impressions may change / as we get to know a person better /, but we often tend to hang on to them / even in the face of contradictory evidence /. Thus, initial opinions may have a strong impact / on our future interactions with people /.

Please mark with / slashes / possible idea units of the speeches below focusing on your own recalling process during interpreting.

Thank you for your attention and participation.

Date **Signature**

Age:
Gender:
Experience in the profession:

APPENDIX G

IDEA UNIT SCORING PROTOCOL

PRE-TEST			
Subject No:	**omitted**	**partially recalled**	**Fully recalled**
Communication theory / Pre-test	**0**	**1**	**2**
The most important element in communication theory			
is input.			
Input includes			
all of the information			
we receive from the external world.			
People have the ability			
to filter this information			
if there is too much of it.			
There are biological and psychological filters.			
Biological means			
a person can only process and retain			
so much information at a time.			
A student cannot remember everything said in a lecture,			
so he or she takes notes on key points.			
The psychological filter is			
like selective attention,			
or you hear what you want to hear.			
So, information a person is not interested in			
does not ever get processed.			
	Score:		

APPENDIX H

CONSECUTIVE INTERPRETING TRANSCRIPTIONS OF POST-TEST SPEECHES

**Transcriptions of consecutive interpreting outputs belonging to the three participants in each group who achieved higher scores in idea unit scoring in post-test

Genealogy: There certainly seems to be a lot more interest in history these days, especially personal or family history. That's why I wanted to take some time in class to talk about non-academic historical research. You probably know this type of research better as genealogy. Genealogy is the investigation of family histories. Professional genealogists use written records and stories people tell in order to learn about where and when people lived and about their lifestyles. Aside from strictly personal interest, the information they gather can lead to reunions of families who have been disrupted by adoption, foster care or immigration. This type of research could also lead to family reunions of distant relatives.

Participant #3 (*n*-back group): Son zamanlarda tarihe büyük bir ilgi var özellikle kendi kişisel aile tarihimize. Bu yüzden bugün sınıfta bu konuya değinmek istiyorum. Aslında insanlar bu tür aile geçmişinin araştırılmasını soy bilimi olarak biliyor. Soy bilimi uzmanları genellikle insanlarla birebir görüşüp onların sözlü hikâyelerini dinleyerek aile geçmişi profili çıkarmaya çalışırlar. Soy bilimi sayesinde elde edilen bilgilerle göç, evlat edinilme hatta koruyucu aile gibi nedenlerle birbirinden ayrılmış aile üyeleri bir araya gelebiliyor ya da uzaktan akrabalarıyla iletişime geçebiliyorlar.

Participant #5 (*n*-back group): Şu sıralar herkes tarihle ilgileniyor ve geçmişi araştırıyor. Ancak herkes sadece geçmişteki olayları öğrenmek için araştırma yapmıyor. Akademik olmayan tarih araştırmaları da söz konusu. Bugün size bunlardan bahsedeceğim. Muhtemelen siz bu araştırma türünü soy bilimi olarak söylersem ne demek istediği daha iyi anlayacaksınız. Soy bilimi araştırmalarında uzmanlar insanların aileleriyle ilgili anlattıkları hikayeler ve geçmişlerinden hatırladıkları anılarla birlikte kişilerin aile tarihçesi yani soylarıyla ilgili bilgi edinmeye çalışırlar. Elde edilen sonuçlarla birçok ailenin uzak akrabaları bulunabiliyor ya da göç veya evlatlık edinme ya da koruyucu aile sistemi gibi sebeplerle birbirinden ayrılmış aile üyeleri bir araya gelebiliyorlar. Ayrıca bu yolla uzak akrabalara da ulaşılabiliyor.

Participant #7 (*n*-back group): Son zamanlarda tarihe olan ilgi büyük oranda artmıştır. Bu ilgi sadece resmi tarihe değil insanların kendi aile geçmişlerine olan ilgiyi de göstermektedir. Bugün size resmi tarihten söz etmeyeceğim onun yerine akademik olmayan tarih çalışması yani soy bilim hakkında konuşacağım. Soy bilimi birçoğunuzun da bildiği gibi ailelerin nerede yaşadıkları nasıl yaşadıkları ve aile üyelerin yaşamlarıyla ilgilenir. Soy bilimiyle uğraşan kişiler hem yazılı hem de sözlü kaynakları kullanırlar, yazılı belgeleri toplarlar. Bu yolla insanların nerede ne zaman nasıl yaşadıklarına dair bilgi edinmeye çalışırlar. Bu tür çalışmaların kişisel ilginin dışında önemli yanlarından biri göç, koruyucu aile ya da evlatlık edinme gibi çeşitli sebeplerle parçalanmış ailelerin bir araya gelmesini sağlamasıdır. Bu sayede insanlar uzak akrabalarına erişme ve onlarla bir araya gelme şansına sahip olabilmektedirler.

Participant #6 (control group): Günümüzde insanlar tarihe daha çok ilgi duyuyor özellikle kişisel ve ailesel tarihe insanlar çok ilgi duyuyor. Ve bugün bunu konuşacağız. Ve bu aile ve kişisel tarih araştırmasına da akademik olmayan tarih araştırmasına da genealoji deniyor. Genealoji profesyonelleri aile ağaçlarını öğrenmek isteyen kişilerden dinledikleri aldıkları bilgilerle onların ailelerinin nereden geldiğini bulmaya çalışıyorlar. Böylece bir Figurede birbirinden ayrı düşmüş evlatlık yoluyla evlatlık verilmiş ya da evlatlık alınmış insanların aileleriyle tekrar buluşmasına birleşmesine olanak sağlıyor. Ailelerin tekrar buluşmasına olanak sağlıyor.

