EFFECT OF VERBAL AND AUDIO REPRESENTATION: RELATIONSHIP BETWEEN COGNITIVE LOAD AND PERFORMANCE UNDER SAVE / ERASE TREATMENT TO CREATE TRANSACTIVE MEMORY CONDITION

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EFFECT OF VERBAL AND AUDIO REPRESENTATION: RELATIONSHIP BETWEEN COGNITIVE LOAD AND PERFORMANCE UNDER SAVE / ERASE TREATMENT TO CREATE TRANSACTIVE MEMORY CONDITION

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This Thesis has been read by us, it has been deemed sufficient and accepted as a PhD thesis in terms of quality and content.

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ETHICAL CONDUCT

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.

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ABSTRACT

EFFECT OF VERBAL AND AUDIO REPRESENTATION: RELATIONSHIP BETWEEN COGNITIVE LOAD AND PERFORMANCE UNDER SAVE / ERASE TREATMENT TO CREATE TRANSACTIVE MEMORY CONDITION

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Transactive memory is simply defined as extending your memory to other people and these days technological devices act as a form of memory extension which is dubbed as Google effect. This study aims to examine how this memory extension affects storing information in long term memory and learning. This experimental study consists of eight groups, all of which contains three phases differing from one another; learning phase, N-Back task and learning test. Learning phase includes eight different groups which are recall (30 statements) or recognition memory (45 statements), statements are given verbally or auditorily with save or erase treatment. The aim of save and erase treatment was to create Google Effect. Recall memory test was fill in the blanks test and recognition memory test was multiple choice for the items learnt in the first phase. Regarding recall memory, N-Back cognitive load results did not display significant main or interaction effects except for verbal stimulation in sensory channel which produced controversial results in 2 and 3-Back conditions. Recall memory fill-in-the-blank test of the learnt items did not display main but interaction effect only in terms of reaction time. There was no main or interaction effect in Recognition memory N-back measurement. Recognition memory multiple choice questions did not have a main effect in terms of sensory channel but displayed difference in save erase treatment. This main effect occurred in reaction time in favor of erase treatment which was higher compared to save treatment and opposite results was expected initially.

Keywords: Transactive Memory, Cognitive Load, Learning, Google Effect

ÖZ

İŞİTSEL VE GÖRSEL SUNUMUN ETKİLERİ: BİLİŞSEL YÜK İLE GEÇİŞKEN HAFIZA DURUMU YARATMAK İÇİN VERİLEN KAYDET / SİL YÖNERGESİ SONRASI PERFORMANS ARASINDAKİ İLİŞKİ

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Geçişken hafıza yalın şekilde başkalarının hafızasının bizim hafızamızın uzantısı olması şeklinde özetlenebilir ve teknolojik aletlerin bu hafıza uzantısı yerine geçme durumuna ise Google etkisi denmektedir. Bu çalışmanın amacı bu hafıza uzantısının bilgiyi uzun süreli hafızamızda tutma ve öğrenme üzerine etkisini araştırmaktır. Bu deneysel çalışmada sekiz grup bulunmaktadır ve her grubun kendi içinde farklılaşan durumlara sahip aşamaları vardır; öğrenme aşaması, N-Geri aşaması ve öğrenme testi. Öğrenme aşamasındaki 8 gruba hatırlama (30 cümle) yada tanıma (45 cümle) ifadeleleri ile işitsel yada yazılı olarak, sil veya kaydet yönergeleri verilmiştir. Sil ve kaydet yönergelerinin amacı Google etkisi yaratmaktır. İlk aşamada öğrenilen bilgiler Hatırlama hafızası boşluk doldurma testi, Tanıma hafızası ise çoktan seçmeli testler ile ölçülmüştür. Hatırlama ve Tanıma farklı hafıza türleri olduğundan ayrı olarak değerlendirilmiştir. Hatırlama grubuna dahil alt gruplarda N-Geri bilişsel yük ölçümlerinde sözel uyaran grubu dışında kalan gruplarda bir ana yada etkileşim etkisi görülmedi ki bu gruptada 2 ve 3-Geri koşullarında tartışmalı sonuçlar ortaya çıkmıştır. Tanıma hafızası grubunun boşluk doldurma testi ana etki göstermezken, sadece reaksiyon süresi bakımından etkileşim etkisi göstermiştir. Tanıma hafızası grubunun N-Geri bilişsel yük ölçümleri bir ana yada etkileşim etkisi ortaya koymamıştır. Tanıma hafızası çoktan seçmeli testi işitsel ve sözlü uyaranlar bakımından bir ana etki ortaya koymamıştır fakat sil ve kaydet yönergelerinde sil lehine cevap süresi bakımından daha yüksek sonuçlar ortaya koymuştur.

Anahtar Kelimeler: Geçişken Hafıza, Bilişsel Yük, Öğrenme, Google Etkisi

To my family for stealing from their time…

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ABBREVIATIONS

CL : Cognitive Load
CLT : Cognitive Load Theory
LTM : Long Term Memory
STM : Short Term Memory
TM : Transactive Memory
WM : Working Memory

Chapter 1
Introduction

1.1 Statement of the Problem

Emerging technology has changed the way people do things in their daily lives from interacting with each other to banking as well as learning. For many years the teachers were considered as the source of information but today information is at our fingertips due to mobile technology. Hilbert (2012) calculated the amount of information in two different years and found that information transmitted a day in 1986 was equal to 55 newspapers and in 2007 it was equal to 175 newspapers. After the introduction of first iPhone in 2007 smart phone sales increased dramatically (Statista, 2021) per year from 122 million units to 1.5 billion and the smartphone users reached 4.3 billion users (Statista, 2021). In the traditional way of learning, the sources were not easy to reach in terms of speed and number of sources. Libraries offered many kinds of books however the search for key words were often limited with the librarians' knowledge of sources, which was very limiting. However, these days people use key words to search for information in various search engines, thus reach the information anytime and anywhere. This phenomenon of getting information anytime, anywhere is called Ubiquitous Learning (Hwang et. al., 2008). Ogata et al. (2009) expands the definition of Ubiquitous Learning to means of technology such as cellular data, Wi-Fi and computer systems as learning devices.

With the increasing size of data per day and the help of devices, pocket sized computers alias smart phones have penetrated into our lives like a bionic limb, we are ascribing our mental activities on these devices. From epistemological view we are not sure how this phenomenon affects our way of remembering information.

In a study supported by Kaspersky Lab, some interesting research findings about the use of smartphones were presented. Carolus et.al., (n.d.) ran an online survey with 1215 people from around the world, but mostly from Germany and the UK and put forward highly interesting results. Age range of the participants was between 15 – 83 Most of the participants were between 20- 29 years of age and either students or employees. Almost all of the users use their phones on regular basis and while people between ages of 40 - 49 are using their phones for work purposes, younger people are using them in their free time. They found that, in an experiment with 95 subjects, when people were invited to a room to wait for 10 minutes, and 73% of the subjects used their phones for about 5 minutes. They waited for around 44 seconds (men 21 - women 57 seconds) before reaching out their phones, when asked how much they waited, male participants reported time around 3 minutes and women over 2 minutes. It can be concluded that people's perception on the frequency of the use of mobile devices is more than it really is and people quickly turn to them as a companion. One of the findings that relates to my study is that when the subjects were invited to a room to perform a task with four different phone proximity manipulations (phone: visible, natural, locked, removed) smartphone visible performance average was 26 % lower than smartphone removed from the room. (Carolus et.al., n.d.) Despite the fact that we don't know what causes this performance to change, it might be asserted that phones somehow distract people or have them ascribe mental effort to themselves.

In another paper (Carolus et al., 2019), mentions the use of smartphones for various tasks as "digital companions" despite its relatively new advent in 2007 with the first iPhone. Kaspersky Lab. conducted a survey and asked 6000 people from 6 different European countries about their habit of technology use. Survey displayed that more people are using their digital devices as their extension or replacement of memory, like not remembering phone numbers as can be found in the phone or to evaluate the information. Moving forward from this point, they even called it "digital amnesia" attributing mental effort to trusted portable devices providing ubiquity, which goes in line with the psychological terminology "transactive memory".

This study is carried out to examine the relationship between transactive memory and cognitive load. Wegner et. al. (1985) "a transactive memory system is a set of individual memory systems in combination with the communication that takes place between individuals". The term transactive memory has many far/near similar versions such as extended mind, extended memory, external cognition, locational externalism, active externalism, vehicle externalism, environmentalism, cognitive extension, distributed cognition, and collective intelligence. While some of the terminologies assert similar definitions, others focus on using other people / means as part of intelligence. During the overview they were found to be studied as a part of psychology but not directly as a part of education or educational studies; therefore, mostly focusing more on attention. Sparrow et. al. (2011) carried out a study on transactive memory and called the finding “Google Effects on Memory” and experiment results may shed light for educational use. They suggested that the transactive memory is when information is kept in others, but the internet has become main channel of this transaction and people, when faced asked challenging questions, primarily think of searching them online via search engines like Google. In one experiment, subjects inclined to think more of search engines when they were given hard trivia questions. In the second one, they were told to type and keep in mind the trivia sentences, those who believed these sentences would be erased recalled more sentences in the test. In the third, participants were told to save sentences in one of the six folders on a computer, they again had better memory under erase treatment than saving to folder but remembered the location of the sentences better than the sentences themselves.

Sparrow’s et.al. (2011) findings asserts that learners will not remember some extend of the information given that they have an external source to keep that information, thus it affects memory. If people reach out to their mobile devices more than they think and the information is available anytime and anywhere, then the question how this process affects memory function and learning is questionable. Study by Sparrow et. al., (2011) does not focus on whether this transaction creates load on memory or offloads it. CL is related to the amount of information stored in Long Term Memory (LTM) and Working Memory (Sweller & Sweller, 2006) CL requires a careful design in instruction so that it will not create overload on WM sources (Sweller, 2010; Özçınar 2009). Conway and Engle (1996) state that individuals’ WM capacity differ from each other despite the fact that they have same capability in arithmetic and that these subjects display variety in the number of vocabularies they remember in reading ability study. Type of load weighed on WM has categorizations based on instructional design, these are intrinsic and extraneous load. Intrinsic load is correlated with the number of elements interacting due to the nature of information and extraneous load is correlated with the type of instruction given (Paas, Renkl, & Sweller, 2003, 2004) The load intended to be created in this study is intrinsic load which is free from the instructional design.

Atkinson and Shiffrin (1966) indicate the importance of sensory channels on short term memory (STM), later called WM (1968) due to the difference in their functions. They see sensory channels as buffers of LTM. In their model sensory channels are eyes and ears, alias audio and visual. (Atkinson & Shiffrin, 1966) However, they did not make a distinction in sensory channel and indicated that this was a question to refer later, by giving the example that when the word cat is introduced, either visually or auditorily, it was enough to get answer from the subjects. Paivio (1986) introduced his theory named Dual Coding and made an distinction on the sensory channels as verbal and non-verbal without an emphasis on either CL or WM (Clark & Paivio, 1991) Another model called three component model which makes a difference in sensory channels was introduced by Baddeley and Hitch in 1974 based on model represented by Atkinson and Shiffrin as this one contained problems (Baddeley, 2000)

Based on the information received from the modals that sensory channels play a role in acquiring information, the tasks in this study include a listen and learn task called Audio hereafter and read and learn task called Verbal hereafter. The results of learning information via different the sensory channel was investigated and included in the results.

1.2 Purpose of the Study

The main aim of this study is to explore how the use of technology as transactive memory affects learning in environments where the information will be easily accessible by the learner and the relation between cognitive load and performance. Prevalence of the mobile technology brings along the chance to reach the information anytime and anywhere, which increases the amount of information people face daily. As Sparrow et. al. (2011) suggested using the technological devices might extend the mind out of the boundaries of human brain and knowing in terms of, encoding, storing and retrieving it. Therefore, this study tried to observe the relation between cognitive load and learning. Cohen et. al. (2009) assert that visual memory is superior to auditory memory in recognition tasks. Therefore, to observe such difference this study created audio and verbal inputs.

Hu et.al., mentions that the use of external source, such as taking note on a paper or phone, might help decrease the mental load; however, Sparrow et. al. (2011) conducted experiments to observe whether using external source and reliance will affect the performance and they used save or erase treatment to draw the attention of the participants to the fact that information will be inaccessible under erase and accessible under save treatment. Save and erase treatments are implemented to observe transactive memory state, called Google effect, in this study.

This study also contained two different memory types: recall and recognition. Baddeley et. al., (2001) extended a previous study to observe recall and recognition memory difference and carried out performance tests and brain scans. They have come to conclusion that recall and recognition are occupied in disparate parts of the brain while acquiring information in semantic memory. Similarly, Cabeza et.al. (1997) also found that recall brought about more activation in various parts of the brain when compared to recognition.

Keeping all abovementioned in mind, this study covered memory types (recall / recognition) which will receive Google Effect (save / erase) treatment via two sensory channels (audio / verbal).

1.3 Research Questions

1. Is there an interaction effect among the treatment (save vs. erase), sensory channel (verbal vs. audio) on cognitive load measured by N-back task during recall memory and recognition memory tasks?

1.1 Is there a main effect of the treatment (save vs. erase) on cognitive load measured by N-back task?

1.2 Is there a main effect of the sensory channel (verbal vs. audio) on cognitive load measured by N-back task?

2. Is there an interaction effect between the treatment (save vs. erase), sensory channel (verbal vs. audio) on recall memory and recognition memory performances?

   2.1 Is there a main effect of the treatment (save vs. erase) on recall memory performance?

   2.2 Is there a main effect of the sensory channel (verbal vs. audio) on recognition memory performance?

3. Is there a correlation between participants' self-perception (beliefs) scores about memory, attention, and prospective memory, and their actual recall and recognition test performances?

Following hypotheses have been made:

*H*1. Erase treatment will cause more cognitive load on participants than save treatment on both recall and recognition memory groups.

*H*2. Audio sensory channel exposure will have more cognitive load on participants than verbal sensory channel on both recall and recognition memory groups

*H*3. Erase treatment will lead to better performance scores both in recall and recognition memory task.

*H*4. Verbal sensory channel will lead to better performance scores both in recall and recognition memory task.

$H5_a$. There is a correlation between belief of memory and recall test performance.

$\mathrm{H5_b}$ There is a correlation between belief of attention and recall test performance.

$H5_c$ There is a correlation between prospective memory and recall test performance.

$H6_a$. There is a correlation between belief of memory and recognition test performance.

$H6_b$. There is a correlation between belief attention and recognition test performance.

$H6_c$. There is a correlation between prospective memory and recognition test performance.

1.4 Significance of the Study

The myth about the capacity of the brain that we use only 10% of it was debunked (De Bruyckere et. al., 2015) but the question why some people have better memories remained. Is memory solely in our brains or is it extended? The transactive memory (Wegner, 1987) examines the extension of the mind among the people around. Even Einstein, one of the most influential and intelligent scientists, commented upon a question about the speed of light that "I don't carry such information in my mind since it is readily available in the books" (as cited in Storm & Stone, 2015) If memory is not one solid unit, then how this extension of memory affect information and knowledge creation is still debated by the theories like Transactive memory.