Participant #11 (control group): Bugün, akademik olmayan bir araştırmadan bahsedeceğim. İnsanlar tarihle ilgilidirler fakat tarih toplumla ilgili olabilir bireysel olabilir. Ben akademik olmayan tarihten bahsedeceğim. Bireysel tarih araştırmasından bahsedeceğim. Bu araştırmada insanlar toplanır ve aileleri ve kendileri hakkında ne zaman nerede yaşadıkları hakkında sorular sorulur. Bu sayede insanlar göç sebebiyle ayrı kaldıkları aile bireyleriyle tekrar bir araya gelebilme şansını yakalarlar. Ayrıca onlardan uzakta yaşayan akrabalarıyla da bir araya gelme şansını elde ederler. Kendi soylarını öğrenme şansını yakalarlar. Bununla ilgilenen bilim dalı soy bilimidir. Soy bilimi uzmanı olan bir kişi yaptığı çalışmalarda bireylere nerede ve ne zaman yaşadıklarını sorar ve bilgi edinirse aile bireylerin tekrar bir araya gelmesi sağlanır.

Participant #14 (control group): Bugün size akademik araştırmaya dayanmayan bir araştırmadan soy biliminden bahsetmek istiyorum. Bildiğiniz gibi soy bilim ailenizin soy ağacınızı bulmanıza yarar. Ailenizin nereden geldiği nasıl yaşadığı hangi hayat şartlarında bulunduğu hayat tarzlarının ne olduğunu araştıran bir bilim dalıdır. Soy bilimi uzak akrabalarınıza yeniden kavuşmanızı sağlar. Göç gibi çeşitli faktörler sonucu ayrı düşen insanların tekrar ailelerine kavuşması soy bilimle mümkündür. Soy bilim ailelerin birleşmesi için çok yararlı bir bilimdir.

Use of Money

Money is something that can be exchanged for goods and services. It has several uses. One is that it is a medium of exchange. It is a lot easier to do business in a money-based economy than a barter-based one. Currency, or money, gives people a lot more flexibility in spending than trying to buy things with chickens or bags of grain. Money is also a way to measure value. When things are given a monetary value, we can compare their costs and values. Thirdly, money is an asset. We can put aside some money and use it at a later date.

Participant #3 (*n*-back group): Para, mal ve hizmetlerin karşılığında değiş tokuş edilen bir şeydir. Parayla alışveriş yapmak tavuk ya da bir çuval tahıl karşılığında alışveriş yapmaktan çok daha kolaydır. Ayrıca para her şeyin pahasını yani değerini belirler. Parayı gelecek için güvence olarak biriktirebiliriz.

Participant #5 (*n*-back group): Para, iş ve ticaret yapabilmek için önemlidir. Takas üzerine kurulmuş bir ekonomidense para üzerine kurulmuş bir ekonomiyle ticaret ve iş yapmak daha kolaydır. Eskiden olduğu gibi tavuk ve torba torba tahılla ödeme yapmaktansa parayla harcama ve ödeme yapmak çok daha kolaydır ve rahattır. Para sayesinde bir şeyin değerini belirleyebiliriz. Ayrıca parayı sadece kullanmakla kalmayıp daha sonra gelecekte kullanmak için de biriktirebiliriz.

Participant #7 (*n*-back group): Paranın belirli kullanım Figureleri ve işlevleri vardır. Bu işlevlerin üçünden söz etmek istiyorum. Bunlardan ilki paranın değiş tokuş aracı olarak kullanılması özelliğidir, yani para sayesinde tavuk veya bir çuval tahılla bir şey almak için takas yapmak zorunda kalmazsınız. Onun yerine parayla istediğiniz şeyi kolaylıkla satın alabilirsiniz. İkinci olarak para bir değer birimidir yani para sayesinde bir şeyin başka bir şeye kıyasla değeri karşılaştırılabilir, hangisinin daha değerli olduğu karşılaştırılabilir. Üçüncü olarak ise para bir yatırım aracıdır. Para sayesinde birikim için paranızı bir kenara ayırabilir ve daha sonra kullanmak için biriktirebilirsiniz.
Participant #6 (control group): Para günümüzde birçok farklı Figurede kullanılabilir. Artık takas usulüne dayalı olan ticaret değil de parayla ticaret yapılmaktadır. Artık eskisi gibi çuvallarla tahıl vererek takas yapmak yerine artık sadece para verip karşılığında bir şey alabiliriz. Ve para eskiyen bir şey değil yani bugün harcamayacaksan parayı kenara koyup daha sonraki zamanlarda harcayabiliriz.
Participant #11 (control group): Para bir değiş tokuş aracıdır. Takasla karşılaştırıldığında paranın etkisi daha büyüktür. Çünkü parayla birlikte ihtiyaçlarınızı giderebilirsiniz. Ayrıca parayı harcamadığınız zaman bir kenara koyup daha sonra tekrar kullanabilirsiniz. Paranın bir diğer özelliği ise çok iyi bir değiş tokuş aracı olmasıdır. Paraya dayalı ekonomi takasa göre daha kolay bir yöntemdir.
Participant #14 (control group): Para ekonominin temelini oluşturan araçlardan biridir. Takas usulü yerine para usulünü kullanan toplumlar ticareti daha serbest Figurede gerçekleştirebilir. Mesela bir torba pirinç ya da tahıl almak istediniz takas yerine para kullandığınızda bunu çok daha kolay bir Figurede sağlayabilirsiniz. Para aynı zamanda önemli bir değerdir.

League of Nations

After the First World War, the League of Nations was established for the purpose of settling conflicts between countries peacefully. As we know from the outbreak of World War II, they ultimately failed in their objective. The League lacked strength because it did not have an army. It relied on its most powerful members to enforce its resolutions, but these countries were reluctant to do so. Britain and France, after World War I were largely pacifist and therefore reluctant to use force against Hitler's growing military regime. In the 1930s, the fascist powers left the League, and eventually World War II brought an end to the League of Nations.
Participant #3 (*n*-back group): Milletler Cemiyeti, 1.dünya savaşından sonra dünyada barışı sağlamaya çalışmak amacıyla kurulsa da bunda başarılı olamamıştır. İkinci dünya savaşında başarısız olduğunu gördük. Ordusu olmadığı için cemiyetin başlarda çatışmaları engelleme görevini güçlü üyelerine bıraktığını görüyoruz özellikle İngiltere ve Fransa Hitler'in karşısında pek fazla etki gösteremediler. 1930larda ne yazık ki Milletler Cemiyeti 2. Dünya savaşını takiben ortadan kalktı.
Participant #5 (*n*-back group): 1.dünya savaşından sonra kurulan milletler cemiyetinin amacı barışçıl çözümler sunmaktı. Ancak milletler cemiyeti bu amacını yerine getirememiştir çünkü kendi ordusu olmadığı için dayatma ya da yaptırım konusunda güçlü üye ülkelere bağımlıydı. Ancak bu tür güçlü ülkeler milletler cemiyetinin kararlarını uygulamakta pasif kalıyorlardı ve güç kullanma konusunda istekli değillerdi. Özellikle Fransa ve İngiltere Hitlerin gücü karşısında tepkisiz

kalıyordu. Bu sebeple 2.dünya savaşıyla birlikte 1930larda milletler cemiyeti son buldu.

Participant #7 (*n*-back group): 1.Dünya savaşından sonra ülkeler arasındaki anlaşmazlıkları çözmek için milletler cemiyeti olarak adlandırılan bir kuruluş kuruldu. Kuruluşun temel amacı ülkeler arasındaki anlaşmazlıkları barışçıl yollarla çözmekti. Ancak 2. Dünya savaşının çıkmasından da anlayabileceğimiz gibi bu kuruluş asıl amacında başarısız olmuştur. Bu kuruluştaki en büyük problem kendi ordusuna sahip olmamasıydı. Kendi ordusuna sahip olmadığı için en güçlü üyelerinin ordularına güveniyordu. Ama bu üyeler ordularını kullanma konusunda istekli değillerdi. Örneğin Hitlerin büyüyen ordusu karşısında İngiltere ve Fransa ordularını kullanmak istemiyordu. Bunun sonucu olarak 1930larda faşist devletler milletler cemiyetinden ayrıldı ve böylece 2. Dünya savaşı milletler cemiyetinin sonunu getirdi.

Participant #6 (control group): Milletler cemiyeti 1.dünya savaşı patlak verdikten sonra anlaşmazlıkları ülkeler arasındaki anlaşmazlıkları bitirmek ve anlaşmalar sağlamak için kurulmuştu. Fakat 2.dünya savaşında 2.dünya savaşı patlak verdikten sonra çöktü ve amaçlarına ulaşamadılar. 1.dünya savaşından sonra Britanya ve Fransa birçok konuda çekingen duruyordu milletler cemiyetinde. Ve faşistler milletler cemiyetinden ayrıldıktan sonra Hitler önderliğinde 2.dünya savaşı patlak verdi ve milletler cemiyetinin bir anlamı kalmadı çünkü bir ordu gücü ya da diğer gücü yoktu.

Participant #11 (control group): Milletler Cemiyeti toplumların devletlerin huzur içerisinde savaşmadan yaşamaları amacıyla kurulmuş bir cemiyettir. Fakat 2.dünya savaşının çıkmasıyla birlikte milletler cemiyetinin başarısız olduğu görülmektedir. Bunun sebeplerinden bir tanesi silah yani ordusunun olmaması. Fransa ve İngiltere milletler cemiyetinin bir üyesiydi fakat ordularını Hitlerin faşist rejimine karşı kullanmakta gönülsüzlerdi. Bu yüzden de 1930larda Hitler büyük bir etki uyandırdı ve 2.dünya savaşı çıktı.

Participant #14 (control group): 1.Dünya savaşının sona ermesinden sonra ülkeler arasındaki sorunların barışçıl yollarla çözülmesi için milletler cemiyeti kurulmuştu. Milletler cemiyetinin askeri bir gücü yoktu. Bu yüzden aldığı kararları uygulatma konusunda başarısız oldu. Askeri gücü güçlü üye devletlerine dayanıyordu. Güçlü üyelerinden İngiltere ve Fransa'nın pasifist yaklaşımlarından dolayı milletler cemiyetinin ömrü kısa oldu. Böylelikle 2.dünya savaşının başlamasına doğru büyük bir adım atılmış oldu.

Magna Carta

I would like to discuss some of the historical events that led to the signing of the Magna Carta. The Magna Carta is the most famous document of British constitutional history and is widely considered to be the first step in what was a long process leading to the establishment of a constitutional monarchy. The Magna Carta required the King to give up a number of rights. As a result, the king had to follow certain legal procedures and to accept that the will of the king was not absolute.

Let's take a look at the background to all this. By the end of the 12th century, that is the late 1100s, the English King had become the most powerful monarch ever seen in Europe. At that time, the king of England even controlled part of northern France, Normandy. (139 words)

Participant #3 (*n*-back group): Bugün Magna Carta'nın nasıl ortaya çıktığından bahsetmek istiyorum. Magna Carta İngiliz anayasa tarihinin önemli noktalarından biridir. 12. yy'nın sonlarında İngiliz kralı inanılmaz bir güce sahipti hatta bu güç o kadar büyüktü ki İngiltere kralı Fransa'nın kuzeyi Normandiya'yı bile kontrol ediyordu. Magna Carta ise kralın sahip olduğu güçleri sınırlandıran bir belgeydi.