This study was planned before the COVID-19 pandemic started and initial experiment interfaces were coded and about 10 days before the piloting process the schools including universities were shut down for two weeks then they did not come back for the next one and a half years. Therefore, distance education in an emergency situation penetrated our lives and teaching was given online via platforms like Zoom, Microsoft Teams and Adobe Connect. After the precautions were announced we decided to move the experiment platform to online. This unfortunate situation has, in a way, helped this experiment to be more significant as the participants were receiving education online via computers and this experiment measuring learning was also online and given via computers for more than six months. This created a more realistic environment for the experiment.

Receiving online education in an emergency situation has provided an advantage to this study since participants were exposed to online education for more than half a year; therefore, this study has been more meaningful for two reasons. The first one is that all participants experienced online education, and the second one is that they were in their natural learning environment rather than a room designed for experiments without distractors.

By the time this experiment was conducted participants were in curfew and were allowed to leave home for only a short time during restricted hours. Computers became their learning environment at home. Materials were sent as soft copies, exams were given online and they all experienced this for several months when the experiment was applied. The main significance this study offers to the literature is that participants were in their usual environment with whatever distractor they may have; cats, moms, dads, smart phones, street noise, food smell etc…

1.5 Definitions

Audio (Auditory): Stimulations given to participants in auditory form during learning phase. It is also used to represent the group.

Verbal: Stimulations given to participants in written (visual) form during learning phase. It is also used to represent the group.

Save: It represents the group that received the stimulation that information entered by the participants is saved on the computer.

Erase: It represents the group that received the stimulation that information entered by the participants is deleted from the computer.

N-Back: It is the task used to create and measure cognitive load.

Recall: It refers to the test style in which participants responded to the questions by filling in the blanks given.

Recognition: It refers to the test style in which participants responded to the questions via four item multiple choice questions.

Chapter 2
Literature Review

2.1 Cognitive Load Theory

Cognitive load theory (CLT) is a theory which has received its bases from the outcomes of studies about the relation between working memory and long-term memory and it helps in understanding the link between cognition and learning (Sweller et al., 2011). The purpose of CLT is to improve learning by helping create instructional use that allow instructional designers to manage cognitive load (Paas & Merriënboer, 2020). Sweller (1988) found out that the ineffectiveness of direct instruction in problem solving exercises is due to the misdirection of attention and also density of cognitive load.

Working memory capacity is considered by the cognitive psychology that it is a system whose capacity has boundaries and not infinite; (Baddeley, 2000) therefore, design of teaching should free the memory resources so that the new information can be assimilated and stored in LTM (Kalyuga, 2011). Atkinson and Shiffrin (1968) introduced their three-store model which consisted of sensory store, information received through eyes, ears and feeling, short term store, indicated as the duration of about 30 seconds for the information to remain in memory, and long-term store, from which you can retrieve information to process. Paivio put forward dual-coding theory which differentiates sensory system stimuli as verbal and nonverbal as well as their process and interaction (Clark & Paivio, 1991). Baddeley and Hitch (1974) proposed the idea that the model presented by Atkinson and Shiffrin was not sufficient since the model was unable to make a distinction between short term memory and working memory. They argued that this failure is due to recency effect, and they presented the results based on immediate and delayed remembering experiments which shows items are remembered less in delayed tests. Recency effect occurs because people tend to remember the facts or items given to them timewise recently more than the items exposed to longer time ago because they were stored in short term memory (Goldstein, 2015). Baddeley and

Hitch (1974) proposed the theory of working memory, the term is used to explain a kind short term memory that not only holds but also processes the information to learn, understand and identify causes. They also emphasized that WM span is not unlimited and differs from people to people (Baddeley & Hitch, 1974; Baddeley, 2000) Therefore, when this limited capacity of WM is surpassed, it can hinder the learning process since it creates an overload in memory (Leppink et. al., 2013) and CLT suggests the instruction to be designed in a way that facilitates learning by eliminating the unneeded load (Merriënboer & Sweller, 2005; Sweller, 2010) can improve learning. Schunk (2012) emphasized the importance of sensory registers and stimuli while processing information in the WM and that rehearsal plays an important role to transfer the information to LTM. Another emphasis was made regarding the rehearsal that items that are rehearsed at the beginning (primacy effect) and at the end (recency effect) are recalled more than the ones in the middle. The items in the recency effect is thought to be in the in the WM, therefore, remembered more. The N-Back task used in this study served two purposes, the first is measuring cognitive load levels of the participants and the second is the prevention of the aforementioned recency effect by interfering between the learning task and performance test by additional load created by N-Back. Kelly and Risko (2019) found that directed forgetting helps prevent the primacy effect as reported on preceding studies on the topic. With this information in mind, it can be assumed that with save treatment in Google effect, which tells the learner that information will be available anytime they need, the primacy effect was also eliminated.

Sweller and Sweller (2006) suggested that cognition and evolution play important roles in five natural information processing systems which offers 5 principles. (Table 1) Sweller (2011) suggested that cognitive structure of human beings must be taken into consideration in CLT, and the two important features of this structure are the characteristics of the knowledge which is classified as biologically primary and biologically secondary (Geary, 2008). The main difference between biologically primary and biologically secondary knowledge is that biologically primary knowledge does not require explicit instruction, which is the basis of CLT. Listening and speaking are acquired with the interaction in society whereas the reading and writing are taught via explicit instruction. (Sweller 2010, 2011). Geary (2008) indicated that humans have not evolved to easily learn the biologically secondary knowledge provided by schools as reading and writing have come into our lives very quickly with formal education in the last century. He also made an emphasis on how our attention and cognition plays a role on learning primary knowledge and people inherently have the skills to acquire them. The knowledge type used in this study covered biologically secondary knowledge as the learning task.

Human cognitive system is based on the following assumptions (Mousavi et.al., 1995) which are; (a) working memory capacity is limited; (b) long term memory has no limit; (c) people mainly learn by forming schemas; (d) automated processes decrease the load on working memory. Cognitive load theorists assume that cognitive capacity is determined by working memory capacity and learning is facilitated by utilizing existing resources (Korbach et.al., 2017) The amount of information presented to individuals during instruction take up space in their working memory and this load is called cognitive load and consists of three types; intrinsic, extraneous, and germane load (Merriënboer & Sweller, 2005; Sweller et al., 1998; Sweller et al., 2011). Element interactivity is an important factor that helps identify the intensity of intrinsic and extraneous load. (Sweller et al., 2011) Element is described as any subject that the learner wants to learn, and high element interactivity refers to anything that cannot be learnt one by one, and elements interact with one another intensely (Chen et. al., 2015, Clark et. al., 2006; Sweller, 2010). Recent studies on CLT started to take two of these cognitive load types into consideration, intrinsic and extraneous, whereas germane load is excluded as a load type and started to be called “germane resources” (Choi et. al, 2014; Kalyuga, 2011; Leppink et. al., 2013; Sweller, 2011). The reason of this omission is because intrinsic and germane load were related to each other in a way that made it difficult to separate, because all the intended effort to increase germane load, like including worked examples, also increased intrinsic load as it added up to elements interacting in the knowledge acquisition process (Choi et. al., 2014)

2.1.1 Intrinsic Load

The load is sometimes due to the nature of the information to be learnt; therefore, the load in the working memory is called intrinsic cognitive load, which is independent of the instructional method used. (Sweller, 1994) and it is found out by degrees of element interactivity (Sweller, 1994; Sweller, 2010) To illustrate, math operation with low element interactivity would be 2+2 = ? and a higher one would be 2+9+8+6+4+7= ? due to numbers interacting. However, intrinsic load is associated the density of the elements rather than their interaction, (Sweller, 2010, Sweller & Chandler, 1994) and above-mentioned addition example may be high for a novice but may not create load for an expert since intrinsic load is also determined by prior knowledge of learners (Anmarkrud et. al., 2019; Leppink et. al., 2013) and the difficulty of the task (Leppink, et. al., 2013)

2.1.2 Extraneous Load

When the nature of the material is presented using a type of instruction or through the type of activities that the learners involve, this type of load is then considered extraneous load. (Sweller et. al, 2010; Sweller, 2011) An example to high extraneous load would be teaching kids an operation with low intrinsic load such as 2+2 by using a series of procedures through applications on a tablet, which kids are unfamiliar with. Bringing four apples instead of unknown software on a kind of tablet to teach the same subject would reduce the extraneous load caused by instruction. Extraneous load is also called as irrelevant load (Clark et. al., 2006) or ineffective load (Paas et. al, 2003)

2.1.3 Germane Load

It is also called effective load as opposed to ineffective or extraneous load. (Paas et. al., 2013) While the most prominent features of both intrinsic and extraneous load lie upon the materials, the third load, germane load, cares about the learner features (Sweller, 2010). It is about the effective load committed to working memory while handling intrinsic load of the material studied. In plain words, if the material itself (intrinsic load) is complicated but taught in a way (extraneous load) that imposes low load, then the possibility of learning will increase since the learner will devote higher germane load to the material itself, and vice versa. On the contrary of intrinsic and extraneous cognitive load, germane load does not comprise any type of load on memory and Sweller et. al. (2011) suggested the term to be changed from germane load to germane “resources” because intrinsic and extraneous load take up space in working memory but germane load simply does not.

Kirschner et. al. (2018) emphasized that CLT and its types are mostly related to learning individually and used for teaching purposes. In their article they shed light on how learning cooperatively, thus transactive aspects, affects cognitive load and learning. In addition to abovementioned Cognitive Load model and types Paas & Merriënboer (1994) look at it from a slightly different point that all the experiments conducted by Sweller and co-authors may help people design their instruction methods that imposes a low load and therefore have benefits in terms of instructional design and learner cognition. They argue measurement of CL tasks to be observed under mental effort and that it is not really possible to observe CL at the time of instruction. This measurement can be done in three aspects; mental load, mental effort and performance (Jahns, 1973, as cited in Paas & Merriënboer, 1994). CLT is about fine tuning the stimulants so that they would not occupy unnecessary load on finite WM, nevertheless CL is not solely about the features of the tasks imposed and schemas already assimilated and accommodated in the brain; therefore, Paas and Merriënboer (2020) introduced three causal aspects that affect WM limit. These aspects are learning task, learner and the learning environment. Their original model was based on “causal and assessment factors” in which causal factors included task and learner in their model in 1994 (Paas & Merriënboer, 1994) Causal factors initially task (environment) and the learner, however their revised model made a significant change which now covers task and learner within an environment. (Choi et. al, 2014) When mentioning the learner aspect Paas and Merriënboer made an emphasis on the learning design which enabled learners to collaborate thus distribute the imposed load amongst the group members (2020). Despite the widespread instructional use, collaboration might be problematic as it is not really possible to detect whether everyone was involved thus the learning was effective or efficient so the emphasis is on performance and similarly instructors focus on the end product rather than the rate of contribution (Kirschner, Paas & Kirschner, 2008) They also indicated that performance was not equal to learning and the suitable measures are needed to assess learning to be able to claim learning has occurred. Paas & Merriënboer (1993) put forward the idea that performance is not a good indicator of learning, and defined performance as degree of completing the task successfully in terms of being fast and accurate or via the exam scores that the students received. Yet, Paas and Merriënboer (2020) asserted that collaboration could help individuals learn better as it frees the WM resources devoted to tasks because they simply borrow from WM capacity of another person. In their model of CL they considered collaboration as a learner aspect and that helps them share the load. Choi et. al. (2014) mentioned an aspect similar to another person in collaboration when they mentioned that cognition is not free from the environment and that it is not easy to tell task from the environment. They also attract attention to the fact that environment, in some cases, can be considered as an extension of the mind outside the brain like the theories of "extended mind" by Clark and Chalmers (1998) and distributed cognition (Michaelian & Sutton, 2013; Jonassen & Henning, 1999; Salomon, 1997; Hollan et.al., 2002) Distributed cognition is defined as distribution of processes in minds of group members (Salomon, 1997), while Hollan et.al., (2002) look at it from human computer interaction perspective. The latter definition by Hollan et. al. (2002) is exemplified with a pilot and cockpit, which despite not mentioned in the study, reminds encoding specificity that will be touched upon in discussion part.

2.2 Google Effect and Transactive Memory (TM)

Transactive memory is defined by Wegner et. al. (1985) as the knowledge of the beholders in groups and how group members communicate on the related tasks; therefore, the exchange of information among or between individuals can be seen easily when monitored. Wegner (1987) mentions the memory in three levels as encoding, storing and retrieval, and states that information can be encoded in one's own memory or an external one such as a notebook or a person. Wegner (1995) uses the analogy of computer network to clarify group mind and explain in three factors; identifying the person who has specific information, distributing items among group, coordinating the distributed knowledge. However, the analogy is used to explain the similarity between human memory and computer network models without the emphasis of information exchange between the computers and humans as a form of the group mind.

Sweller and Sweller (2006) introduced five principles (see Table 1) to explain how information is processed and that put an emphasis on human cognition and evolution. The second principle goes hand in hand with TM since it suggests that information is not processed in human cognition only but also taken from the minds of others.

The first principle, information store, is a vast store of both primary and secondary knowledge (Geary, 2008) to recall information. The second principle, borrowing and organizing, suggest that secondary knowledge is transferred from the long term memory of one person to another. Kirschner et al. (2018) hypothesizes that borrowing could be an significant aspect of collaborative learning, which might increase the effectiveness of learning. Tomasello et. al. (2012) contributes to the second principle from an ontogenetic point of view and calls it the *interdependence principle*, which focuses on comprehensive process of building knowledge via collaboration. This sub-principle (Kirschner et al., 2018) is used to explain how the knowledge is acquired via transaction activities such as interaction with others and also devices like computers.

Technology is defined as “the use of science in industry, engineering, etc., to invent useful things or to solve problems” and also “a machine, piece of equipment, method, etc., that is created by technology” by Merriam Webster (2021) dictionary. Socrates expressed his idea about the technology and criticized the use of wax tablets by putting forward the idea that he believed knowledge is within the human soul and wax tablets contain only signs, to remember people must keep them in their soul, not tablets (Gonzalez, 2007) Although there is not a specific distinction made on what is on one’s mind and what is on the wax tablet called, today some descriptions exist. Zins (2007) has a few definitions of information and knowledge on various domains; however when the universal definition of the terms are taken the distinction becomes clearer. *Information* stands for signs (as Socrates also indicated) which are based on verifiable facts, when *knowledge* stands for signs that symbolizes facts justified by the beholder. (Zins, 2007) Einstein accidentally drew attention to this distinction upon a question by a reporter about the speed of sound when he said he did not hold that information in his memory since it is readily accessible from the books and the purpose of learning (in college) is not put these data in one's brain but to teach it to think (Isaacson, 2017)

Sparrow et al. (2011) investigated the Transactive Memory effect of technology in replacement of a person who holds the needed information. The results stated by Sparrow et al. (2011) are that: people think of using a search engine rather than thinking of asking a more knowledgeable individual, they remember more information when they think that information will not be available to reach later, and lastly when individuals are directed to enter the information onto computers to given folders it was observed that they remembered the folder name rather than the information itself. Schooler and Storm (2021) confirmed the save and erase condition effect by making the contribution that this effect occurs on condition that subjects believe save condition takes place in an environment they consider as trustworthy. Google Effect was not detected when participants thought it was not a trustworthy process. They also commented that Google effect was not replicated in some studies; therefore, criticized however, the reason could be that reliability of the process was not taken into consideration.