Participant #5 (*n*-back group): Şimdi size Magna Carta'nın imzalanması olayından bahsetmek istiyorum. Bu belge tarihteki en önemli anlaşmalardan birisi özellikle İngiltere monarşi tarihi için önemli bir olay. Magna Carta'nın imzalanmasıyla birlikte kralın mutlak yetkisi elinden alınmış oldu. Artık kral istediği her şeyi özgürce yapamayacaktı ve bazı kurallara uyması gerekecekti. Bu belgeyle Kralın yetkileri sınırlandırılıyordu. 12. yy sonlarına kadar İngiltere tarihteki en önemli krallıklardan birisiydi ve İngiltere kralı Avrupa'nın en güçlü kralıydı. Hatta İngiltere kuzey Fransa'yı dahi yönetiyordu.

Participant #7 (*n*-back group): Magna Carta belgesi tarihte en çok bilinen belgelerden bir tanesidir. Magna Carta aslında anayasal monarşi dediğimiz şeyin ilk temellerini atmak için imzalanmıştır. Magna Carta'nın imzalanması İngiltere'nin anayasal monarşisinin temellerini atmıştır. Magna Carta'nın imzalanmasıyla kralın yetkileri bir nebze de olsa sınırlandırılmıştı. Magna Carta'ya göre kralın hükmü kesin hüküm değildir ve bazı sınırlamalar vardır. 12. yy sonlarına doğru gelindiğinde İngiltere monarşisi Avrupa'da en büyük monarşi haline gelmişti hatta o kadar genişti ki Fransa'nın kuzey bölgelerini bile İngiltere kralı yönetiyordu.

Participant #6 (control group): Bugün size İngiliz anayasa hukukunun temeli olan Magna Carta'dan bahsedeceğim. Magna Carta günümüzdeki Britanya anayasa hukukunun temelini oluşturmaktadır. Magna Carta anlaşmasına göre kral elindeki birkaç gücü bırakmak zorundadır ve kralın gücü asla mutlak değildir bu anlaşmaya göre. 11.yy döneminde 11. yy zamanında kral o kadar güçlüydü ki Fransa'nın güneyini Normandiya'yı bile kontrol altına alabilecek kadar güçlüydü.

Participant #11 (control group): Magna Carta gelmiş geçmiş en önemli resmi belgelerden bir tanesidir. Magna Carta'nın amacı kralın bazı haklarını bırakmasını sağlamak ve daha çok anayasal monarşinin kurulmasına sebep olmaktır. Magna Carta'yla birlikte anayasal haklara özellik verilmiştir. Geçmişte tarihe baktığımızda 12. yy'da neredeyse İngiliz kralı kuzey Fransa'yı dahi yönetebiliyordu sahip olduğu mutlak hâkimiyetten dolayı. 12. yy da birçok bölgeyi yönetmesinin sebebi geniş hâkimiyete sebep olmasından ötürüdür.

Participant #14 (control group): Bugün size tarihi bir doküman olan Magna Carta'dan bahsetmek istiyorum. Magna Carta tarihin en önemli dokümanlarından biridir. Magna Cartayla birlikte İngiltere kralı haklarının bir kısmından vazgeçmiş. Magna Carta imzalanmadan önce İngiltere kralı Avrupa'nın en güçlü monarşilerinden birini yönetiyordu. Bu monarşi kuzey Fransa'daki Normandiya'yı bile kapsıyordu. 12. yy en önemli monarşilerinden biri Magna Cartadan sonra anayasal reforma geçti ve de bu yıllar sonra anayasal bir monarşinin doğmasına neden oldu.

Culture

What exactly is culture? A definition that comes straight out of a textbook would be this: “culture is the complex whole that includes knowledge, beliefs, arts, morals, laws, customs and any other habits and capabilities acquired by human beings as members of society. Culture refers to all those ways of thinking, feeling and behaving that are socially transmitted from one generation to the next.” A bit long-winded, but a definition of culture really has to be. It is a big idea to cram into just a few words. In case you are having trouble grasping the idea of what our textbook definition actually means, I will give you a paraphrased version. Culture is basically any aspect of human life that is learned and taught and then passed on to younger generations.

Participant #3 (*n*-back group): Kültür tam olarak nedir? Kültürün bir ders kitabındaki tanımına baktığımızda şöyle bir tanım görebiliriz. Kültür, insanların toplumun bir parçası olarak sahip oldukları her hangi davranış biçimi, inançları, düşünceleri vb. özelliklerini, örf ve adetlerini yansıtan her şeydir.Eğer kültürün böyle bir tanımı anlaşılır gelmiyorsa kültürü size farklı bir Figurede şöyle anlatabilirim. Kültür insanların hayatlarında öğrendikleri ve başkalarıyla paylaştıkları her türlü toplumsal unsurdur.

Participant #5 (*n*-back group): Kültür nedir? Eğer bir ders kitabını açıp kültürün tanımına bakarsak kültürün uzunca bir tanımını bulabiliriz. Bu tanıma göre kültür birden fazla şeyin birleşimden oluşur bunlar ise toplumu oluşturan insanların inançları, düşünceleri, alışkanlıkları, yetenekleri, dini inançları, örf ve adetleri olarak sıralanabilir. Bu tabii ki çok kapsamlı bir açıklama ama kültür gibi bir kavram için açıklamanın bu kadar kapsamlı da olması gerekiyor. Eğer bu uzun açıklama karmaşık geldiyse şöyle kısaltabiliriz. Kültür insan hayatını ilgilendiren, öğrenilen ve öğretilen kişiden kişiye ve nesilden nesile aktarılan değer ve olguların tümüdür.

Participant #7 (*n*-back group): Kültür aslında oldukça geniş bir tanıma sahiptir özellikle okul kitaplarında kültürün tanımı oldukça geniş bir alanı kapsamaktadır. Kültür genel olarak şöyle tanımlanır: toplum içinde yaşayan insanların edindikleri bilgileri, davranışları, tepkileri, yaşayış Figureleri, alışkanlıkları gelenekleri ahlaki değerleri aslında toplum içindeki her şey kültür anlamına gelir. Kültürün bu kadar geniş bir tanımının olması tuhaf gelebilir ama aslında bu çok normaldir çünkü kültür topluma ait her türlü düşünme ve yaşayış şeklini ifade eder. Eğer bu tanımı anlamakta sıkıntı çektiyseniz size kültürün tanımını tekrar şu Figurede özetleyebilirim. Kültür bir nesilden diğer nesle geçen, toplum içinde yaşayan insanların birbirlerine öğrettikleri ve öğrendikleri yaşayış biçimi olarak ifade edilebilir.

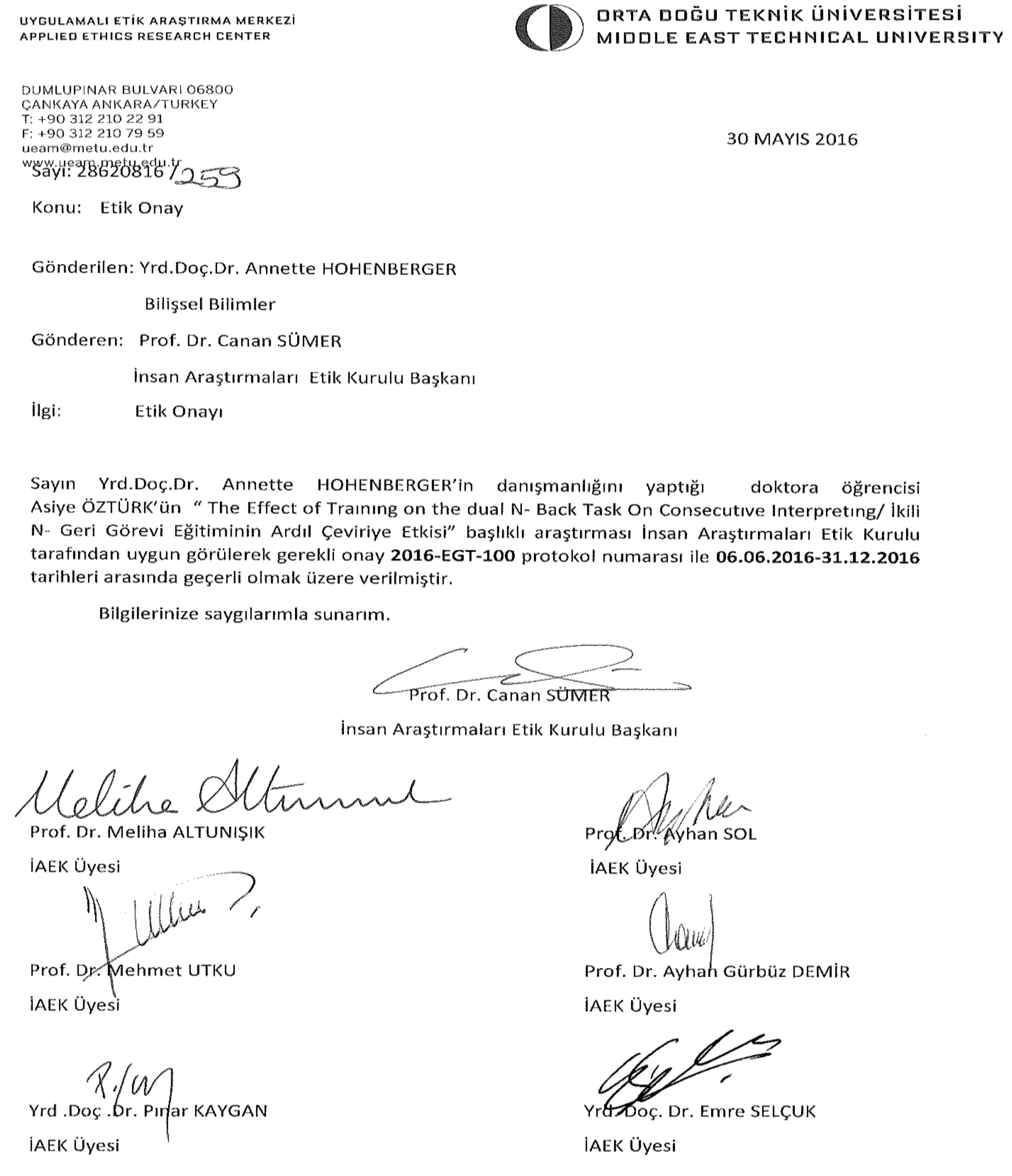
Participant #6 (control group): Bugün size kültürün tanımından bahsedeceğim. Kültürün tanımına herhangi bir kitaptan bakacak olursak kitapta yer alan tanımına bakacak olursak kültür herhangi bir toplumda bulunan insanların yaşadıkları birçok şey ahlak değerleri yaptıkları sanat ve her şeye ve bu şeylerin daha genç jenerasyonlara aktarılması. Ama bu biraz karışık, kafa karıştırıcı gelebilir. Daha kısa anlatacak olursak insanların her yönden etkilendiği davranışlar ve durumların deneyimlenmesi ve daha sonraki jenerasyonlara aktarılması diyebiliriz.

Participant #11 (control group): Kültürün ders kitaplarındaki tanımına baktığımız zaman kültür sosyal, ahlaki, geleneksel, ahlaki, hukuksal konuların bazı inançların gelenek ve göreneklerinizin bir toplumun yaşayış şeklinin tümüdür. Aynı zamanda bunların bir nesilden bir nesle geçirilmesi toplumdan topluma geçirilen toplumsal bir anlayıştır. Kısaca kültür bir toplumun genel düşünceleri, genel inançları genel inandığı şeyler ve genel durumlarıdır. Kültürü daha kısa özetleyecek olursak toplumdaki davranışların bir nesilden diğer nesle aktarılmasıdır.