Table 1
Natural Information Processing System Principles

Principle	Function
Information Store	Store information in long term memory
Borrowing and reorganizing	Information is borrowed from others
The Randomness as genesis	Create new ideas (problem solving)
The narrow limits of change	Working memory to combine long term and sensory memory to create novel information
Environmental organizing & linking	Bring environment information and information store together.

It is a question mark why it was named Google Effect when it also included other search engines such as Yahoo, but it also no wonder why it was named so since omniscient Google holds the 92% of the market share worldwide amongst search engines (Search Engine Market Share, 2021) Wegner and Ward (2013) pointed out that we normally ascribed our mental abilities to people with whom we have face to face relations, but this ascription has changed greatly from human to the Internet. They have argued that this change is due to the speed and amount of information the Internet holds, which they call as “all knowing friend” and also claim that the Internet brings information quicker than our brain does. Varshney (2012) tested this hypothesis and compared the number of references between 2004 and 2011 at MIT Electrical Engineering and Computer Science doctoral theses. The results indicated an increase in the number of references and Varshney (2012) argued that this increase might be due to the fact that students knew where to find information more than the actual information. This use of physical action, here the use of computers, to remember things easier without increasing mental effort like using one’s fingers to solve addition problem is called Cognitive Offloading (Risko & Gilbert, 2016). Cognitive offloading is used in some areas such as interface design based on a paradigm called distributed cognition and aims to decrease the number of items to be learnt to operate an interface (Yacci & Rozanski, 2012). Norman (2013) explained it as “knowledge in the head” and knowledge in the world” and used the example of recognizing coins but not being able to describe them yet use them correctly. Based on this example Yacci and Rozanski (2012) drew attention to students assignments where they might be using Google to write a report and in this case teachers can’t be measuring knowledge retrieved from long term memory about content but they measure only performance but not learning, With the coin example in mind in which cues, marks on coins, are used successfully as distributed cognition, my study contains two types of performance tests; recall (cued recall method; fill in the blanks), recognition (multiple choice test) memory. Recognition is when we try to identify previously exposed stimuli (Goldstein, 2015) just like identifying a coin we encounter everyday but in a recall memory test we try to retrieve it by producing it.

Chapter 3
Methodology

This experimental study was conducted via a website that is specifically designed and coded. Prior to the start of the experiment participants logged in to the web site by using the username and password provided to them. After entering demographic information, participants answered three questions using a slider bar. These questions focused on self-perception about attention, memory, and prospective memory.

The main focus of this experiment was to examine whether save erase treatment, alias Google effect, would lead to any effect in learning. The study that this experiment was based on indicated that people remembered the storage location of information rather than the information itself (Sparrow et. al., 2011) We also know from the studies explaining the cognitive processes that sensory channel, auditory and visual, play role in the storage of information (Atkinson & Shiffrin, 1966; Paivio, 1986; Baddeley & Hitch, 1974). Therefore, two sensory channels were added to learning process in addition to save or erase treatment. The original Google Effect study did not make a distinction in terms of sensory channel. Creswell (2015), mentioned that it might not usually be sufficient to have one treatment to explain the result and if added, a factorial design is used when observing two independent variables on an outcome. Dependent variables in N-Back were number of correct, incorrect reactions and also correct and incorrect reaction durations in milliseconds. Independent variables were sensory channels (audio/verbal) and treatment (save/erase). Test performance utilized number of correct answers to given questions as dependent variables. Sensory channel (Audio/Verbal) and Treatment (Save/Erase) were also used as independent variables.

N-Back and test performance needed differences to be measured, they contained two dependent variables and two independent variables (treatment and sensory channel) that contained two levels (save/erase and audio/verbal); therefore, a 2 x 2 multivariate analysis of variance (MANOVA) was conducted to see if independent variables had main and interaction effects (Fraenkel, 2012).

3.1 Setting

This experiment was initially designed to be given offline on a computer in a silent cognitive psychology laboratory and the software was brought alive a week before the pandemic limitations was applied. Upon the announcement of the COVID-19 pandemic by the Turkish government educational institutions were closed in 2020 spring term and student were advised to go home for two weeks. However, students did not come back for face-to-face education and no predictions were able to be made about the start of face-to-face education. Therefore, we decided to conduct the experiment online and the software had to be recoded to function as an online web page.

The setting was the online platform consisted of three stages: Learning task (Figure 1), N-Back and learning test. Details of learning tasks are given below as there are eight tasks which are differing from one another slightly. N-Back task was used to create an extra load for intervention and to measure the CL, learning test consisted of two types, recall (cloze test) and recognition (multiple choice). As the experiment was conducted online the participants were in their natural online learning environments.

The comment, from the former Monitoring Committee was taken into consideration; previous design was based on typing the sentences onto a screen, but it took three times longer to complete compared to audible repetition of statements through the microphone. Speech recognition technology was utilized, and it also helped to ensure that participants practiced the statements to learn.

3.2 Participants

Participants were university students between the ages 18 and 25. They were from 3 different foundation universities located in Turkey. Ethical form was approved by the Board of Ethical Committee. Consent form was given in a video prior to experiment owing to the fact that placing this form on the web site caused malfunctions. The video displayed the consent form, which was also read aloud, then the video continued with the steps of the experiment and what participants should do. The video was needed since during the piloting some participants indicated that they did not know what to do although there were explicitly given in instructions right before each step. The most confusing part was N-Back as it was something new for participants and also the mouse cursor had to disappear during that stage and participants did not think they were doing anything. The video gave a walkthrough and contained worked examples to help participants.

337 participants were admitted to the experiment online, 106 of the participants started but did not complete the experiment due to either technical problems (from their computers or website servers) or unwillingness to complete it. 13 participants amongst the remaining 231 participants who completed it had missing data; therefore, they are excluded. Final number of participants providing accountable data is 218. Age of the participants range from 18 to 25. Table 2 below contains detailed demographic information.

Table 2
Demographic Table of the Participants in Each Group

Group	n	Gender: F*, M**	Mean (age)	St. Dev (age)
Recall Total	113	94 F, 18 M	19.27	1.62
Recall Audio Erase	27	22 F, 5 M	19.29	1.49
Recall Audio Save	27	22 F, 5 M	19.33	1.62
Recall Verbal Erase	35	27 F, 5 M	19	1.68
Recall Verbal Save	24	23 F, 1 M	19.5	1.74
Recognition Total	105	80 F, 25 M	19.11	1.26
Recognition Audio Erase	25	20 F, 5 M	20	1.63
Recognition Audio Save	24	20 F, 4 M	19.04	1.30
Recognition Verbal Erase	29	24 F, 5 M	18.62	0.5
Recognition Verbal Save	27	16 F, 11 M	18.88	0.97

*Female
** Male

Participants were from three different foundation universities in Turkey. Two of the universities were in the first 15 according to Council of Higher Education (YÖK, 2021), report from 2019 and the other was in first 35 out of 50 universities. Since we do not hold the students’ affiliation of universities there is no exact number however, majority of healthy data (estimated 85%) were from a university within the first 10 in ranking and with mostly medicine related departments.

3.3 Procedures

Experiments were given online through a web page specifically designed for this study. Each participant had a unique username and password for log-in. After answering demographic information such as age and gender the study started. It consisted of three stages for all participants despite the changes in the tasks. There were 8 different tasks (see Figure 1) . The first part was a learning task, the second part was N-back test, and the third part was learning task assessment. Learning task and assessment had either 30 or 45 statements, 30 being called recall, 45 being called recognition. General knowledge questions were transcribed as statements and then grouped as easy, moderate and difficult according to frequency results of the study (Güler & Irak, in press) and were equal in number. 10 from each three difficulty levels in recall phase and 15 from each three difficulty levels in recognition phase are selected. The order of statements that participants encountered according to difficulty level was randomly selected using a formula in excel.

As this study also observes Google Effect and measuring cognitive load, some elements in the treatments need clarification. Google effect (Sparrow, Liu, & Wegner, 2011) suggest that participants remember more information if they think that it will be removed from the computer. Therefore, this study also has save and erase treatments, save means participants will think that the information will be saved on computer and be available to them whenever they need, erase means the information will be erased right after they are entered onto computer. To reinforce this, participants were displayed save or erase information after every entry. For the instructions of the tasks see Appendix.

Recall and recognition are the other terms that need clarification. In the recall phase participants were instructed to answer each question in a blank using the information from the learning task. Recognition means participants were instructed to recognize the correct answer from among the 4 options. Then participants' both number of correct and incorrect recall or recognition performance scores were calculated as memory performance.

The other terms used in this study are Audio and Verbal (visual) sensory channel. In the first step, there was a learning task. Participants were given trivial statements through different sensory channels to see if they also had an effect or not. Audio means participants heard the statements from the computer speaker or headphone and rehearsed them audibly. Verbal means participants saw and read the statements on a screen and then rehearsed them audibly. All the audibly rehearsed statements are processed via speech-to-text software built within Chrome browser and converted to text for evaluation. Audio statements heard by the participants were recorded in an isolated room via a professional microphone by using a sound processing software called Audacity. The aim of recording it in an isolated room was to prevent background noise. Statements were vocalized in a moderate speed, without putting special emphasis on the words to not cause prejudgment about the key words. However, an emphasis close to natural has been made, since participants in preliminary piloting found the non-emphasis vocalization robotic and the robot like voices violate Voice Principle in Multimedia Learning (Mayer, 2009) and hinders learning

3.3.1 Data Collection Instruments

This study contains a secure web site with a certificate in order for it to enable microphone on a computer. In the web site there are three stages; learning task, N-back task and performance task. Recall and recognition performance results were used in the analyses. Recall and recognition performance comprises audio or visual learning task under save or erase treatments, which added up to 8 different screens that participants were exposed.

3.3.1.1 *Learning Task*

There are 8 different tasks in this study; however, each task shares some similar conditions. The two phases are Recall and Recognition. The reason they are called recall and recognition is due to their assessment style in the final step. In the assessment, recall refers to the blank in a statement that needs to be remembered and filled in by typing the missing part. Recognition refers to the blank that needs to be identified out of 4 choices given. Technically, recall is a cloze test type and recognition is multiple choice.

Each recall and recognition tasks include Save or Erase condition, under each, audio or visual (verbal) sensory channels of input is given. Audio refers to when participants heard the statement and, Verbal refers to when participants read the statements from the screen. The other 4 recognition tasks include the same types, but number of statements are 15 statements more in number. In both audio and verbal treatment participants were asked to repeat the statements audibly. Voice of the participants are processed using speech-to-text, built-in API in Chrome browser. Speech-to-text results are prone to errors especially due to noise and may not produce fully correct results (Čeidaite & Telksnys, 2010); therefore, it is used to see whether participants were really uttering the exact statements or random words during the study in order to eliminate contaminated data.

Learning task involves 30 or 45 (see appendix) general information statements. 30 statements are for recall questions, 45 statements are for recognition questions. Statements are in Turkish and were normed by Güler and Irak (in press) with various difficulty stages. She compiled answers to questions from three different sources and ran the study with 354 participants. Statements from 3 difficulty levels were chosen randomly in equal numbers depending on learning task. Levels are easy, moderate and difficult. Some sentences in this study including words from foreign languages such as names were removed on condition that they were phonetically hard to write for Turkish speakers (e.g. oftalmoloji, odometer, Kingston). These types of words are kept provided that they are not asked in assessment part or phonetically legible by Turkish speakers or are exposed to commonly in Turkish.

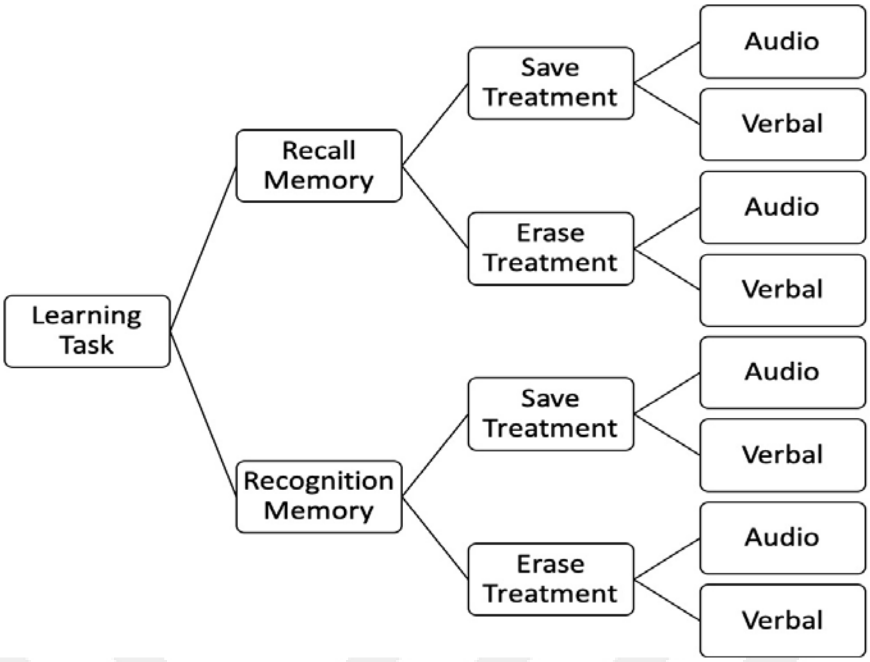

Figure 1 Learning Task - Experiment groups

3.3.1.1.1 Recall Memory Learning Task

Participants were exposed to randomly ordered 30 trivial statements. 10 statements from each difficulty level, easy, moderate, difficult were picked randomly. The number of recall statements are less than recognition as participants had to remember what is given in the blanks from memory, rather than just recognize from given options.

3.3.1.1.2 Recall Save Learning Task

In the beginning of the learning task participants were displayed an information page that said all the statements they were about to encounter would be saved on computer and be available to them should they need. Participants would see the "saved" message after every statement to make sure they kept in mind it being saved.

3.3.1.1.3 3.3.1.1.3 Recall Save Audio Learning Task

30 statements were presented to participants auditorily and one-by-one. Participants heard the statements and then repeated them audibly. The Turkish version of the following statement popped up on screen "Your entry has been saved to Trivia folder" (Girmiş olduğunuz cümle Trivia dosyasına kaydedilmiştir) after each submission.

3.3.1.1.4 Recall Save Verbal Learning Task

30 statements were presented to participants in written form and one-by-one. Participants were asked to read the statements from the screen audibly. The info "Your entry has been saved to Trivia folder" emerged after every statement.

3.3.1.1.5 Recall Erase Learning Task

In the beginning of the learning task, participants saw the page that said the statements they were about to see would be erased, additionally, they would see this "erased" message after every statement to make sure they kept in mind that would not see the statements again in any latter stage.

3.3.1.1.6 Recall Erase Audio Learning Task

30 statements were presented to participants auditorily and one-by-one. Participants heard the statements and then repeated them aloud. The info "Your entry has been erased" popped up after every statement.