Participant #14 (control group): Kültür nedir? Kültürün tanımına baktığımızda bir sözlüğü açıp kültürün tanımına baktığımızda kültürün bir toplumu oluşturan etik değerler, kurallar, çeşitli gelenekler olduğunu görürüz. Bu kültürü açıklamak için oldukça uzun bir tanımlama gibi görünebilir. Ama kültürü birkaç kelimeye sığdırarak tanımlamak çok zordur. Çünkü kültür bir toplumu oluşturan değerlerin yeni jenerasyonlara aktarılmasıdır. Başka bir Figurede özetleyecek olursak toplumun değerlerinin toplumun yapı taşlarının bir sonraki nesle aktarılmasıdır.

APPENDIX I

ETHICAL APPROVAL FORM



UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr
www.ueam.metu.edu.tr

30 MAYIS 2016

Sayı: 28620816 /253

Konu: Etik Onay

Gönderilen: Yrd.Doç.Dr. Annette HOHENBERGER
Bilişsel Bilimler

Gönderen: Prof. Dr. Canan SÜMER
İnsan Araştırmaları Etik Kurulu Başkanı

İlgi: Etik Onayı

Sayın Yrd.Doç.Dr. Annette HOHENBERGER'in danışmanlığını yaptığı doktora öğrencisi Asiye ÖZTÜRK'ün " The Effect of Training on the dual N- Back Task On Consecutive Interpreting/ İkili N- Geri Görevi Eğitiminin Ardıl Çeviriye Etkisi" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2016-EGT-100** protokol numarası ile **06.06.2016-31.12.2016** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Canan SÜMER
İnsan Araştırmaları Etik Kurulu Başkanı

Prof. Dr. Meliha ALTUNIŞIK
İAEK Üyesi

Prof. Dr. Ayhan SOL
İAEK Üyesi

Prof. Dr. Mehmet UTKU
İAEK Üyesi

Prof. Dr. Ayhan Gürbüz DEMİR
İAEK Üyesi

Yrd .Doç .Dr. Pınar KAYGAN
İAEK Üyesi

Yrd. Doç. Dr. Emre SELÇUK
İAEK Üyesi

APPENDIX J

MIXED ANOVA RESULTS FOR HBO VALUES

***N*-BACK TASK PRE TEST VS. POST TEST / two-tailed**														
	time			**n-back**		**time*group**		**n-back*group**		**n-back*time**		**n-back*time*group**	
opt	**df**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**
1	**1, 11**	0,120	0,735	5,413	0,040*	2,479	0,070**	0,556	0,471	1,088	0,319	4,039	0,070**
2	**1, 9**	0,094	0,766	1,920	0,199	0,431	0,528	0,011	0,918	1,073	0,327	0,723	0,417
3	**1, 12**	0,241	0,632	3,311	0,094	0,871	0,369	1,527	0,240	1,826	0,201	1,239	0,287
4	**1, 10**	0,207	0,659	0,509	0,492	1,477	0,252	0,019	0,894	1,790	0,211	0,002	0,969
5	**1, 12**	1,035	0,329	0,408	0,535	1,846	0,199	0,835	0,379	0,033	0,860	2,180	0,166
6	**1, 9**	0,018	0,896	0,955	0,354	0,250	0,629	0,024	0,881	0,008	0,932	0,277	0,612
7	**1, 10**	0,013	0,913	2,805	0,125	1,583	0,237	0,117	0,739	0,453	0,516	0,781	0,397
8	**1, 6**	1,141	0,327	0,303	0,602	2,558	0,161	0,021	0,889	0,125	0,736	0,067	0,804
9	**1, 10**	0,020	0,891	2,876	0,121	0,246	0,631	1,174	0,304	2,667	0,134	2,396	0,153
10	**1, 6**	1,209	0,314	0,438	0,533	0,264	0,626	2,129	0,195	0,023	0,886	0,387	0,557
11	**1, 12**	0,006	0,940	3,836	0,074**	0,582	0,460	0,010	0,923	1,352	0,268	1,770	0,208
12	**1, 8**	0,054	0,823	1,429	0,266	0,253	0,628	2,949	0,124	0,007	0,937	2,535	0,150
13	**1, 12**	0,361	0,559	6,711	0,024*	0,041	0,842	4,214	0,063**	0,086	0,774	0,138	0,717
14	**1, 10**	0,464	0,511	7,421	0,021*	0,001	0,982	0,003	0,959	0,502	0,495	0,719	0,416
15	**1, 11**	1,162	0,304	21,166	0,001*	1,532	0,242	0,562	0,469	0,972	0,345	0,053	0,822
16	**1, 12**	0,480	0,502	7,387	0,019*	1,054	0,325	0,593	0,456	0,288	0,602	1,619	0,227
***n*-back levels=2-back vs. 3-back / group= *n*-back vs. control / test= pre-test vs. post-test**													

_N_-BACK POST TEST VS. FOLLOW-UP / two-tailed

	time		**time*group**		**n-back level**		**n-back*group**		**n-back*time**		**n-back*time*group**	
opt	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**
1	1,814	0,215	1,890	0,207	8,639	0,003*	1,221	0,321	1,556	0,241*	0,529	0,599
2	2,737	0,132	6,239	0,034*	3,354	0,058*	4,190	0,032*	2,845	0,084	3,068	0,071**
3	2,825	0,127	0,728	0,416	2,812	0,087	3,030	0,073**	2,945	0,078**	2,135	0,147
4	1,168	0,311	0,727	0,419	1,002	0,389	2,795	0,091	0,505	0,613	0,769	0,480
5	8,415	0,020*	1,291	0,289	1,204	0,326	0,916	0,420	1,019	0,383	1,523	0,248
6	0,413	0,544	0,127	0,734	1,836	0,202	0,295	0,750	1,207	0,333	0,176	0,841
7	11,063	0,009*	1,973	0,194	1,011	0,384	0,615	0,552	0,843	0,447	0,103	0,902
8	5,055	0,059	0,508	0,499	1,297	0,304	0,638	0,543	0,306	0,741	0,170	0,846
9	3,304	0,102	0,162	0,697	1,838	0,188	0,047	0,954	0,754	0,485	0,349	0,710
10	12,781	0,009*	3,094	0,122	4,308	0,035*	0,468	0,636	0,803	0,467	0,395	0,681
11	3,505	0,098	0,252	0,629	3,838	0,043*	0,096	0,909	1,091	0,360	0,014	0,986
12	1,823	0,226	1,792	0,229	4,239	0,040*	0,531	0,601	0,910	0,429	0,593	0,568
13	3,054	0,114	0,210	0,657	4,947	0,019*	0,358	0,704	3,727	0,044*	0,632	0,543
14	5,454	0,080	2,595	0,183	0,485	0,632	2,385	0,154	1,719	0,239	0,093	0,912
15	0,223	0,650	0,415	0,538	5,834	0,013*	1,288	0,303	0,002	0,998	0,150	0,862
16	2,164	0,180	0,547	0,481	10,627	0,001*	1,385	0,279	0,222	0,803	3,541	0,053*

_n_-back levels=2-back-3-back-4-back

group= _n_-back vs. control

test= post-test vs. follow-up

CONSECUTIVE INTERPRETING PRE TEST VS. POST TEST / two-tailed

	time		**time*group**		**consecutive**		**consecutive*group**		**time*consecutive**		**time*consecutive*group**	
opt	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**
1	3,55	0,09	0,75	0,40	2,51	0,14	1,18	0,30	1,87	0,20	0,51	0,49
2	0,54	0,48	0,13	0,73	0,36	0,56	0,58	0,47	2,25	0,17	0,52	0,49
3	1,06	0,32	8,88	0,01*	4,07	0,07**	0,11	0,74	4,47	0,06**	0,64	0,44
4	3,52	0,09	0,04	0,85	0,65	0,44	6,73	0,03*	0,23	0,64	0,34	0,58
5	1,35	0,27	5,09	0,05*	14,11	0,00*	6,38	0,03*	15,75	0,00*	12,03	0,01*
6	0,20	0,66	0,33	0,58	0,94	0,36	2,20	0,18	0,10	0,76	0,05	0,83
7	0,32	0,59	3,07	0,11	9,29	0,01*	0,01	0,91	0,00	0,97	0,06	0,82
8	0,72	0,44	0,28	0,63	1,62	0,27	0,01	0,94	0,82	0,42	0,27	0,63
9	1,20	0,30	0,00	0,96	0,87	0,37	0,95	0,35	0,39	0,55	0,01	0,93
10	0,01	0,94	0,78	0,41	0,22	0,65	1,22	0,31	0,50	0,50	0,39	0,55
11	0,00	0,95	1,10	0,32	1,19	0,30	0,95	0,35	0,06	0,81	0,03	0,87
12	0,15	0,71	0,04	0,85	0,17	0,69	1,66	0,24	0,11	0,75	0,48	0,51
13	1,64	0,22	4,55	0,05*	2,62	0,13	0,04	0,85	0,11	0,74	0,18	0,68
14	0,01	0,93	1,90	0,20	1,58	0,24	2,89	0,12	0,00	0,96	7,69	0,02*
15	4,38	0,06**	0,33	0,58	0,07	0,79	4,39	0,06**	1,20	0,30	4,72	0,05*
16	0,88	0,37	0,52	0,48	8,86	0,01*	0,26	0,62	0,08	0,78	1,37	0,27

consecutive interpreting phases= 1. comprehension 2. reformulation

group= *n*-back vs. control

test=pre-test vs. post-test

CONSECUTIVE INTERPRETING POST TEST VS. FOLLOW-UP / two-tailed

	time		**time*group**		**consecutive**		**consecutive*group**		**time*consecutive**		**time*consecutive*group**	
opt	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**	**F**	**sig**
1	0,03	0,86	0,20	0,67	0,05	0,83	1,37	0,28	2,56	0,15	0,16	0,70
2	0,00	1,00	4,48	0,06**	0,11	0,75	0,94	0,36	1,18	0,31	0,30	0,60
3	1,28	0,29	0,94	0,36	0,00	0,99	0,50	0,50	14,14	0,00*	0,28	0,61
4	0,35	0,57	0,13	0,73	0,72	0,43	1,12	0,33	1,19	0,31	0,71	0,43
5	2,20	0,18	4,56	0,07**	0,00	0,95	1,21	0,30	7,66	0,02*	0,00	0,97
6	0,65	0,46	1,16	0,34	0,28	0,62	0,21	0,67	2,49	0,19	3,71	0,13
7	0,96	0,36	1,18	0,31	0,24	0,64	0,65	0,44	2,71	0,14	0,13	0,73
8	0,15	0,71	0,01	0,93	5,72	0,05*	0,02	0,90	1,62	0,25	0,13	0,74
9	0,93	0,36	0,09	0,77	0,00	0,99	0,53	0,48	1,35	0,27	0,03	0,88
10	0,01	0,94	1,76	0,23	0,20	0,67	0,08	0,78	0,11	0,75	1,28	0,30
11	0,02	0,90	0,29	0,60	0,05	0,83	0,01	0,94	1,10	0,32	0,01	0,93
12	0,11	0,76	0,06	0,82	0,01	0,92	0,91	0,38	0,70	0,44	2,18	0,20
13	0,23	0,64	2,47	0,15	0,10	0,76	0,00	1,00	4,84	0,06**	0,13	0,72
14	0,25	0,64	0,21	0,67	0,97	0,38	2,92	0,16	0,39	0,56	0,27	0,63
15	0,15	0,71	0,51	0,50	0,74	0,42	12,49	0,01*	0,27	0,62	0,00	0,96
16	0,06	0,82	0,32	0,59	5,27	0,06*	1,48	0,26	0,05	0,84	0,01	0,93