3.3.1.1.7 Recall Erase Verbal Learning Task

30 statements were presented to participants in written form and one-by-one. Participants were asked to read the statements from the screen audibly. The info "Your entry has been erased" popped up after every statement.

3.3.1.1.8 Recognition Memory Learning Task

Participants were exposed to 45 trivial statements. Just like the recall learning task, this task also covered statements from three difficulty levels. Fifteen statements from easy, average, and difficult levels were randomly ordered.

Same 30 statements from the recall learning task were used in recognition task. Five extra statements were added to each difficulty level, adding up to 45 in total.

3.3.1.1.9 Recognition Save Learning Task

Participants were exposed to randomly ordered 45 statements of trivial information. There were fifteen statements from each difficulty level, easy, moderate, and difficult. Prior to start of the treatment participants read the information that their entries would be saved onto computer and be available to them at a later stage. After each statement, participants received the message that “Your entry has been saved to Trivia folder”

3.3.1.1.10 Recognition Save Audio Learning Task

Participants received the statements auditorily and then practiced aloud by uttering them through the microphone on the computer.

3.3.1.1.11 Recognition Save Verbal Learning Task

Participants received the statements in written form and then practiced them audibly by uttering them through microphone on the computer

3.3.1.1.12 Recognition Erase Learning Task

Participants read and practiced 45 trivial statements on the computer and practiced them audibly. Before they started, they were given the information on the computer screen that their entries would be erased. A pop-up message displayed the following message after every statement practice, “Your entry has been erased”

3.3.1.1.13 Recognition Erase Audio Learning Task

Upon hearing 45 audio statements individually from the computer, participants practiced them loudly. After each statement they saw the message “Your entry has been erased”

3.3.1.1.14 Recognition Erase Verbal Learning Task

Statements were given to participants in written form and they were asked to read each statement audibly. After each statement they saw the message “Your entry has been erased”

3.3.1.2 *N-back task*

Upon completing one of the eight learning tasks, every participant went through an N-back task. N-back is used to measure working memory (WM) capacity of individuals (Owen et. al., 2005). N refers to item that needs recalling, in this study, a letter that comes N item prior to it. 2-back means participant must react to a certain alphabet letter (target) given that it appeared previously exactly two letters ago. 2 and 3 back tasks were given as eight sets, first two of which were used for training. This task contained visual modality, in other words alphabet letters on a screen. Task started with some written briefing about the procedure followed by two training sets. As the task was found to be hard to comprehend in piloting, a video explaining the procedure was also given. Randomly picked letters appeared on the screen for 500ms with an interval of 2000ms that followed. The participants were instructed to click on the mouse on condition that they have seen the two or three preceding letters (2-Back or 3-Back). There were 18 letters in each set, six of which were correct and any other reaction were considered incorrect. After each set there was an interval of 20-second-break.

3.3.1.3 *Learning Task Assessment*

As stated, the rationale behind calling treatments as recall or recognition depended on the learning task assessment. The statements with a deleted word (options) that needs answers which do not have any clues to remember are called recall (cloze test) and the blanks that have clues as choices are called recognition (multiple choice) statements.

Participants were asked not the whole sentence but the key words from each statement. To clarify “Po is the longest river in Italy” and the key word is “Po”, the name of the river. The choice of the key words is not random. The original study by Güler and Irak (in press), includes general knowledge questions but not statements. Original study by her asked “What is the name of the longest river in Italy?”. The words answering the wh_ questions from the original study were taken as the key words since they comprise the semantic memory task data.

The options in the multiple choice test are not made up or phonetically similar words but real options with logical information. To give an example “Cheetah” is the key word in fastest running animal but choices also include fast animals. Recall and recognition statements are not different from each other but recognition is more in number, meaning recognition statements also comprises recall questions.

In spite of the sensory channel or save/erase treatment the test was common for all. For recall, participants had to remember and type the answer on the web site or leave it blank button, and for recognition they had to choose one of the 4 options given also they had the chance to select the “I don’t remember” option so that they would not make random selections that would contaminate the statistical data.

3.4 Limitations

The distribution of the participants were not balanced in terms of gender. There were 94 female and 18 male participants in Recall memory group as a whole group. There were 80 female and 25 male participants in Recognition memory group. Male participants comprise only about 25 % of the participants. This was not intentional but not full randomized either. The majority of the data came from one university and the ratio of the girls is also very similar to the ratio of the participants.

The loss of data from the participants was another issue. In addition to 218 participants, data from 119 participants were lost mostly due to unknown reasons. After piloting we added a comment page to receive feedback from participants about whether they problems during the experiment or not. Upon this addition web site did not work properly and we needed to remove it, this is why we do not know the exact reasons. Some left because they are bored, did not have microphone, or web site did not work properly. This meant we lost valuable data from 119 people which could have contributed with more results to analyze.

Initially the experiment was designed on a computer to work an offline software. After the pandemic breakout the students did not come back to school; therefore, everything needed to be transferred to online to gather data. There were two drawbacks of this transition. The first one was that the process was designed to be given on a computer in a Cognitive Psychology lab without any distractors like smart-phones, decoration, noise, accessibly to other web sites and live instruction. This has been important especially for N-Back task which requires a detailed instruction and attention of the novice participants. Having had to transfer everything onto an online system also brought about problems. Technological problems like the internet connection failure or reading the instructions on the computer rather than receiving them from an assistant face-to-face have emerged. Nonetheless, we can look at distraction issue from two perspectives. Negative one is that participants were in their usual environment so they might have been distracted by the other people around or the notifications on their phones. As stated earlier in this study the proximity to the personal phone affects performance significantly so the farther the phone is the better (Carolus et.al., n.d.). Positive side can be that as the focus of this study is to examine the effect of transactive memory while learning via technology, this natural environment may help reflect more realistic responses.

Owing to difficulty of reaching a high number of participants and technical problems, this study could not take measurements after some interval. Everything happened in one session. Admitting the participants to the test at a later time, like a week later, might have produced different results.

One of the studies about Google effect by Storm and Stone (2015) managed to replicate the effect when participants saved the information themselves onto the computer, like the study by Sparrow et. al., (2011) did, on condition that participants found the process reliable. Abovementioned studies indicated the use of reachable folders or files, either created by participants or the experimenters. Due to technical infrastructure of the online platform this manipulation was not possible. In this study we tried to create “save or erase” effect by displaying the message “the statement you entered is saved on Trivia folder” and “erase” effect by “the statements you entered is deleted from the computer” and all of them were given after each entry. The aim of this message was to ensure that participants believed statements were saved onto specific folder by creating an item-method directed forgetting. Lee (2021) defines directed forgetting by giving participants after each statement the cue to either “forget” or “remember” them. Groups which receive “forget” instruction remember the items less than the “remember” items. Save treatment was used to help transact participants’ memories to devices by believing that they do not need to remember as it will be accessible later, similar to forget instruction that they don’t need to remember.

This study also focused on creating a semantic memory task. Changing the tasks in a way that would foster episodic memory might have yielded different results and therefore provide a comparison between the memory types. During the learning phase the statements were divided according to their difficulty level and statements from 3 levels were used. Using statements from high difficulty level in the learning phase might have led to more significant results and give a better semantic memory measurement. Using more challenging semantic knowledge statements might have caused information overload and transaction effect might have been observed as the mind looks for ways to reduce the load via ways like using environment like cognitive offloading.

In the original face-to-face experiment design, a working memory task was thought be used so that it would give us the chance to compare the results obtained via N-Back and also the performance. However the online design itself has been very problematic in terms of coding and utilization since it required learners to do tasks beforehand like allowing the application to use microphone or using/installing Chrome browser.

Chapter 4
Results

Results of total 106 participants were not taken into account owing to the fact that they were not completed by the participants, additional 13 participants had missing information due to obstacles faced during data collection process online. The results are given in the following in three categories. First one includes the initial tests which show a. whether the groups are equally distributed in terms of cognitive load b. whether to use three or four sets of N-Back data set. The second analysis displays the N-Back results which measures the cognitive load. The third analysis show the performance results of eight different conditions.

4.1 Initial Tests

Two initial tests were used to determine the health of the data collected. In the first one a t-test was applied to observe if the groups were equally distributed in terms of cognitive load or working memory performance. In the second one a two-way multivariate analysis of variance (MANOVA) was conducted to see the disparities between three and four sets of N-back tasks. Participants were exposed to eight different strings of N-back task in which the first two string series (2-back and 3-back) were thought to be the training despite the fact that they were given explanation both in a video and written form just before the actual task started. They are called three sets because first two series of strings were disregarded and are called four sets because all of them are included.

4.1.1 Homogeneity of Cognitive Load Group Member Distribution

The n-back task in the study was used to measure cognitive load. First of all, group homogeneity needs to test that participants in different conditions are equal in terms of this performance. In order to observe the distribution of the groups in terms of their cognitive load scales, a series of analysis were applied.

4.1.1.1 *Comparison of 2 and 3 Back Conditions*

In the first phase of the analyses, in order to observe whether the groups were distributed homogenously in terms of their cognitive load, results based on conditions and their performance were analyzed. 2-back conditions and 3-back conditions were compared using paired t-tests. All of these t-tests indicated that participants displayed less correct responses in 3-back – being harder – than 2-back condition, -being easier- and cognitive load effect took place. Results also indicated that there were no differences among the groups (save, erase, audio and verbal) for both recall and recognition memory tasks in terms of cognitive load regardless of the conditions for all the groups in the performance tasks.

Recall memory correct response score was higher for 2-back (M = 7.21, SD = 2.09) than 3-back (M = 6.69, SD = 2.41) conditions; t (112) = 3.00, $p < 0.01$.

Recognition memory correct response score for 2-back (M = 7.53, SD = 1.92) was higher than recognition 3-back (M = 6.83, SD = 2.30) conditions; t (104) = 3.72, $p < 0.01$.

In addition for save treatment, number of correct response for 2-back condition (M = 7.60, SD = 1.69) was significantly higher than 3-back condition (M = 6.99, SD = 2.21) conditions; t (101) = 3.43, $p < 0.01$.

Also, for erase treatment, number of correct response for 2-back (M = 7.15, SD = 2.24) was significantly higher than 3-back (M = 6.56, SD=2.46) conditions; t (115) = 3.31, $p < 0.01$.

As for audio sensory channel, number of correct response for 2-back (M = 7.28, SD = 2.12) was higher than audio 3-back (M = 6.52, SD = 2.62); *t* (102) = 3.85, $p < 0.001$

Regarding the verbal sensory channel, the number of correct responses for 2-back (M = 7.44, SD = 1.91) was higher than verbal 3-back (M = 6.98, SD = 2.07); *t* (114) = 2.86, $p < 0.01$.

Table 3
Equality of Distribution Of Groups In Terms Of Cognitive Load Measured Via N-Back Task.

	RcMG*	RgMG**	Save	Erase	Audio	Verbal
2-Back	M = 7.21, SD = 2.09 n = 114	M = 7.53, SD = 1.92 n = 105	M = 7.60, SD = 1.69 n = 102	M = 7.15, SD=2.24 n = 116	M = 7.28, SD = 2.12 n = 103	M = 7.44, SD = 1.91 n = 115
3-Back	M=6.69, SD=2.41 n = 114	M = 6.83, SD = 2.30 n = 105	M=6.99, SD=2.21 n = 102	M=6.56, SD=2.46 n = 116	M = 6.52, SD = 2.62 n = 103	M = 6.98, SD = 2.07 n = 115

* Recall Memory Group
** Recognition Memory Group

4.1.1.2 *Comparison Between Groups 2X2 MANOVA Analysis*

In order to observe whether there are differences n-Back task performances among the experimental conditions of the study a 2 x 2 MANOVA was applied. Recall and recognition memory groups were analyzed separately, and dependent variables were number of correct responses for 2 and 3 back conditions.

For recall memory group, the main effect on save and erase treatment on 2-back $F\ (2, 108) = 1.60$, $p = .08$ and on 3-back responses $F\ (2, 108) = 1.60$, $p = .14$ were not significant.

However, there was a main effect in sensory channel (audio/verbal) $F\ (2, 11) = 3.71$, $p = .028$. Verbal sensory channel scores ($M = 7.56$, $SD = 1.78$) were higher than Audio sensory channel ($M = 6.83$, $SD = 2.33$) in 2-back correct scores. 3-back correct scores indicated similar results, Verbal sensory channel scores ($M = 7.25$, $SD = 2.05$) were higher than Audio sensory channel means ($M = 6.52$, $SD = 3.00$).

There is no interaction affect between the treatment (save / erase) and sensory channel (audio/verbal). $F\ (2, 108) = 1.30$, $p = .28$

Recognition group 2 and 3 back results analysis had no main effect between save and erase treatments $F\ (2, 100) = 4.05$, $p \geq .05$. Similarly, 2 and 3 back results had no main effect on sensory channel (audio/verbal) $F\ (2, 100) = .69$, $= p \geq .05$.

There is no interaction between the treatment (save / erase) and sensory channel. $F\ (2, 100) = 1.13$, $p = .23$

4.1.1.3 *Comparison Analysis of Correct and Incorrect Difference of 2 Back and 3 Back*

Another 2x2 MANOVA run to investigate effects of condition and treatment on the differences score between 2-back and 3-back for number of correct and incorrect responses. Analysis was conducted for recall and recognition memory tasks separately. Difference refers to subtraction of true 3-back scores from 2-back scores.

Recall memory groups correct and incorrect difference scores indicated no main effect in Treatment (save/erase) $F(2, 108) = .05$, $p = .95$, no main effect in Sensory channel (audio/verbal) $F(2, 108) = .691$, $p = .50$. There was also no interaction effect $F(2, 108) = 1.20$, $p = .30$

Recognition memory groups correct and incorrect difference scores indicated no main effect in Treatment (save/erase) $F(2, 100) = .287$, $p = .75$, no main effect in Sensory channel (audio/verbal) $F(2, 100) = .150$, $p = .86$. There was no interaction effect $F(2, 100) = 1.180$, $p = .31$

4.1.2 Selection of Three or Four Sets of N-back.

Participants were given total 8 N-back strings and four of them were 2-Back and four of them were 3-Back. The sequence was one string of 2-Back and then one string of 3-back and so forth. Originally first 2-Back and 3-Back were thought to be trainings for N-back. However, when three sets (three 2-Back and three 3-Back strings) and four sets (four 2-back and four 3-back strings) were compared, two-way MANOVA results for three and four sets indicated similar results in terms of significance. However, the Box's M Values of three-set were $p < 0.01$ Therefore, we decided to use four-set because the covariance matrices results were higher than 0.01 (Hahs-Vaughn, 2016; Field, 2009) in order to run a MANOVA. Box's covariance matrices for dependent variable (four-set results) are equal across groups. Two-back Correct Mean Time and Two-Back Incorrect Mean Time MANOVA tests revealed Box's M $p = 0.001$.

4.2 Measuring Cognitive Load

A 2 X 2 multivariate analysis of variance (MANOVA) was conducted to identify the effect of the treatment (audio/verbal), condition (save/erase) and for both memory tasks (recall and recognition) on the cognitive load. Dependent variables means value of number correct, number of incorrect and their reaction times for both 2-back and 3-back conditions.

4.2.1 Recall Memory N-back Analysis

The analysis covered 2-Back and 3-Back results which took number correct and incorrect answers and duration of correct incorrect responses.

4.2.1.1 *Recall 2-Back Correct – Incorrect Mean N-back Analysis*

The main effects of sensory channel (audio/verbal) ($p = .089$) and treatment (save/erase) ($p = .172$) on 2-back Correct mean scores were not significant.

There was no significant interaction effect between sensory channel (audio/verbal) and treatment (save/erase) on both 2-back Correct and Incorrect mean results, ($p = .103$)

However there is a significant difference between groups within sensory channel (audio/verbal). Verbal groups had higher means than audio group. In 2-back Correct mean analysis verbal group results ($M = 7.56$, $SD = 1.78$) were higher than audio group results ($M = 6.83$, $SD = 2.34$). Similarly, 2-back incorrect results indicated that verbal group results ($M = 14.07$, $SD = 3.59$) were higher than audio group results ($M = 12.63$, $SD = 4.41$).

Table 4

Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Mean And 2-Back Incorrect Mean

Variable	Treatment	Sensory channel	Mean	SD	n
2-Back Correct	erase	audio	6.67	2.51	27
		verbal	7.14	1.87	35
		Total	6.94	2.16	62
	save	audio	7.00	2.18	27
		verbal	8.17	1.49	24
		Total	7.55	1.96	51
	Total	audio	6.83	2.34	54
		verbal	7.56	1.78	59
		Total	7.21	2.09	113
2-Back Incorrect	erase	audio	11.67	4.60	27
		verbal	13.77	3.83	35
		Total	12.85	4.28	62
	save	audio	13.59	4.08	27
		verbal	14.50	3.24	24
		Total	14.02	3.70	51
	Total	audio	12.63	4.41	54
		verbal	14.07	3.59	59
		Total	13.38	4.05	113

Table 5

Effect Of Sensory Channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Means And 2-Back Incorrect Means

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Treatment	2-Back Correct Means	1	12.76	3.04	.08	.03
	2-Back Incorrect Means	1	48.83	3.00	.08	.03
Sensory Channel	2-Back Correct Means	1	18.70	4.46	.04	.04
	2-Back Incorrect Means	1	62.87	3.98	.05	.04
Treatment * Sensory channel	2-Back Correct Means	1	3.30	.79	.38	.00
	2-Back Incorrect Means	1	9.93	.63	.43	.00

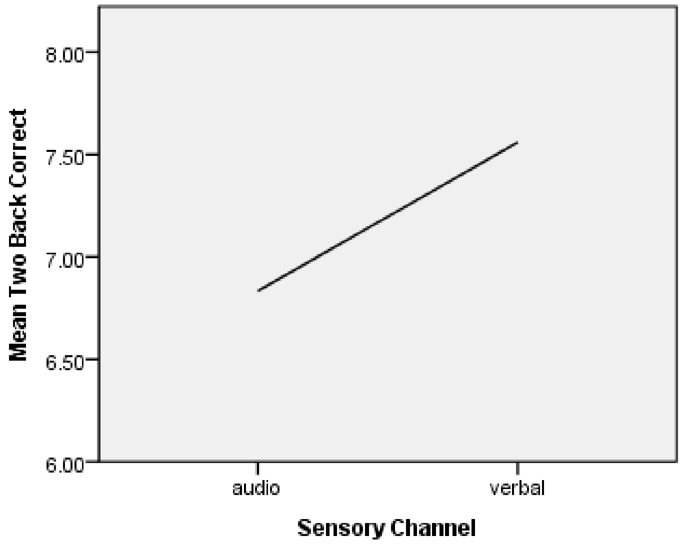

Figure 2. Difference Between Sensory Channel (audio/verbal) Stimulations in 2-Back Correct Answers

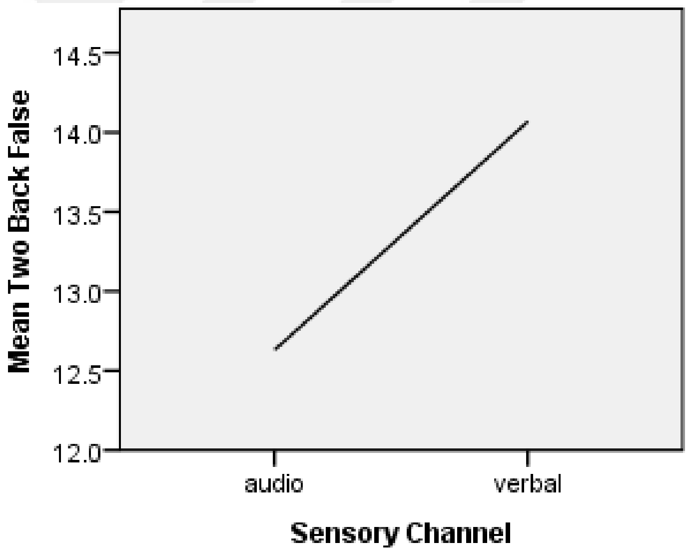

Figure 3. Difference Between Sensory Channel (audio/verbal) Stimulations in 2-Back Incorrect Mean

4.2.1.2 *Recall 2-Back Correct – Incorrect Mean Time N-back Analysis*

The main effect of treatment (save/erase) on 2-back mean time scores was not significant. F (2,108) = .79, p = .46

The main effect of Sensory channel (audio/verbal) had a main effect on 2-back mean times score was significant F (2, 108) = 3.83, p = .025. Results indicated that total scores Sensory channel in 2-back incorrect mean time (M =

417.40, SD = 167.08) were higher than total scores Sensory channel in 2-back correct mean time (M = 330.75, SD = 168.63)

There is no interaction effect between treatment (save/erase) and sensory channel (audio/verbal) F (2,108) = .28, p = .76

Table 6

Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Mean Time And 2-Back Incorrect Mean Time

Variable	Treatment	Sensory channel	Mean	SD	n
2-Back Correct Mean Time	erase	audio	324.55	176.10	27
		verbal	354.48	190.88	35
		Total	341.45	183.71	62
	save	audio	283.32	141.08	27
		verbal	356.47	151.11	24
		Total	317.74	149.04	51
	Total	audio	303.94	159.41	54
		verbal	355.29	174.39	59
		Total	330.75	168.64	113
2-Back Correct Mean Time	erase	audio	367.70	144.66	27
		verbal	449.38	152.88	35
		Total	413.81	153.66	62
	save	audio	378.93	159.65	27
		verbal	469.99	199.62	24
		Total	421.78	183.55	51
	Total	audio	373.32	151.00	54
		verbal	457.76	172.06	59
		Total	417.41	167.08	113

Table 7

Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Mean Time And 2-Back Incorrect Mean Time

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Treatment	2-Back Correct Mean Time	1	10673.20	.38	.54	.00
	2-Back Incorrect Mean Time	1	7026.66	.26	.61	.00
Sensory channel	2-Back Correct Mean Time	1	73623.47	2.60	.11	.02
	2-Back Incorrect Mean Time	1	206750.09	7.72	.01	.07
Treatment * Sensory channel	2-Back Correct Mean Time	1	12946.38	.46	.50	.00
	2-Back Incorrect Mean Time	1	610.76	.02	.88	.00

4.2.1.3 ***Recall 3-Back Correct – Incorrect Mean Analysis***

The main effect of treatment (save/erase) on 2-back mean scores was not significant. F 2, 108) = 1.34, p = .27

The main effect of Sensory channel (audio/verbal) had a main effect on 2-back mean times score was significant F (2, 108) = 3.63, p = .030. Results indicated that total scores Sensory channel in 3-back incorrect mean (M = 11.30, SD = 4.24) were higher than total scores Sensory channel in 3-back correct mean (M = 6.70 , SD = 2.41)

There is no interaction effect between treatment (save/erase) and sensory channel (audio/verbal) F (2, 108) = .56, p = .57)

Table 8

Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean And 3-Back Incorrect Mean

Variable	Treatment	Sensory channel	Mean	SD	n
3-Back Correct mean	erase	audio	5.67	2.22	27
		verbal	7.06	2.13	35
		Total	6.45	2.26	62
	save	audio	6.52	2.99	27
		verbal	7.54	1.93	24
		Total	7.00	2.58	51
	Total	audio	6.09	2.64	54
		verbal	7.25	2.05	59
		Total	6.70	2.41	113
3-Back Incorrect mean	erase	audio	9.63	4.04	27
		verbal	11.80	4.30	35
		Total	10.85	4.30	62
	save	audio	11.59	4.58	27
		verbal	12.13	3.65	24
		Total	11.84	4.14	51
	Total	audio	10.61	4.39	54
		verbal	11.93	4.02	59
		Total	11.30	4.24	113

Table 9
Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean And 3-Back Incorrect Mean

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Treatment	3-Back Correct mean	1	12.38	2.25	.14	.02
	3-Back Incorrect mean	1	36.27	2.07	.15	.02
Sensory channel	3-Back Correct mean	1	40.37	7.33	.01	.06
	3-Back Incorrect mean	1	50.62	2.89	.09	.03
Treatment * Sensory channel	3-Back Correct mean	1	.93	.17	.68	.00
	3-Back Incorrect mean	1	18.59	1.06	.30	.01

4.2.1.4 *Recall 3-Back Correct Meantime – Incorrect Meantime Analysis*

The main effect of treatment (save/erase) on 2-back mean time scores was not significant. F (2, 108) = .815, p = 45

The main effect of Sensory channel (audio/verbal) had a main effect on 2-back mean times score was marginally significant F (2, 108) = 3.00, p = .054. Results indicated that total scores Sensory channel in 3-back incorrect mean time (M = 711.28, SD = 257.09) were higher than total scores Sensory channel in 3-back correct mean time (M = 342.04 , SD =.178.32)

There is no interaction effect between treatment (save/erase) and sensory channel (audio/verbal) F (2, 108) = .572, p = 57

Table 10
Descriptive Statistics For The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean Time And 3-Back Incorrect Mean Time

Variable	Treatment	Sensory channel	Mean	SD	n
3-Back Correct Mean Time	erase	audio	274.86	140.68	27
		verbal	382.00	187.53	35
		Total	335.34	175.80	62
	save	audio	329.76	201.61	27
		verbal	373.15	160.09	24
		Total	350.18	182.77	51
	Total	audio	302.31	174.40	54
		verbal	378.40	175.49	59
		Total	342.04	178.32	113

Table 10 (con)

Variable	Treatment	Sensory channel	Mean	SD	n
3-Back Incorrect Mean Time	erase	audio	646.24	245.73	27
		verbal	778.09	270.27	35
		Total	720.67	266.07	62
	save	audio	655.58	215.66	27
		verbal	749.67	275.85	24
		Total	699.86	247.86	51
	Total	audio	650.91	229.04	54
		verbal	766.53	270.54	59
		Total	711.28	257.09	113

Table 11
Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean Time And 3-Back Incorrect Mean Time

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Treatment	3-Back Correct Mean Time	1	14692.76	.48	.49	.00
	3-Back Incorrect Mean Time	1	2523.81	.04	.84	.00
Sensory channel	3-Back Correct Mean Time	1	157020.82	5.10	.03	.04
	3-Back Incorrect Mean Time	1	353748.45	5.50	.02	.05
Treatment * Sensory channel	3-Back Correct Mean Time	1	28169.98	.91	.34	.01
	3-Back Incorrect Mean Time	1	9881.26	.15	.70	.00

4.2.2 Recognition Memory N-back Analysis

4.2.2.1 *Recognition 2-Back Correct – Incorrect Mean N-back Analysis*

The main effect of treatment (save/erase) on 2-back mean scores was not significant. $F(2,100) = .205$, $p = .82$

The main effect of sensory channel (audio/verbal) on 2-back mean scores was not significant. $F(2,100) = 1.401$, $p = .25$

There is no interaction effect between treatment (save/erase) and sensory channel (audio/verbal) $F(2,100) = .605$, $p = .55$

Table 12

Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Mean And 2-Back Incorrect Mean

Variable	Treatment	Sensory channel	Mean	SD	n
2-Back Correct Mean	erase	audio	7.76	2.18	25
		verbal	7.10	2.43	29
		Total	7.41	2.32	54
	save	audio	7.79	1.22	24
		verbal	7.56	1.55	27
		Total	7.67	1.40	51
	Total	audio	7.78	1.76	49
		verbal	7.32	2.05	56
		Total	7.53	1.92	105
2-Back Incorrect Mean	erase	audio	14.72	4.65	25
		verbal	12.62	3.71	29
		Total	13.59	4.26	54
	save	audio	14.21	2.77	24
		verbal	13.78	4.12	27
		Total	13.98	3.52	51
	Total	audio	14.47	3.81	49
		verbal	13.18	3.92	56
		Total	13.78	3.91	105

Table 13

The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Mean And 2-Back Incorrect Mean

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Sensory channel	2-Back Correct Means	1	1.53	.41	.52	.00
	2-Back Incorrect Means	1	2.72	.18	.67	.00
Treatment	2-Back Correct Means	1	5.20	1.40	.24	.01
	2-Back Incorrect Means	1	41.78	2.78	.10	.03
Sensory channel * Treatment	2-Back Correct Means	1	1.15	.31	.58	.00
	2-Back Incorrect Means	1	18.18	1.21	.27	.01

4.2.2.2 *Recognition 2-Back Correct – Incorrect Mean Time N-back Analysis*

The main effect of treatment (save/erase) on 2-back mean time scores was not significant. $F(2, 100) = .692$, $p = .50$

The main effect of sensory channel (audio/verbal) ($p = .89$) on 2-back mean time scores was not significant. $F(2, 100) = .121$, $p = .89$

There is no interaction effect between treatment (save/erase) and sensory channel (audio/verbal) $F(2, 100) = 2.619$, $p = .08$

Table 14

The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Mean Time And 2-Back Incorrect Mean Time

Variable	Treatment	Sensory channel	Mean	SD	n
2-Back Correct Mean Time	erase	audio	359.70	178.95	25
		verbal	303.08	154.84	29
		Total	329.29	167.27	54
	save	audio	263.63	109.28	24
		verbal	333.90	107.89	27
		Total	300.83	113.14	51
	Total	audio	312.64	155.20	49
		verbal	317.94	133.98	56
		Total	315.47	143.59	105
2-Back Incorrect Mean Time	erase	audio	420.32	162.88	25
		verbal	375.63	148.09	29
		Total	396.32	155.26	54
	save	audio	365.82	105.76	24
		verbal	398.16	140.42	27
		Total	382.94	125.15	51
	Total	audio	393.62	139.22	49
		verbal	386.49	143.58	56
		Total	389.82	140.93	105

Table 15

The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 2-Back Correct Mean Time And 2-Back Incorrect Mean Time

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Treatment	2-Back Correct Mean Time	1	27786.01	1.39	.24	.01
	2-Back Incorrect Mean Time	1	6670.86	.33	.56	.00

Table 15 (con)

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Sensory channel	2-Back Correct Mean Time	1	1217.92	.06	.81	.00
	2-Back Incorrect Mean Time	1	995.11	.05	.82	.00
Treatment * Sensory channel	2-Back Correct Mean Time	1	105112.80	5.26	.02	.05
	2-Back Incorrect Mean Time	1	38727.98	1.94	.17	.02

4.2.2.3 *Recognition 3-Back Correct – Incorrect Mean N-back Analysis*

The main effect of treatment (save/erase) on 2-back mean scores was not significant. F (2, 100) = .47, p = .63

The main effect of sensory channel (audio/verbal) (p = .37) on 2-back mean scores was not significant. F (2, 100) = 100, p = .37

There is no interaction effect between treatment (save/erase) and sensory channel (audio/verbal) F (2, 100) = 1.835, p = .16

Table 16
The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean And 3-Back Incorrect Mean

Variable	Treatment	Sensory channel	Mean	SD	n
3-Back Correct Mean	erase	audio	6.68	3.06	25
		verbal	6.72	2.40	29
		Total	6.70	2.70	54
	save	audio	7.33	1.88	24
		verbal	6.67	1.73	27
		Total	6.98	1.82	51
	Total	audio	7.00	2.55	49
		verbal	6.70	2.09	56
		Total	6.84	2.31	105
3-Back Incorrect Mean	erase	audio	12.60	3.67	25
		verbal	10.90	4.12	29
		Total	11.69	3.98	54
	save	audio	11.79	2.73	24
		verbal	11.44	4.05	27
		Total	11.61	3.46	51
	Total	audio	12.20	3.24	49
		verbal	11.16	4.06	56
		Total	11.65	3.72	105

Table 17
Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean And 3-Back Incorrect Mean

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Treatment	3-Back Correct Means	1	2.32	.43	.51	.00
	3-Back Incorrect Means	1	.44	.03	.86	.00
Sensory channel	3-Back Correct Means	1	2.53	.47	.50	.00
	3-Back Incorrect Means	1	27.45	1.98	.16	.02
Treatment * Sensory channel	3-Back Correct Means	1	3.30	.61	.44	.01
	3-Back Incorrect Means	1	12.01	.87	.35	.01

4.2.2.4 *Recognition 3-Back Correct – Incorrect Mean Time N-back Analysis*

The main effect of treatment (save/erase) on 2-back mean time scores was not significant. F (2, 100) = .43, p = 65

The main effect of sensory channel (audio/verbal) on 2-back mean time scores was not significant. F (2, 100) = 1.066, p = 35

There is no interaction effect between treatment (save/erase) and sensory channel (audio/verbal) F (2, 100) = .089, p = 35

Table 18
Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean Time And 3-Back Incorrect Mean Time

Variable	Treatment	Sensory channel	Mean	SD	n
3-Back Correct Mean Time	erase	audio	309.24	140.83	25
		verbal	334.18	140.66	29
		Total	322.64	139.97	54
	save	audio	319.04	101.13	24
		verbal	366.02	155.10	27
		Total	343.91	133.32	51
	Total	audio	314.04	121.83	49
		verbal	349.53	147.32	56
		Total	332.97	136.54	105

Table 18 (con)

Variable	Treatment	Sensory channel	Mean	SD	n
3-Back Incorrect Mean Time	erase	audio	653.18	204.69	25
		verbal	692.51	271.36	29
		Total	674.30	241.38	54
	save	audio	637.47	172.07	24
		verbal	703.17	237.27	27
		Total	672.26	209.74	51
	Total	audio	645.49	187.62	49
		verbal	697.65	253.24	56
		Total	673.31	225.49	105

Table 19

The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On 3-Back Correct Mean Time And 3-Back Incorrect Mean Time

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Treatment	3-Back Correct Mean Time	1	11317.11	.60	.44	.01
	3-Back Incorrect Mean Time	1	166.42	.00	.95	.00
Sensory channel	3-Back Correct Mean Time	1	33768.34	1.80	.18	.02
	3-Back Incorrect Mean Time	1	72020.02	1.40	.24	.01
Treatment * Sensory channel	3-Back Correct Mean Time	1	3173.89	.17	.68	.00
	3-Back Incorrect Mean Time	1	4538.83	.09	.77	.00

4.2.3 Comparison of N-Back High and Low Achievers with Performance Scores

One way MANOVA was conducted to observe whether there are differences between n-back high and low achievers in terms of performance. Upon the calculation of mean scores in N-Back (2 and 3 Back) participants were grouped as high and low achievers and they are used as independent variables. High achievers scored above the average, and low achievers scored below the average. 2-Back and 3-Back high and low achievers were calculated and analyzed separately. Dependent variables were number of correct performance answers, number of incorrect performance answers, mean reaction time of correct answers (milliseconds), mean reaction time of incorrect answers (milliseconds) of both Recall and Recognition memory.

Recall memory tasks did not indicate any differences. There was no significant difference between 2-back high and low achievers in any of the recall memory performance task number of correct answers, number of in correct answers, mean reaction time of correct and mean reaction time of incorrect answers. $F (3, 109) = 2.064$, $p = \geq .05$

Similarly, there was no significant difference between 3-back high and low achievers in terms of recall memory performance task number of correct answers, number of in correct answers, mean reaction time of correct and mean reaction time of incorrect answers. $F (3, 109) = .546$, $p = \geq .05$

However, recognition memory tasks indicated difference. There was significant difference between 2-Back high and low achievers in terms of recognition memory correct answers and recognition memory incorrect answers $F (3, 101) = 3.176$, $p \leq .01$ but no difference in terms of correct and incorrect answer reaction times. $F (3, 101) = 3.176$, $p \geq .05$

Table 20

Effect of High and Low N-Back Acievers on Recognition Memory Number of Correct, Incorrect Answers and Correct Incorrect Reaction Time for 2-Back Group.

2-Back Recognition Groups	High / Low	Mean	SD	n
RgMIA*	low (< M=7.37)	5.03	4.50	35
	high (> M=7.38)	2.84	2.93	70
	Total	3.57	3.66	105
RgMCA**	low (< M=7.37)	39.97	4.50	35
	high (> M=7.38)	42.16	2.93	70
	Total	41.43	3.66	105
RgMCRMT***	low (< M=7.37)	5623.14	2187.77	35
	high (> M=7.38)	5670.83	1583.18	70
	Total	5654.93	1796.72	105
RgMIRMT****	low (< M=7.37)	8433.31	5806.90	35
	high (> M=7.38)	9110.50	7426.37	70
	Total	8884.77	6907.77	105

*Recognition Memory Number of Incorrect Answers
** Recognition Memory Number of Correct Answers
***Recognition Memory Correct Answer Reaction Time Mean
**** Recognition Memory Incorrect Answer Reaction Time Mean

Table 21

Effect of High and Low Achievers On For Recognition Memory Number of Correct, Incorrect Answers and Correct, Incorrect Reaction Time for 2-Back Group.

Source	Dependent Variable	df	MS	F	Sig.
2-Back Recognition	RgMIA*	1	111.47	8.95	0.00
Groups	RgMCA**	1	111.47	8.95	0.00
	RgMCRMT***	1	53058.30	0.02	0.90
	RgMIRMT****	1	10700211.47	0.22	0.64

*Recognition Memory Number of Incorrect Answers
** Recognition Memory Number of Correct Answers
***Recognition Memory Correct Answer Reaction Time Mean
**** Recognition Memory Incorrect Answer Reaction Time Mean

Similar results were produced in 3-Back recognition memory task. There was significant difference between 3-Back high and low achievers in terms of recognition memory correct answers and recognition memory incorrect answers $F(3, 101) = 2.208$, $p \leq .05$ but no difference in terms of correct and incorrect answer reaction times $F(3, 101) = 2.208$, $p \geq .05$ (Table 23)

2-Back and 3-Back high achievers displayed higher correct scores in the recognition memory performance task and 2-Back and 3-Back low achievers had higher incorrect scores in the recognition memory task, which shows that N-back scores are an indicator of degree of performance for the recognition memory tasks.

Table 22

Descriptive Statistics Effect of N-back High and Low Achievers For Recognition Memory Number of Correct, Incorrect Answers and Correct, Incorrect Reaction times for 3-Back Group.

3-Back Recognition Groups	High & Low	Mean	SD	n
RgMIA*	Low (< M = 7)	4.20	4.16	59
	High (> M = 7.01)	2.76	2.74	46
	Total	3.57	3.66	105
RgMCA**	Low (< M = 7)	40.80	4.16	59
	High (> M = 7.01)	42.24	2.74	46
	Total	41.43	3.66	105

Table 22 (con)

3-Back Recognition Groups	High & Low	Mean	SD	n
RgMCRMT***	Low (< M = 7)	5527.83	1707.21	59
	High (> M = 7.01)	5817.96	1912.02	46
	Total	5654.93	1796.72	105
RgMIRMT****	Low (< M = 7)	9450.88	6639.43	59
	High (> M = 7.01)	8158.67	7245.96	46
	Total	8884.77	6907.77	105

*Recognition Memory Number of Incorrect Answers
** Recognition Memory Number of Correct Answers
***Recognition Memory Correct Answer Reaction Time Mean
**** Recognition Memory Incorrect Answer Reaction Time Mean

Table 23
Effect of N-back High and Low Achievers For Recognition Memory on Number of Correct, Incorrect Answers and Correct, Incorrect Reaction times for 3-Back Group.

Source	Dependent Variable	df	MS	F	Sig.
3-Back Recognition Groups	RgMIA*	1	53.79	4.13	0.04
	RgMCA**	1	53.79	4.13	0.04
	RgMCRMT***	1	2175674.32	0.67	0.41
	RgMIRMT****	1	43160356.24	0.90	0.34

*Recognition Memory Number of Incorrect Answers
** Recognition Memory Number of Correct Answers
***Recognition Memory Correct Answer Reaction Time Mean
**** Recognition Memory Incorrect Answer Reaction Time Mean

4.3 Recall and Recognition Memory Performance Tests

Recall test refers to the blanks in questions where students need to remember the answers and write them into the box. Minor spelling mistakes (e.g. dermatology - dermotolog, Antarktika - Antartika) in answers were accepted if they did not change the meaning.

For recognition memory task, participants completed a recognition test in which each question was presented along with four alternatives, additionally "I don't remember" button was added to avoid false positive results.

4.3.1 Recall and Recognition T-test Comparison

In order to see whether there was a difference between recognition and recall performance scores, an independent t-test was applied. It was hypothesized that participants would give more correct answers in recognition task than recall task questions as recognition requires less mental effort due to four choices given. The problem prior to analysis was that Recognition had 45 questions, whereas Recall had 30. In order to normalize the numbers to be able to compare, the number of correct answers were divided by the total number of questions, which is called relative frequency calculation. Results show that participants had more correct responses in recognition tests (M = 92.06, SD = 8.14) than recall tests (M = 70.62, SD = 16.69), t (216) = 11.91, p = .000

Table 24
Test Type Comparison of Results (Recall / Recognition)

	Test Type	N	Mean	SD	Std. Error Mean
Correct	recognition	105	92.06	8.13	.79
answers	recall	113	70.62	16.69	1.57

4.3.2 Recall and Recognition Analysis

The second research question aimed to observe whether condition (save / erase) and treatment (verbal / auditory) had effects on performance in free recall and recognition memory performances. 2x2 Two-way MANOVA was used to analyze the results separately for recall and recognition since they contain disparate results.

4.3.2.1 *Recall Memory Performance Analysis*

A 2 x 2 two-way MANOVA analysis revealed that there is no main effect in terms of sensory channel (audio / verbal), similarly no main effect was observed in treatment (save / erase).

There was an interaction effect between sensory channel (audio / verbal) and treatment (save / erase) on Correct Mean Time scores $F(2, 108) = 3.950$, $p = .022$

Despite the fact that there was no main effect in treatment, there was a difference between save ($M = 22.37$, $SD = 4.94$) and erase ($M = 20.21$, $SD = 4.89$) treatment in terms of number of correct answers., $p = .03$

Table 25

Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On Number of Recall Memory Correct And Recall Memory Reaction time Mean of Correct Answers

Variable	Sensory channel	Treatment	Mean	SD	n
Recall Memory Number of Correct	audio	erase	21.15	4.40	27
		save	22.67	5.17	27
		Total	21.91	4.81	54
	verbal	erase	19.49	5.18	35
		save	22.04	4.77	24
		Total	20.53	5.13	59
	Total	erase	20.21	4.89	62
		save	22.37	4.94	51
		Total	21.19	5.01	113
Recall Memory Reaction Time Mean of Correct	audio	erase	12284.37	6676.96	27
		save	8949.11	3822.10	27
		Total	10616.74	5645.37	54
	verbal	erase	9536.09	3931.90	35
		save	11420.42	5318.77	24
		Total	10302.59	4599.17	59
	Total	erase	10732.92	5431.97	62
		save	10112.08	4707.59	51
		Total	10452.72	5104.92	113

Table 26

The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On Number of Correct Recall And Reaction time Mean of Correct Recall

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Sensory channel	RcMCA**	1	36.26	1.50	.22	.01
	RcMCRMT***	1	531607.43	.02	.88	.00
Treatment	RcMCA**	1	115.04	4.77	.03	.04
	RcMCRMT***	1	14587771.51	.59	.45	.01
Treatment * Sensory channel	RcMCA**	1	7.46	.31	.58	.00
	RcMCRMT***	1	188786033.13	7.58	.01	.07

** Recall Number of Correct Answers

*** Recall Reaction time Mean of Correct Answers

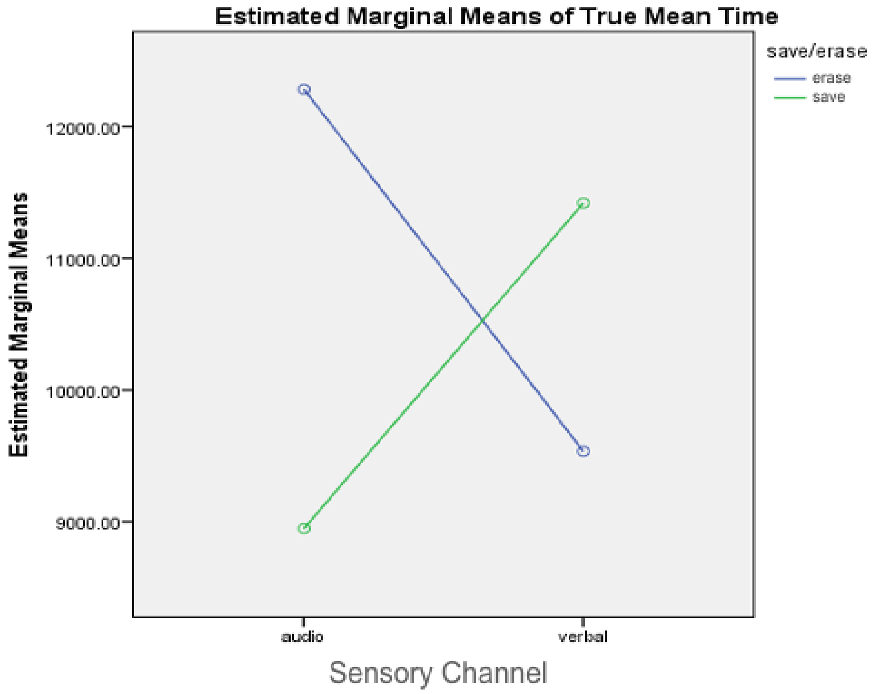

Figure 4. Interaction Effect of in Sensory Channel (Audio / Verbal) Reaction Time Mean Of Correct in Recall Memory Performance

4.3.2.2. Recognition Memory Performance Analysis

A 2 X 2 two-way MANOVA analysis did not reveal a main effect on sensory channel (audio / verbal). However there was a main effect in treatment (save / erase) F (2, 100) = 4.369, p = 0.15. Correct recognition reaction time results of erase treatment (M = 5971.68, SD = 1782.24) is higher than that of save treatment (M = 5145.90, SD = 1598.86)

There was no interaction effect between sensory channel (audio / verbal) and treatment (save / erase).

Table 27

The Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On Recognition Memory Number of Correct Answers And Recognition Memory Correct Answer Reaction Time Mean

Variable	Sensory channel	Treatment	Mean	SD	n
*RgMCA**	audio	erase	40.68	3.93	25
		save	41.38	4.11	24
		Total	41.02	3.99	49
	verbal	erase	40.97	4.00	29
		save	42.67	2.20	27
		Total	41.79	3.34	56
	Total	erase	40.83	3.93	54
		save	42.06	3.27	51
		Total	41.43	3.66	105
*RgMCRMT***	audio	erase	6172.16	1832.88	25
		save	5491.50	1791.56	24
		Total	5838.78	1826.44	49
	verbal	erase	5798.86	1751.03	29
		save	4838.70	1366.93	27
		Total	5335.93	1636.64	56
	Total	erase	5971.69	1782.24	54
		save	5145.90	1598.86	51
		Total	5570.59	1737.74	105

* Recognition Memory Number of Correct Answers

** Recognition Memory Correct Answer Reaction Mean Time

Table 28

Effect Of Sensory channel (Audio/Verbal) And Treatment (Save/Erase) On Recognition Memory Number of Correct Answers And Recognition Memory Correct Answer Reaction Time Mean

Source	Dependent Variable	df	MS	F	Sig.	Partial Eta Squared
Sensory channel	*RgMCA**	1	16.24	1.23	.27	.01
	*RgMCRMT***	1	6873122.78	2.40	.12	.02
Treatment	*RgMCA*	1	37.48	2.84	.09	.03
	RgMCRMT	1	17575214.33	6.14	.01	.06
Treatment * Sensory channel	*RgMCA*	1	6.61	.50	.48	.00
	RgMCRMT	1	509962.40	.18	.67	.00

* Recognition Memory Number of Correct Answers

** Recognition Memory Correct Answer Reaction Mean Time

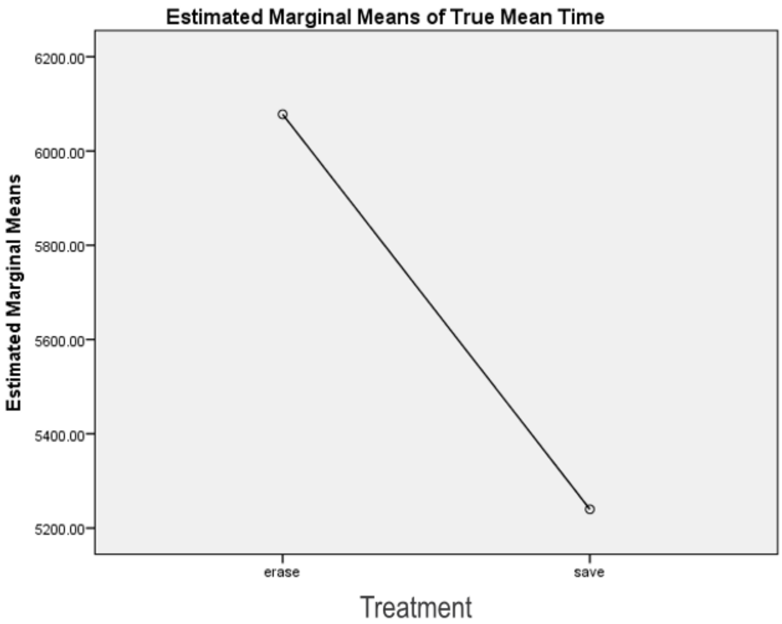

Figure 5. Main effect of recognition test treatment (save / erase) correct mean time

4.4 Correlation Analysis of Performance and Self-Evaluation Scores

Prior to the actual tasks, participants were asked three more additional questions on the web page where they entered the demographic information. The questions were a. how well is your attention? b. how well is your memory? c. how well do you think you will remember the statements given to you? Question A is referred as Belief about Attention (BaA), question B is referred as Belief about Memory (BaM) and question C is referred as Prospective Memory (PM) in the analysis below. Participants gave their answers using with a slider scale which had no numbers or signs on it and were asked to move the slider to the right side if they wanted to give higher scores for themselves. Their score invisible slide moves created scores out of ten with decimals for the research. First two questions helped the students to introspect and reflect on their general attention and memory beliefs; however, the last one was a prospective memory question. Recall and Recognition scores were analyzed separately.

None of the three self-evaluation scores of participants indicated a correlation in recognition test; however, all of the three self-evaluation scores were correlated with their recall test results.

4.4.1 Correlation between BaA, BaM, and PM scores for Recognition Memory Task Performance

As shown in Table 3, participants had more correct answers in recognition questions than recall questions. A Pearson product-moment correlation coefficient was conducted to test the relationship between recognition memory number of correct responses and BaA, BaM, and PM scores. There were no correlations between recognition correct responses and attention, recognition correct responses and memory, and recognition correct responses and prospective memory.

4.4.2 Correlation between BaA, BaM, and PM scores for Recall Memory Task Performance

There was a positive correlation between recall performance test true mean scores (RTM) and BaM r = 0.27, n = 113, p = 0.004. There was a positive correlation between recall true mean scores and memory r = 0.34, n = 113, p = 0.000. There was a positive correlation between recall true mean scores and prospective memory r = 0.28, n = 113, p = 0.003.

Table 29
Recall Memory Correlations Between Recall Group Performance Test Correct Mean and Attention, Memory, Prospective Memory

	BaA**	BaM***	PM****	NoCRc*****
BaA**	.	.53*	.59*	.27*
BaM***		.	.77*	.34*
PM****			.	.28*
NoCRc*****				.

* p < .01
**BaA – Belief about Attention
***BaM – Belief about Memory
**** PM – Prospective Memory
***** NoCRc Number of Correct Recall

Chapter 5
Discussion and Conclusion

5.1 Discussion

This study aimed to investigate how having the information at the fingertips, alias Google Effect by save and erase treatment, impacts learning given via two sensory channels (verbal and auditory). This study also looked upon the effect of these channels while observing the cognitive load levels of learners and the relationship between the cognitive load and performance.

The results did not confirm the hypotheses made for this study; therefore, they are discussed in two categories N-back and Learning and Memory. The studies that helped shape the hypotheses were not replicated

Results indicated that all the groups had homogenous distribution in terms of cognitive load. 3-Back load is harder to detect than 2-Back and less correct reactions are given by participants in this study. This a good indicator that the groups are cognitively loaded by the task and memory capacity of the groups is not superior or inferior than each other. This is important to ensure the accurate results about the memory. The most significant results were expected in memory performance scores. Better scores were hypothesized to be obtained from Erase treatment in both recall and recognition performance tests in alignment with the foundations of this study by Sparrow et al. (2011)

5.1.1 N-Back

Because of the number difference of statements in recall memory (30) and recognition (45) it might be a question whether 45 statements caused participants to be more cognitively loaded than 30 statements. This study found no difference between recall and recognition groups in terms of cognitive load when made an overall comparison. It is noteworthy to add that this has not been a focus of the study. My study focused on recall and recognition individually because they are different memory models and contained different performance tests both in terms of type and number of questions asked and also statements to be rehearsed. But both groups took the same N-Back task. The main aim of the

N-back task was to create additional load between the learning phases and memory performance tests.

N-Back measurements are the initial findings to be discussed, in the next step we will discuss the memory performance results.

Regarding the N-back analysis some interesting findings were revealed. Similar to the results above Erase group was expected to display higher cognitive load as erase manipulation was thought to create an effect that would force the participants allocate more mental effort. Save process was thought to reduce load since this save process creates a cognitive offloading which decreases the demands on memory (Risko & Gilbert, 2016) because participants believed they could access to learnt materials if they needed. However, no such results were observed in either Recall or Recognition groups in terms of Save and Erase. Therefore, it can be concluded that Save and Erase manipulation did not impose a cognitive load on the learners.

In addition, Audio stimulation was also thought to have more load than Verbal, because it is harder to process. Cohen (2009) indicated that visual memory is better than auditory in recognition; whereas, there were no significant differences in Audio and Verbal in recognition memory in this study. Three significant main effects observed in Verbal and Audio sensory channels were in 2-Back True/False mean time and 3-Back True N-back and 3-Back True/False mean time scores of Recall memory. They were higher for Verbal sensory channel than Audio in Recall memory group. Recall memory Verbal sensory channel scores were consistent with Cohen (2009) that visual memory is superior to audio in all N-Back scores. Despite not having a main effect, 2-Back True/False scores were significantly higher for Verbal than Audio. An unexpected result was that Verbal sensory channel scores were higher in all of the Recall memory N-back measurements, it was higher in correct, incorrect, correct reaction time and incorrect reaction time. True and False scores are correlated in a knowledge test but in N-Back they are not so this might be expected. This N-back result did not have a projection on memory performance scores.

In order to observe whether there was a difference between the N-Back and recall, recognition memory performance scores analyses were run. After N-back mean scores were calculated, the ones below the mean score was named as low achievers and others are named high achievers. Recall memory group N-Back high and low achievers indicated no difference on performance and also reaction time of response. However, Recognition memory group N-Back and performance scores yielded different results than that of recall memory group. When participants were grouped as high and low achievers according to their N-back performances, a significant difference between 2-Back and 3-Back high and low achievers and their performance scores was observed. High achievers in these two groups had more correct answers than low achievers. Reaction time difference was not significant. This may be an indicator that N-Back is a tool that helps predict the recognition memory performances in terms of high and low N-Back achievers. On the other hand, upon observing the difference between high and low achievers' scores a Pearson correlation test was run with all N-back results regardless of achievement level and it indicated that Recognition memory performance scores were correlated with 2-Back and 3-Back scores but Recall memory performance scores were not correlated with both 2-Back and 3-Back scores. Despite the fact that high and low scorers in N-back conditions helped predict the Recognition performance, no such effect was observed in terms of Recognition and N-back correlation. Goldstein (2014) mentioned a study by Beilock and Carr (2005) in which they grouped participants as low and high working memory and it was seen that high working memory group performance decreased to the same level as low working memory under pressure. When piloted participants completed the tasks in my study around 40 minutes, many under 40 minutes but an online meeting was held with them about the steps and they also chose their time to complete them. In the experiment from one of the three universities from which the majority of the results were obtained from, students were admitted to the experiment before lunch time. When the instructions and password sharing included, participants started experiment about 10 or 15 minutes later and this might have created a kind of pressure on them to hurry up and have their breaks as soon as possible.

5.1.2 Learning and Memory

Regarding the recall and recognition memory test performance results, comparison analyses indicated no significant main effect in Save and Erase treatments in both Recall and Recognition memory groups in terms of correct answers in performance tests. The only difference in Recognition memory was in reaction time between save erase treatment and erase treatment group answered questions in a longer reaction time, which was on the contrary of what was expected. Erase treatment group was thought to answer more quickly because they were believed to have out more mental effort while learning.

In Recall memory although there was no significant main effect of save and erase, pairwise results indicated a significant difference between save and erase only. But the results did not support Google effect and save treatment group had higher number of correct answers. However, based on Google Effect theory that people remember more if they think the information will be deleted and be unavailable, more correct answers were expected for erase group since they were believed they needed to keep things more in mind. The number of correct answers were expected to be higher and reaction time to answer to be lower. Some studies like Friede's (2013) failed to replicate Google effect and another study (Schooler & Storm, 2021) about the Google effect found that one reason that it fails to replicate could be due to the fact that people remember erased information more on condition that they think the process can be relied on. This phenomenon is discussed in detail below.

Another perspective came from a study which tried to replicate the results from Google Effect and they found out the similar results that people remember the information better if they think it will be erased. Nevertheless, replicated study by Schooler and Storm (2021) put forward that Google Effect occur on condition that participants think the saving step is seen as trustworthy. To summarize in order for save process to be more detrimental people needed to rely on the media they are saving the information to. We believe that we did not violate this case as our experiment was given online and participants used their own computers, which can be trusted because they were their own property. Yet, there might be one concern regarding this issue, although the interface kept reminding participants that statements were saved onto the computer into a folder named Trivia, they did not see or create folder, thus might have considered it undependable so it is questionable what reliability or trustworthiness of the devices are about. Having not been given a folder beforehand might have created the feeling of insecurity about where that trivia folder is located on the computer. As computer users, they might have expected a folder to appear for them to save as if they are downloading files or folders from the internet. The original experiment was designed to be given in a lab and after each step participants would save the results on the computer; however, the experiment needed to be carried out online due to pandemic and lack of participants in the physical institution. Transactive memory also suggest that the person to be interacted should be reliable in order for information transaction to take place. Therefore, it can be said that reliability issue is not only for the tech devices but for the people as well. Vygotsky also made emphasis on more knowledgeable others (MKO) who will lead you the way in your zone of proximal development (Doolittle, 1991). Today this MKO can also be a computer or a kind of electronic performance support systems which will assist the learner to discover or construct knowledge. Hence, the media or the person must have qualities that make it trusted. In addition to this, motive to learn might differ, to exemplify a teacher saying the students that one specific topic will be covered in the examination and an experiment telling the participants that they will later be asked given statements create different motivation. Soderstorm and Bjork (2015) indicated that, in terms of verbal information, being tested plays a role as a kind of retrieval practice that helps modify knowledge in the head. Therefore, a delayed test, like a week, in this experiment might have produced different scores.

The difference between Save and Erase treatments in Recall memory test can be looked upon from another perspective. The participants received statements via two different sensory channels in those treatment groups. When sensory stimulants were ignored Save and Erase treatment indicated significant difference. Yet, we can look at from encoding specificity perspective (Tulving & Thompson, 1973) which asserts that the way information is encoded, or the cues provided help the way it is recalled. The diver study by Godden and

Baddeley (1980) found out that the environment plays a role in remembering the information later, participants who learnt items underwater scored better underwater than on land. We used an intrinsic context (Hewitt, 1977), features of stimulants like the letters and voice, to make sure participants are exposed to the Save or Erase stimulants. Despite the fact that encoding specificity might have had an effect in Save and Erase condition, it fails to explain why Audio and Verbal stimulants did not yield a difference. Verbal group had verbal questions however Audio group did not receive auditory questions but verbal questions, which had no effect on Recall or Recognition sensory channel groups.

Most of the participants were in their first year of university, right after intense and long years of preparation for university exam in Turkey. They might have ignored erase or save manipulations and only considered questions as Erase (must remember) because they knew there would be a test later and thus, paid more attention. Or it may be the opposite; participants might not have relied on the process from the very beginning (Schooler & Storm, 2021) and considered the experiment as something to forget. It might be a good idea for the future studies to ask upon completion the participants how seriously they took the experiment to observe their perception. However, one of the rare significant result in this study found a relation between participants' recall / recognition performance and their perception of memory, which helps assert that they took it seriously. Thus, we have a reason to believe they took it seriously.

The hypothesis was that erase treatment given to participants would be more inclined to keep newly introduced statements than the save group as save group was consistently reminded that they had access to these statements whenever they needed. This way a cognitive offloading process would take place. This transaction of memory in the form of saving information to computer was thought to create a kind of relief on the participants, thus create a forget reinforcement. Kelly and Risko (2019) mentioned that the process of saving information may communicate the message that participants do not need to keep them in mind and also causes intervention in proactivity and diverts their attention to another information. Giving the constant reminder, after each item, that the information will be saved onto computer was thought to promote item-method directed forgetting. Directed forgetting (MacLeod, 1998) effect suggests that subjects who are instructed to forget items will perform badly. In alignment with this effect, we expected difference between save and erase treatment, however, it is also stated in the article that directed forgetting might occur on condition that the subjects do not believe in the necessity to try to keep the items in mind. Therefore, this perception might have had an effect on save group that they don't really have to attribute mental load to task. We used well-known and well-studied methodology to measure participants recall (fill in the blank) and recognition memory performance (multiple choice questions). Baddeley et. al., (2001) points out the distinction between recall and recognition from neuropsychological viewpoint. MacLeod (1998) made an emphasis on recall and recognition tests and indicated that it was easier to observe directed forgetting effect in recall, in which subjects try to retrieve information from the memory. On the contrary the same effect was not observed in recognition tests. They later found out that directed forgetting also emerges but when to be forgotten information is presented as items, alias forget instruction is given after each item. Recognition performance test indicated difference between save and erase treatment in the analysis. However, there was a diversion, this difference was due to reaction time, not in terms of correct answer number. Even though directed forgetting effect was easier to observe in recall tasks and there was no significant difference in recall subgroups (save/erase or audio/verbal). It can also be argued that forget items are recalled less because of lack of sufficient rehearsal and attention. Engle (2002) point out that WM capacity does not comprise of the memory but one's ability to direct their attention in order to keep or get rid of information.

Another sister terminology that goes with directed forgetting is cognitive offloading (Risko & Gilbert, 2016), which also is aligned with Google Effect since it refers to physical actions to enhance recall process. Cognitive offloading means the use of external materials to decrease the demands that is processed cognitively (Hu et. al., 2019) Both of them use a kind of media as a storage device and also make the claim that people remember the location of the information more than the information itself. Previous studies have shown that allowing people to offload information can significantly improve performance on short-term and prospective memory tasks (Gilbert, 2015a, 2015b; Risko & Dunn, 2015). However, it remains unknown how people choose to offload cognitive demands during encoding and retrieval (Risko & Dunn, 2015). Hu et. al., (2019) about their article on cognitive offloading pointed out that using physical tools or actions may change how people process information and this may be dependent on people's prospection of the memory (in my study Belief About Memory (BAM), Belief About Attention (BAA) and Prospective Memory). Therefore, participants answered three metacognitive questions prior to the experiment. The answers to these questions were analyzed as Recall and Recognition groups. Recognition memory performance tasks correct answers and metacognitive self-perception answers were not correlated. One of the rare significant results that my study revealed is the correlation between BAM, BAA, Prospective Memory and Recall memory performance task. As an overall score the correlation of Recall and self-perception scores were high. As indicated on Table 24 Recognition questions received more correct answers than Recall. There was no question or explanation about participants' question type anticipation, so we do not know which type of a test the participants had in mind (recall or recognition) when asked how many correct answers they were going to remember. From the significant results it may be asserted that participants thought of free recall type of test.

We used both audio and verbal stimulation during the learning phase of the experiments. From various neurological domains, the processing difference between auditory and verbal memories is quite apparent (Fletcher et. al., 1995) For example neural networks active during retrieval in episodic memory differ from networks in retrieval from semantic memory. Recall memory learning phase contained identical 30 statements and recognition contained identical 45 statements for both verbal and audio. Verbal group read the statements from the screen while audio listened to the same number of questions and in the same order. When recording the statements, a very neutral tone of male voice was used. The tone was between robot like and lecturing. Robot like voice would violate Mayer's (2009) voice principle and lecture emphasis would make the key words in statements quite apparent. The statistics did not indicate a difference between verbal and audio sensory stimulation. We used a well-known method to create semantic memory task and exposed participants to trivial statements graded as low, middle and high difficulty level. Tulving (1986), defines semantic memory as abstract knowledge which is not based on any timely memory. In all of the eight groups, the learning phase was tried to create an environment in which the participants would not associate with a cue or memory. The statements presented were quite dull, for verbal it was white font statements with a black background and auditory it was statements without specific intonation or emphasis. We intentionally aimed to create this environment as the focus of this research was to observe the effect of transaction on semantic memory. The N-Back task was also used to create timely and cognitive intervention in order to reduce the episodic memory creation. Episodic memory deals with events or episodes (Tulving, 1983) which makes way for a “mental time travel” (Tulving, 2001; Goldstein, 2014). We are not sure if this N-Back intervention has been fully successful in this sense. This experiment might have included Episodic memory learning task to see if it would produce different results in order to compare semantic and episodic memory learning.

Semantic memory learning phase did not yield significant results in this study. The results might have been different if we included episodic memory tasks. Many experts studying in this field believed that the way to semantic memory through episodic memory (Tulving, 2001); therefore, using an episodic memory learning might have created different results and could be compared with the semantic memory learning results. Memory is grounded in the sensory channels and embodiment is an important element (Vallet et. al., 2017) , and as Storm and Stone (2015) indicated even the saving the process done by the participants can help change the results in Google effect. Saving example is given here as a way to create a episodic memory task as a means of embodiment.

Verbal sensory channel performance scores did not yield better scores than Audio sensory channel in any of the Recall and Recognition memory. Cohen et. al., (2009) stated that spatial recognition memory outperforms audio recognition. This effect was not observed in either Recall or Recognition. The results might have been caused by rehearsal in the learning phase. Participants joining the experiment read (verbal) or heard (audio) the statements then rehearsed them audibly. The purpose of this was to make sure experiment was taken seriously because there was no control over the participants as it was held online. Their oral production was processed by speech to text processor. This process might have caused a frustration more than they usually do because speech to text software stopped if the participant paused about 2 seconds and therefore they repeated the statement in order to move on the next statement.

Jonassen and Henning (1999) see transactive memory as a form of constructivist approach to creating one’s own mental models. And constructivist models are based on the notion that individuals are capable of building their own knowledge by the help from external media or people via means like problem solving or projects. They also distinguish knowledge as the one in person’s mind and also distributed across the environment what they call “knowledge in the world”. My study focused on the cognitivist part to see the cost of transacting on long term memory. However, constructivist approaches stretch the cognition beyond boundaries of the mind. Jonassen and Henning (1999) suggest that knowledge is distributed across social environment and the objects interacted like the tools, people or activities. Communities of practice are given as an example which goes in alignment with Wegner’s (1987) transactive memory theory.

This view that knowledge is dispersed across is sometimes criticized due to the fact that knowledge cannot always be constructed effectively in the absence of prior knowledge. With the prevalence of information, as Sparrow et. al., (2011) put it; “having information at the fingertips”, the amount of information exposed has increased and may cause an overload of information (Jungwirth & Bruce, 2002). This overload may cause too much information to bear in mind thus lead to cognitive load. Knowledge in the world is an ontological point of view but Hyslop-Margison and Strobel, J. (2007) suggest teachers look at it from epistemological mindset. Schunk (2012) mentions three perspectives of constructivism (exogenous, endogenous, dialectical) and two of these perspectives (exogenous and dialectical) make an emphasis on environment while constructing knowledge. Vogel-Walcutt et. al., (2011) found that learning occurs more, though slightly, in a constructivist approach that is given using teaching based on CLT. Valcke (2002) indicates in the article that CLT is usually held under cognitivist perspective, however, also addresses several authors like Mayer, Moreno, Kirschner, Van Bruggen and Jochems to make their contributions about CLT theory and constructivism. In different perspectives they point the environment in knowledge construction and how CLT theory such as worked examples help learners. Schunk (2012) makes a connection between constructivism and situated cognition, a theory that suggests the cognition stretches beyond the brain and mind to situations and contradicts with the information processing models that include sensory channels, WM and LTM. In the light of the information that mind is stretched to the environment, we need more studies to see how handheld or wearable devices nested in our lives aid storing or transacting information.

5.2 Conclusion

This study fails to produce meaningful significant results to draw conclusions despite a detailed structure of experiment and number of participants in each group. As discussed earlier the most probable reason for the insignificant results seems to be the high profile of the students. Despite the fact that data were collected from three different foundation universities in Turkey, majority of the data came from a university the profile of which mainly consists of medicine related departments with a high percentage from a centralized and standardized university entrance exam. Also the students in Turkish high schools start university preparation a few years before the exam. This may have affected the results in favor of higher scores and constant tests are part of a typical student in Turkey. Their ability to control their attention can be said to be higher.

Using an external source as a memory extension did not yield significant results in Recall memory or Recognition memory. We know from the literature that Recall and Recognition are different memory types which are also shown in neuropsychology experiments and in some people suffering from dementia. This difference between memory types is confirmed by the results in this study and

Recall memory group has produced less correct answers in percentages when compared to the percentages of Recognition memory. The difference between them is significant. Yet these two memory types were not compared but evaluated in their own terms.

N-Back task was used for two reasons, the first one was to create a cognitive load by intervening between the learning task and the test phase, the second one was to measure participants capacity in terms of cognitive load. Recall memory learning task 30 statements from 3 difficulty level and Recognition contained 45 statements. As stated, we did not compare results of two memory types for this study; however, an analysis was run out of curiosity to see whether 45 statements have somehow caused more load than 30 statements. Just like the other results, this was also not significant in correct and incorrect reaction scores in N-back.

Recall Memory produced a significant result in N-back in sensory channel but only in Verbal. This result does not lead to a consistent interpretable finding because Verbal scores were higher in 2 and 3-Back correct and 2 and 3-Back incorrect reactions also in correct and incorrect reaction times. Leaving this non-interpretable data aside, there was no other significant result in N-Back cognitive load measurement.

Regarding semantic memory tasks no significant results were observed. Sensory channel stimulation via Verbal and Auditory did not lead to difference in either recall or recognition tests.

Having access to information anytime and anywhere was thought to make a difference in alignment with many other studies that confirm transactive memory and Google effect. Similar to the other results in this study no significant difference was observed in both of the memory groups in terms of constant Save and Erase treatment.

Significant results came from self-perception scores and recall memory task results. Participants were asked how well they thought they would be regarding attention, memory and prospective memory. Participants in Recall memory group managed to introspect and displayed a correlation with their memory performance scores. However this effect was not observed in

Recognition memory tasks so we can conclude that participants thought of open ended questions like the recall type of questions.

5.3 Pedagogical Implications

The unfortunate events during this study helped it produce sound results, though not very prescriptive like the results that this study was upon. This study was planned to be run in a neuropsychology lab isolated from noise and distractors. However, this higher education institution was shut down and participants took the experiment at home and on their own computers. Having had it at home, participants took it in their natural environment with all the possible distractors like cats, parents, or phones. Another aspect is that they used their own computers meaning, in this study it is of importance that participants are believed to perceive the device as reliable, via which they acquired information. As stated previously in this study perceiving the information source as reliable (Schoolar & Storm, 2021) affected the replication of Google effect.

Another aspect is that by the time this experiment was run the students were exposed to online education for six or more months via their computers owing to COVID-19 pandemic. This long period exposure to learning via the computers is believed to eliminate Novelty Effect, which is defined as new appeal that affects one’s eagerness to join or fulfill a task. Sheehan (2001) found out that participation to electronic surveys, compared to paper and pen, diminished in time because of the reduction of novelty effect. Therefore, learning via computers was not a new thing, on the opposite a five-hour everyday routine.

Having eliminated novelty effect and isolated experimental conditions, educators can utilize the results in their digital pedagogy. Knowing the fact that information is accessible to user anytime does not significantly affect the performance on learning when compared to situations in which they do not have access to information. A student taking the photo of the whiteboard in the classroom is not an unusual note taking behavior anymore, even became a subject of the memes. To Google Effect, this should lead learners to remember the location of the information rather than the information itself. Teachers want the information to be stored in the long-term memory, but it is the student who decides what to do with it. This study indicated no significant difference under save or erase conditions; therefore, it can be said that being able to access the information anytime may not directly affect the storage of semantic information in the long-term memory.

Keeping in mind that anytime access to information does not lead to difference in learning may help instructors design their teaching accordingly. If the ubiquitous access did not lead to difference, then the learner engagement, which attracts attention to the topics and improves learning (Hyslop & Strobel, 2007), can be taken into consideration. When utilizing cognitivist or constructivist approaches, instead of worrying that learners will not be willing to store information in the long-term memory if they have easy access, instructors may focus on increasing the learner engagement.

In constructivist theories in which the learner actively constructs knowledge, prior knowledge plays an important role to accommodate new information (Vygotsky & Cole, 1978). It would be a good idea, say in a problem-based learning environment, instructors should choose to divert learners' attention to the prior knowledge needed in order to solve the problem. In a collaborative environment, digital or face-to-face, learners will undergo different parts of the topic but come up with one solution made up of combination of ideas. Therefore, instructors may choose which information to prioritize and which ones to transact for learner use. In this case connectivism plays a crucial role as the information will be transacted to technology which allows the information accessible anytime and anywhere. Connectivism theory principle asserts that "learning may reside in non-human appliances" (Siemens, 2005, as cited in Goldie, 2016)

5.4 Suggestions for Further Research

As stated above connectivism theory and Google effect assert the expansion of mind to technological devices. An in-depth search of connectivism in education can be looked upon to observe the effects of non-human forms of mind.

This study used a behavioristic measurement (N-Back) to both create an extra load to prevent recency effect and also to measure the cognitive load created by auditory/verbal and save/erase stimulations. Some similar studies used interventions like games to abolish the recency effect. Instead of an objective behavioristic measurement future studies can utilize an objective physiological measurement like heart rate, fNIRS or eye-tracking to see the instantaneous load the statements create on the learner so that the cognitive load can be measured at the time of learning task. Above mentioned objective measurement may be backed with a subjective measurement like the nine-point-scale by Paas (1992) at the end of the experiment.

We used questions from a normed study in the learning task by (Güler & Irak, in press), however; a check button could have been placed to see whether they had known the statements beforehand. The task may be differentiated and focused on one topic that participants did not know so that it would be easier to eliminate prior knowledge effect.

In this study we tried to eliminate creation of clues by presenting learning tasks in a dull way, white text on black background in verbal task, and natural but unemotional and unstressed tone in auditory task. The aim was to make sure to expose participants to semantic memory task. For future research a comparison between a semantic and episodic memory task can be made to see which one creates more load on memory and is effective for learning. To emphasize the effect on long term memory it would be a good idea to be able to give the test after a longer period, like a week later.

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