consecutive interpreting phases= 1. comprehension 2. reformulation

group= ***n*****-back vs. control**

test=post-test vs. follow-up

APPENDIX K

PRE-TEST IDEA UNIT SCORES

PRE-TEST		**Alexander**		**Pets**		**Telescope**		**Plants**		**Communication**		**mean**	**mean**
		score	**percent**	**score**	**percent**	**score**	**percent**	**score**	**percent**	**score**	**percent**	**score**	**percentage**
1	**1**	10	31	18	47	23	58	19	38	4	11	15	37
3	**1**	18	56	20	53	25	63	20	40	14	37	19	50
4	**1**	8	25	5	13	16	40	6	12	10	26	9	23
5	**1**	14	44	18	47	23	58	21	42	19	50	19	48
7	**1**	20	63	19	50	20	50	27	54	20	53	21	54
11	**1**	10	31	16	42	16	40	14	28	13	34	14	35
13	**1**	14	44	16	42	8	20	5	10	10	26	11	28
16	**1**	11	34	14	37	17	43	7	14	5	13	11	28
17	**1**	12	38	17	45	18	45	9	18	12	32	14	35
2	**2**	10	31	10	26	15	38	16	32	0	0	10	25
6	**2**	20	63	22	58	20	50	20	40	18	47	20	52
8	**2**	8	25	24	63	16	40	12	24	3	8	13	32
9	**2**	17	53	14	37	14	35	15	30	5	13	13	34
10	**2**	4	13	6	16	5	13	6	12	5	13	5	13
12	**2**	16	50	18	47	18	45	22	44	14	37	18	45
14	**2**	20	63	20	53	0	0	22	44	17	45	16	41
15	**2**	9	28	18	47	9	23	10	20	8	21	11	28
18	**2**	9	28	18	47	26	65	22	44	31	82	21	53

1: *n*-back group; 2: control group

APPENDIX L

POST-TEST IDEA UNIT SCORES

POST-TEST		**Money**		**Nations**		**MagnaCarta**		**Culture**		**Genealogy**		**mean**	**mean**
		score	**percent**	**score**	**percent**	**score**	**percent**	**score**	**score**	**score**	**percent**	**score**	**percentage**
1	**1**	15	42	20	53	25	54	26	68	20	56	21	**55**
3	**1**	26	72	25	66	25	54	24	63	26	72	25	**66**
4	**1**	12	33	17	45	11	24	16	42	12	33	14	**35**
5	**1**	23	64	22	58	30	65	26	68	30	83	26	**68**
7	**1**	31	86	33	87	38	83	24	63	32	89	32	**82**
11	**1**	16	44	10	26	10	22	15	39	20	56	14	**38**
13	**1**	14	39	12	32	10	22	14	37	17	47	13	**35**
16	**1**	13	36	18	47	24	52	15	39	12	33	16	**42**
17	**1**	17	47	26	68	32	70	23	61	14	39	22	**57**
2	**2**	14	39	9	24	20	43	15	39	15	42	15	**37**
6	**2**	20	56	22	58	22	48	20	53	24	67	22	**56**
8	**2**	9	25	8	21	15	33	14	37	14	41	12	**31**
9	**2**	12	33	24	63	20	43	12	32	16	44	17	**43**
10	**2**	10	28	12	32	10	22	11	29	10	28	11	**28**
12	**2**	15	42	20	53	25	54	14	37	24	67	20	**50**
14	**2**	20	56	24	63	24	52	23	61	23	64	23	**59**
15	**2**	14	39	15	39	16	35	18	47	12	33	15	**39**
18	**2**	12	33	8	21	28	61	15	39	25	69	18	**45**

1: *n*-back group; 2: control group

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Öztürk, Asiye

Nationality: Turkish (Bulgarian Dual Citizenship)

Date and Place of Birth: 16.02.1987, Sofia, BULGARIA

e-mail: asiye.ztrk@gmail.com

EDUCATION

Degree	**Institution**	**Year**
PhD	Middle East Technical University, Cognitive Science	2018
MA	Hacettepe University, Translation & Interpretation	2012
BA	Hacettepe University, Translation & Interpretation	2009

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2013-2018	Atılım University, Translation & Interpretation	Lecturer
2009-2013	Atılım University, Translation & Interpretation	Research Assistant

TEACHING EXPERIENCE

Teaching mostly interpreting-related courses such as consecutive interpreting, simultaneous interpreting, conference interpreting, etc. at undergraduate level

AWARDS

METU Graduate School of Informatics, 2013-2014 Academic Year Course Performance Award

FOREIGN LANGUAGES

Native Turkish, Advanced English, Upper-intermediate German, Beginner Italian

POSTER PRESENTATIONS

Öztürk, A., Hohenberger, A. "The Effect of Training on the Dual N-back Task on Consecutive Interpreting Performance". Cognitive Science Seminars CogSci in Germany CogSci in Turkey, METU, Ankara, 23 May 2014

Öztürk, A., Hohenberger, A. "The Effect of Training on the Dual N-back Task on Consecutive Interpreting: A Pilot Study". IPCITI, 9th International Post Graduate Conference in Translation & Interpreting, Heriot Watt University, 14-16 November, 2013

Unpublished MA Thesis: “Directionality in Simultaneous Interpreting: English-Turkish Language Pair”, Hacettepe University, Ankara

SUMMER SCHOOL

Edinburgh Interpreting Research Summer School, Heriot-Watt University, Edinburgh, 30 June-4 July 2014: