Effects of exercise on working, short term, and semantic memory self-evaluation, and performance in young, and older adults.

MSc student: Deniz Aygun
First supervisor: Dr Chiara Guerrini
Second supervisor: Dr Grant Abt
International supervisor: Dr Luís Pires

December 2018
Psychology, School of Life Sciences
Faculty of Health Sciences
University of Hull
I would like to express my deepest gratitude to Dr Chiara Guerrini for kindly providing her time to supervise this research from beginning till the end. I would like to show my appreciation to Dr Luís Pires for externally supervising the thesis and his endless help and support in designing and analysing the research. I would also like to thank Dr Grant Abt for his supervision in bringing different perspective and support of Sports Sciences and especially giving ideas on the exercise component of the research.

I would like to show my deepest gratitude to all participants who dedicated their time to participate in this research. Without their help, none of this would be possible.

To my fellow colleagues, thank you for making the experience fun and enjoyable and being there when I needed the most motivation throughout my time at the university.

Last but not least, I like to thank my family, friends and partner for all their endless support, advice, inspiration and encouragement through the making of this research paper. I am forever grateful to all of you.
# Table of Contents

Abstract ........................................................................................................................................... 5
Introduction ....................................................................................................................................... 6

1. Physical Activity .......................................................................................................................... 6
   1.1 Studies with different age populations .................................................................................... 8
      1.1.1 Young Adults .................................................................................................................. 8
      1.1.2 Older Adults ................................................................................................................... 9
      1.1.3 Comparative studies (young vs old) ............................................................................... 12

2. Metacognition .................................................................................................................................. 13

3. Memory .......................................................................................................................................... 16
   3.1. Semantic memory .................................................................................................................. 17
   3.2. Short-term and Working memory ......................................................................................... 20
      3.2.1. Short-term Memory ....................................................................................................... 20
      3.2.2. Working Memory ........................................................................................................... 21

4. Aims of the study ............................................................................................................................ 25

5. Methodology ................................................................................................................................... 26
   5.1. Active and non-active: The criteria ....................................................................................... 26
   5.2. Participants ............................................................................................................................. 28
   5.3. Materials and Procedure ....................................................................................................... 29
      5.3.1. Initial Assessment ........................................................................................................... 29
      5.3.2 Physical Activity Questionnaire ....................................................................................... 30
      5.3.3 Self-Evaluation Measures ............................................................................................... 30
      5.3.4 Neuropsychological tests ............................................................................................... 31
   5.4. Data Analysis Plan .................................................................................................................. 33

6. Results ............................................................................................................................................ 35
   6.1 Performance analysis ................................................................................................................ 36
   6.2 Self-evaluation analysis ........................................................................................................... 39
   6.3 Correlations between self-evaluations and performance levels in comparison to
      Young and Old groups .............................................................................................................. 41

7. Discussion ....................................................................................................................................... 43
   7.1. Semantic Memory .................................................................................................................. 43
   7.2. Short-term Memory ............................................................................................................... 44
      7.2.1. Verbal Short-term Memory ............................................................................................ 44
7.2.2. Visuospatial Short-term Memory ......................................................... 45

7.3. Working Memory ........................................................................................................ 46
  7.3.1. Verbal Working Memory ......................................................................................... 46
  7.3.2. Visuospatial Working Memory ................................................................................ 47

7.4. Association between self-evaluation and performance ........................................ 48

7.5. Limitations and Future Directions ........................................................................... 48

7.6. Conclusion ..................................................................................................................... 50

8. References ....................................................................................................................... 51

9. Appendix ......................................................................................................................... 69
  9.1 Appendix A - Consent Form ....................................................................................... 69
  9.2 Appendix B - Health and Demographics questionnaire .............................................. 70
  9.3 Appendix C - Mini Mental State Examination questionnaire ..................................... 72
  9.4 Appendix D - Geriatric Depression Scale questionnaire ........................................... 76
  9.5 Appendix E - Activities questionnaire ........................................................................ 77
  9.6 Appendix F - Semantic memory self-evaluation questionnaire .................................... 78
  9.7 Appendix G - Short term and working memory self-evaluation questionnaires ....... 79
Abstract

Studies have suggested that cognitive abilities decrease with age. However, research with young people have illustrated that young adults perform better on series of cognitive tests compared to older adults, demonstrating declining memory and cognition as a dominant feature of aging. One of the biggest factors that is found to have an effect on the brain is physical exercise, including benefits on health, wellbeing, and cognitive functions. There is a limited number of researches that measure participants’ performance of cognitive capacity, in conjunction with physical activity status in younger and older adults and none for self-evaluation of cognitive capacity in conjunction with physical activity status.

The aim of study is to analyse the effects of exercise on self-evaluation and performance in memory functioning in young and old adults. Participants were assessed on several neuropsychological assessments on short-term memory, working memory and semantic memory.

The results indicated ageing and exercise effects in the performance of semantic memory and only aging effect on the self-evaluation of verbal short-term memory, perhaps, due to older adults’ over-pessimistic beliefs about their declining memory. Additionally, there were no associations between self-evaluations and performance levels, concluding that self-reported memory predictions not capturing actual memory status. Future studies need to be conducted to clarify the physical exercise effects.
Introduction

1. Physical Exercise

One of the most salient factors that has been reported to have an effect on the brain’s health is physical exercise (Cotman, Berchtold, & Christie, 2007). Health, wellbeing, and cognitive functions are also positively affected by exercise (Kramer & Erickson, 2007a). Additionally, it has been demonstrated that variables such as age, gender, duration, intensity, frequency or types of exercise can modulate the effects of exercise on physical, and mental health (Hopkins, Davis, VanTieghem, Whalen, & Bucci, 2012; Penedo & Dahn, 2005).

Cardiovascular exercise is one of the most common type of exercise that has been used to promote the improvement of the cardiovascular system capacity (Hillman, Erickson & Kramer, 2008). According to the American College of Sports Medicine, cardiovascular exercise is defined as any activity that increases heart rate, and respiration while using large muscle groups repetitively, and rhythmically. Walking, jogging, swimming, aqua aerobics, rowing, cycling, or boxing are a few examples of the types of cardiovascular exercise. Similarly, aerobic exercise is defined as exercise that promotes a greater oxygen intake. Both terms interconnect as these two types of exercise achieve the same results of improved fitness. Aerobic refers to oxygen intake whereas cardio refers to heart rate. Essentially, one cannot be achieved without the other, as there is not a way to increase the respiratory rate without increasing heart rate. Swimming, jogging, walking, running, dancing, cycling, playing tennis, and other activities that keep a person moving for a sustained period of time will provide an aerobic, and cardio workout (Farrokhi, Baker, & Fitzgerald, 2015). A simpler blanket term for both is cardiorespiratory fitness as both the aerobic, and cardiovascular exercises increase the endurance level. Additionally, cardiorespiratory fitness increases the endurance of skeletal muscles by making the distribution of oxygen more efficient by the heart. This exercise must be administered at least twice a week for 10 minutes minimum for it
to have an effect in the body, and the brain, as the contraction of major muscles must be repeated often enough to elevate the heart rate to target level (Tomporowski, 2003).

Consequently, short-term participation in cardiovascular, and/or aerobic exercise programmes has shown potential effects on a broad range of cognitive domains including memory, attention, and executive functions (Chodzko-Zajko, Proctor, Fiatarone & Singh et al., 2009).

On the contrary, resistance exercise is defined as any exercise that causes muscles to act against external resistance with the expectation of increases in strength, mass, and/or endurance. Resistance exercise works by causing microscopic damage to the muscle cells, which in turn are quickly repaired by the body to help the muscles regenerate, and grow stronger (Cassilhas et al., 2007). As resistance exercise consists of rather short, and high-intensity training, or low intensity but frequent training, it uses the oxygen stored in the muscles whereas cardiovascular uses the oxygen produced by the breathing. However, depending on the duration, and intensity of the training, the anaerobic energy systems like phosphocreatine, and glycogenolysis will be activated. These are major chemical changes that are associated with muscular activity (Parnas & Ostern, 1934; Smilios, Pilianidis, Karamouzis, & Tokmakidis, 2003). Examples of resistance training include free weights, weight machines, resistance bands, and using one’s own body mass.

Regardless of the exercise type, numerous observational studies have reported that people who are physically active seem less likely to experience cognitive decline in semantic, working, and short-term memory compared to inactive people (Smith et al., 2013; Sibley & Beilock, 2007; Lautenschlager et al., 2008). Smith et al. (2013) were particularly interested in the effects of exercise on semantic memory in a cross-sectional study. They were analysing brain networks activation in a functional Magnetic Resonance Imaging (fMRI) study investigating 17 mildly cognitive impaired participants, and 18 healthy participants. Their findings determine that exercise might have an effect on improvement of neural efficiency
during semantic memory information retrieval process, and may lead to improvement in overall cognitive functioning.

Lautenschlager et al., (2008) investigated whether exercise reduces the rate of cognitive decline among older adults, and revealed that a 6-month interventional program of exercise improved attention, and memory in older adults with subjective memory impairment.

Sibley & Beilock (2007) investigated the effects of exercise on working memory. Their results suggested that acute sessions of exercise (30 minutes of self-paces exercise on treadmill) were found to be most beneficial for healthy young adults compared to older adults. Etnier et al., (1997) reported similar results in nonverbal reasoning, and working memory. Those findings have been corroborated by a subsequent study of Hillman et al., (2009) indicating higher cognitive functioning in attention, working memory, and processing speed for high demanding executive, and memory tasks, even with active people over 70 years old.

1.1 Studies with different age populations

Exercise is often suggested as an intervention to prevent cognitive deterioration in ageing, since it helps to potentiate cognitive reserve (Barulli & Stern, 2013). Cognitive reserve is referred to as the difference in cognitive processes as a function of education, lifetime intellectual activities, and other environmental factors that explain differential susceptibility to functional impairment in the presence of pathology (Stern, 2002). This is associated with focal volume changes in the brain that are relevant to task demand, which suggests that both long-term intellectual stimulation, as well as focused cognitive interventions can produce structural alterations (Lerch et al., 2011; Nithianantharajah & Hannan, 2009).
1.1.1 Young Adults

It has been suggested that aerobic exercise improves cognitive functions throughout the lifespan especially when performed in childhood, and/or adolescence (Hillman, Erickson, & Kramer, 2008). A recent longitudinal study also determined that light physical activity at an early age is protective of future cognitive ability for older age (Stubbs, Chen, Chang, Sun, & Ku, 2017). Bielak, Cherbuin, Bunce, & Anstey (2014) investigated age-related cognitive decline and exercise. The result indicated physical activity participation positively predicted baseline performance on fluid cognitive reserve (i.e., perceptual speed, short-term memory, working memory, and episodic memory) across all age groups but was a better predictor for the young adults’ cohort. The results indicate that physically active young adults have higher initial cognitive reserve to begin with than physically non-active young adults, and therefore, this advantage is maintained over time into older adulthood.

1.1.2 Older Adults

There have been major investigations on the effects of physical activity on behaviour, and cognition in older adults over the years (Chang, Nien, Tsai, & Etnier, 2010; Elsawy & Higgins, 2010; Erickson, Hillman, & Kramer, 2015; Weuve et al., 2004). As generally assumed, age brings decline in performance of cognitive tasks that require cognitive processes (Hertzog, Kramer, Wilson, & Lindenberger, 2008). It is supported that physical activity is a significant moderator of age-related cognitive decline (Bherer et al., 2013).

Preventing cognitive decline, an interventional study by Anderson-Hanley et al. (2012), found that after performing CyberCycling (i.e., an interactive reclining bike that uses games, and virtual environments to engage users in exercise), older adults achieved better cognitive performance \([N=79, \text{mean age (M)} = 75, \text{standard deviation (SD)} = 8.05, \text{mean years of formal education (YoE)} = 12.6]\) than older adults who did not perform
CyberCycling. The effects included improved executive functions, and enhanced brain-derived neurotropic factor, and these effects were stronger for traditional exercisers, suggesting that this kind of cognitive, and physical exercise intervention has greater potential for preventing cognitive decline.

The role of regular physical activity on prevention of dementia, and its role on increasing cognitive capacity, or slowing down cognitive deterioration are key topics to be addressed in older adults’ studies. A study by Laurin, Verreault, Lindsay, MacPherson, & Rockwood (2001) investigated the association between physical activity, cognitive impairment, and dementia in 6434 subjects who were 65 years, and older. Neuropsychological tests, and subjective measurements of physical activity were taken. Results indicated higher physical activity associations with lower risks of Alzheimer’s disease, any type of dementia, and lowered risk of cognitive impairment. Similarly, a study by Abbott et al. (2004a) explored the association between walking, and future risk of dementia in 2257 physically capable older males aged 71-93 years old in a longitudinal study. Results suggested that physical activity such as walking is linked to a decreased risk of dementia, and promoting active lifestyles could help to achieve healthier late-life cognitive function.

The type, and the duration, or intensity of physical activity is also important in this field. Previously mentioned research by Laurin et al. (2001) demonstrated the effects of different levels of physical activity. Their results suggested moderate to high levels of physical activity were linked to lower risks of dementia. Similar significance was also found between higher levels of physical activity, and participants with cognitive impairment without dementia. In respect to the intensity of physical activity, different results have been reported with females, and males suggesting that gender is also an important variable to control in this research filed. Weuve et al. (2004) examined female nurses (M=76), and
reported that performing higher levels of physical activity over 2 years was associated with enhanced cognitive ability compared to performing lower levels of physical activity. Conversely, Abbott et al. (2004b) investigated a similar research question with a sample of males in a prospective cohort study. Researchers reported that moderate to high levels of physical activity were associated with lower risks of developing dementia over a follow-up longitudinal period of 6 years.

Positive relationships are found between an higher dosage of exercise, and cognitive health (Kirk-Sanchez & McGough, 2014). The duration of around 16 to 20 weeks of physical activity was found to be needed to improve cardiorespiratory fitness in older adults (Chodzko-Zajko et al., 2009) whereas, a duration of extra 6 to 12 weeks is often needed to enable any cognitive improvements within older adults (Lautenschlager & Cox, 2013).

Other studies with older adults were interested in the neuroanatomical basis of the physical exercise effects. Erickson et al.'s (2015) meta-analysis, using Event-Related Brain Potentials (ERPs), and fMRI studies suggested that physically active older adults (+60 years old) show greater volume of hippocampus, prefrontal cortex, and basal ganglia, greater brain connectivity, and white matter integrity. This results in a more efficient executive, and memory functions compared to non-active older adults. Other studies found an increased brain plasticity in a physical active older adults sample (performing aerobic exercise) (Chaddock, Voss, & Kramer, 2012). A meta-analysis reviewing studies using neuroimaging techniques also suggested that physical activity seems to increase cognitive performance by reducing age-related brain tissue loss, and increasing the efficiency of brain function (Voelcker-Rehage & Niemann, 2013).

A review on physical activity, and the quality of life in older adults (Rejeski & Mihalko, 2001) seem to indicate that increased levels of physical activity are associated with better health, and quality of life in older adults. Overall, the findings suggest that physical
activity can improve quality of life regardless of age, level of activity, or health status (Daskalopoulou et al., 2017).

1.1.3 Comparative studies (young vs old)

Studies investigating the relationship between physical activity, and cognitive function in young, and older adults were also conducted. A cross-sectional study of Taddei, Bultrini, Spinelli, & Di Russo (2012) observed the performance levels of young, and older fencers (N=40) in a go/no-go task, and reported faster reaction times in young, and older fencers compared to participants that do not practice fencing, or any other physical activity. Accordingly, researchers suggested a positive relationship between physical activity, and cognitive functions. In another comparison study, Voss et al. (2010) investigated the association between cardiovascular fitness, and cognitive performance (spatial memory, and executive control) within young adults (N=32, age range=18-35), and older adults (N=120, M=55-80) in a fMRI study. Results indicated higher functional connectivity within the age-sensitive frontal regions in young, and older adults with higher levels of cardiovascular fitness in comparison to the ones with lower levels of cardiovascular fitness. This higher levels of functional connectivity was also found to mediate improved cognitive performance (specifically in spatial memory, and executive control tasks).

Effects of different types of exercise on young, and older adults’ cognitive functioning has also been studied. A retrospective study by Dik, Deeg, Visser, and Jonker, (2003) investigated 62-85 years old males, and females (N=1241) from the age of 15 to 25 about their physical activity status. The results suggested a positive relationship between aerobics exercise, and processing speed for young, and older females than males. Stretching, toning, or relaxation exercises were found to have very little impact on cognitive functioning (Erickson et al., 2011). The reason for lack of effectiveness might be the minimal metabolic
Exercise and Memory

(Ruscheweyh et al., 2011), and coordinative (Voelcker-Rehage, Godde, & Staudinger, 2011) demands of these particular physical activities.

2. Metacognition

The simplest definition of metacognition is thinking about thinking. It is widely used in educational psychology, referring to higher order of thinking that involves active control over learning processes called metacognitive activity (Livingston, 1997). Flavell (1979) first proposed the idea that metacognition consists of both metacognitive knowledge (one’s stored knowledge, or beliefs about oneself, and others, about tasks, about actions, or strategies, and how all those interact to affect the outcomes), and metacognitive experiences, or regulation (conscious cognitive, or affective experiences that occur during the thinking processes). Later, he divided the metacognitive knowledge into three categories: 1) knowledge of person variables (general knowledge of how human beings learn, and process information as well as individual knowledge of one’s own learning processes), 2) task variables (knowledge about the nature of the task as well as the type of processing demands that it will place upon the individual), 3) strategy variables (knowledge about both cognitive, and metacognitive strategies, as well as conditional knowledge about when, and where it is appropriate to use such strategies).

Similarly, other researches also established the metacognition components as knowledge, and regulation (Lai, 2011; Palincsar & Brown, 1987; Roberts & Erdos, 1993). Metacognitive knowledge consists of the knowledge about oneself as a learner, and the factors that might affect performance, knowledge about strategies, and knowledge about when, and why to use those strategies.

Metacognitive regulation is the monitoring of ones cognition, and includes planning activities, awareness of comprehension, and task performance, and evaluation of the efficacy
of monitoring processes, and strategies therefore the actions we take in order to learn (Sandi-Urena, Cooper, & Stevens, 2011). Biology behind metacognitive regulation (involving attention, conflict resolution, error monitoring, inhibitory control, and emotional regulation) is presumed to be mediated by a neural circuit involving midfrontal brain regions (Fleming & Frith, 2014; Fernandez-Duque, Baird, & Posner, 2000).

Measurement of metacognition is naturally difficult since it is not an explicit behaviour. However, according to Akturk, and Sahin (2011), there are two types of measurements that can be applied to measure metacognition: subjective reports based on individual’s own telling (questionnaires, and interviews), and objective behaviour measurements (systematic observation, and think aloud protocols). Subjective measurements such as questionnaires (example question: ‘Are there any strategies that I have used before that might be useful?’), and interviews are criticized as people might be reluctant to express their ideas, and experience; possibility that the questions might not be fully understood; and the questions might stimulate socially attractive questions (Baker & Cerro, 2000). On the contrary, the use of such questionnaires allow researchers to collect data with larger groups in less time, and these measures can be reliable, and effective in contexts where it is not possible to observe motivation, and cognitive engagement (Pintrich & DeGroot, 1990). There are objective measures such as the ‘think aloud protocol’. This allows the researcher to determine persons’ metacognitive ideas “online” as telling how they would handle a problem verbally. Think aloud protocols are useful in the laboratory conditions but they are not functional in natural conditions, such as, classroom environments (e.g., since students are asked to think aloud while they are performing a task, it is necessary that they leave their typical learning environment).

Awareness of self can be considered as a conscious metacognitive representation of many mental states (Zeman, 2001). This ability to adopt evaluative judgements is essential
for guiding one’s own behaviour, and decisions (Frith & Frith, 1999). It is practical, as it allows to realistically predict whether a given mental task can be, or whether it has been successfully completed (Proust, 2010). Studies about the importance of self-knowledge, and physical activity suggest that people with higher meta-memory capacity considers themselves as more physically active, has fewer health complaints, and has higher internal locus of control compared to physically non-active people (Stevens, Kaplan, Ponds, & Jolles, 2001). This supports the use of measures of self-evaluation while using both cognitive, and physical activity measures subjectively.

A study investigating metacognition in young (N=49, M=23), and older adults (N=42, M= 69) by assessing self-efficacy in computer knowledge suggested similar results in actual performance scores, but differences in ‘feeling of knowledge’ (prospective judgements on their knowledge), and ‘confidence levels’. Older adults were found to have lower ‘confidence’, and ‘feeling of knowledge’ compared to young adults in ratings for computer knowledge. Under-confidence is one possible source of the difficulties that older adults may experience in mastering new skills (Marquie, Jourdan-Boddaert, & Huet, 2010). Another age-related study exploring metacognition investigated the benefits of training for the use of metacognitive monitoring as a resource that older adults can use to improve their learning, and memory performance (Dunlosky, Kubat-Silman, & Hertzog, 2003). Their intervention was to train older adults to monitor their learning via self-testing, and to use the self-testing to restudy the items not yet been learned. This training programme resulted in greater performance than more traditional encoding strategy training when older adults were given the chance to self-pace their study. In conclusion, it has been demonstrated that older adults lack metacognitive ability, particularly in comparison with young adults (Best, Hamlett, & Davis, 1992; McCallum, McKinney, Gilmore, & Ledford, 1985; Vecchi, Albertin, &
To the best of our knowledge there are no studies that investigate the effect of physical exercise on metacognition.

3. Memory

The human memory has not failed to fascinate researchers for centuries. Sternberg (1999) suggested that “memory is the means by which we draw on our past experiences in order to use this information in the present” (p. 390). Tulving (1972) recognises that an adequate definition of memory should also encounter conscious, and non-conscious aspects of memory. Since memory has profound influence on human existence, historically it has been inseparable from experimental studies of mental health, and behaviour. Since memory still remains as thriving endeavour to study, it is also progressing rapidly with many new discoveries, and ideas in the literature (Schacter, 2013).

There are three ways of encoding information in the memory: visual (picture), acoustic (sound), and semantic (meaning). In addition memory has two types of storage capacities: long-term memory, and short-term memory storage. The way the information is stored has an effect on its retrieval process (details such as brain regions associated with each storage, and encoding capacities are discussed further in the current thesis). Only Semantic Memory (SM), Short-term Memory (STM), and Working Memory (WM) will be investigated throughout the current thesis.

The processing-speed theory may explain the deterioration of cognitive functioning related to ageing. This theory proposes that increasing age in adulthood is associated with decrease in speed of processing operations, leading to impairments of cognitive functioning (Salthouse, 1996). A study by Finkel, Reynolds, McArdle, & Pedersen, (2007), also supports this theory, suggesting that processing speed is a leading indicator of age changes in memory,
and spatial ability but not in verbal ability in a 16-year longitudinal study involving 806 participants aged 50 to 88 years old.

3.1. Semantic memory

The term semantic memory was first introduced by Tulving (1972) on the role of human memory organisation. Semantic memory refers to one’s store of knowledge about the world, including factual information, and the knowledge of words, and concepts. Such information is not tied to the space, or time of learning. In other words, semantic memory reflects our knowledge of the world around us, hence the term ‘general knowledge’ is often used. It holds generic information that is acquired across various contexts, and is used across different situations (Lambon Ralph & Patterson, 2008). The expression “semantic” was adopted from linguists to refer to a system of memory for “words, and verbal symbols, their meanings, and referents, the relations between them, and the rules, formulas, or algorithms for influencing them” (Tulving, 1972).

Interestingly, the organisation of the knowledge system seems to be unchanged with age although the access to information may somewhat be slower in older adults, particularly for words, and names (Light, 1992).

The brain region found to be responsible for semantic memory, and its knowledge is thought to be the anterior temporal lobe (ATL) (Bonner & Price, 2013). This finding arises from the studies that pinpoint the brain region that is responsible for encoding semantic memory which is disrupted in certain forms of dementia (Patterson, Nestor, & Rogers, 2007). A recent meta-analysis suggested similar findings as the visual object processing often recruits ventral ATL structures, whereas linguistic, and auditory processing tend to recruit lateral ATL structures (Visser, Jefferies, & Lambon Ralph, 2010). Additionally, overlapping ATL activity peaks were generated by semantic memory stimuli such as spoken works,
written words, and picture stimuli. Nevertheless, the findings do indicate some degree of association of the modality-specificity in the semantic functions to ATL.

Over the years, a number of objective, and subjective testing materials have been produced to test semantic memory. Pyramids, and Palm Trees test (PPTT) is one of these tests that is widely used to measure semantic memory through associations of words, and pictures (Howard, Patterson, & Thames Valley Test Company, 1992). A test that was developed from the PPTT is the SEMEP (SEMantic-EPisodic) memory test assessing semantic, and episodic knowledge across multiple tasks: naming, recognition, free recall, and semantic matching (Vallet et al., 2017). Similarly to PPTT, Camel, and Cactus Test (CCT) (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000) also measures semantic memory through associations between words, and pictures but has a crucial difference: whilst in PPTT subjects have to choose from one of two possibilities, individual have to choose one of four possibilities in CCT. Therefore having less chances of selecting without knowledge. An additional advantage of this test is that all items are coloured pictures which is a notable difference in relation to other semantic memory tests (usually with black, and white pictures) as colour is an important semantic attribute. Lastly, a battery that bring most of the tests together is the Cambridge Semantic Memory Battery (Adlam, Patterson, Bozeat, & Hodges, 2010) including tests: Category fluency (living, and manmade), and the 64-item task (naming, and word–picture matching); Sorting task; Camel, and Cactus Test (pictures, and words), and Pyramids, and Palm Trees test (pictures, and words). This battery is explicitly developed to diagnose specific semantic category deficits, however it was concluded that it failed to differentiate between Semantic Dementia, and Alzheimer’s disease.

Another neuropsychological test extensively used to assess semantic memory consists of variations of Facial Recognition Tests, where the participant is presented with number of photographs of famous people, and asked to name the people if they recognise them.
original *Famous Faces Test* consisted of black, and white photographs of people through the 1920s to 1970s with recall time to name the person shown on the photograph (Albert, Butters, & Brandt, 1980a). This test was later updated to study memory in Alzheimer patients. This updated version doubled the number of photographs being used, and changed the timescale to 1940s - 1990s, in addition to having semantic, and phonemic prompting cues to recognition process (Hodges, Salmon, & Butters, 1993).

Nonetheless, other studies suggest that SM remains intact with age (Nilsson & Larsson, 2007), and that, when found, difficulties with SM in old age are due to retrieval failures rather than structural changes in the brain (Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992). In face recognition tasks testing SM, older adults might find it difficult to name the famous person but hold relevant information about the character. This difficulty may be due to lexical retrieval rather than semantic memory (Stuart-Hamilton, 2012). Therefore, it is crucial that, during semantic naming tasks, all relevant semantic information about an item is recorded to account for any memory retrieval deficit, and differentiate it from a lexicon retrieval deficit.

A study by Smith et al. (2013), investigated the semantic memory, and other cognitive functions after 12-week exercise interventions (treadmill walking at a moderate intensity) in 35 subjects. After completing the intervention, and various neuropsychological tests, results suggested that exercise showed improvements on semantic memory, and cognitive functions however more trials needed to determine the effectiveness in delaying any cognitive impairment.

In this study, a contemporary, and updated version (Guerrini et al in preparation) of a *Face Recognition Task* (Alberts, Butters, and Brandt, 1980) was used, in which, participants be asked to name a reduced number of twenty-six public faces (film stars, singers, public figures, political figures). If they unable to name them but recognise the face, then they were
asked to provide any information about the public character that they recognized. This allowed the researcher to test semantic memory excluding that the inability to name the famous face was due to access to lexicon.

### 3.2. Short-term and Working memory

The theoretical concepts of short-term memory, and working memory have been in literature to provide understanding for maintenance, and manipulation of information, (Aben, Stapert, & Blokland, 2012). Thus, they are two separate theoretical concepts with different tasks used to measure each notion, the terms often overlap in the literature. Detailed descriptions will be discussed further in the current thesis.

#### 3.2.1. Short-term Memory

The term short-term memory (STM) refers to holding limited amounts of information for a short time interval with relatively little processing effort such as remembering a new telephone number. It is a unitary system, a single system without any subsystems (Healy, 2001). STM recodes information by linking new information to already existing available information in long-term memory (LTM). Although STM, and LTM work interconnectedly, there are crucial key differences between the two. STM has limited capacity whilst LTM can store unlimited amounts of information for indefinite period. Information should be revised to use in STM, differently to rather passive LTM, as it is not easily disturbed by interruption. The way that forgetting occurs is also characterised separately in either processes. Whilst STM uses trace dependant forgetting – which the information fades away if not rehearsed immediately; LTM on the other hand uses cue dependant forgetting system - which information is permanently recorded but retrieval could be dependent on the appropriate cues given. What is stored also differs as physical qualities such as vision, taste, touch, and sound
is stored in STM, whereas information in terms of meaning, and/or semantic codes are stored in LTM.

A study by Gathercole (1999) identified the distinct cortical brain structures underpinning the principle components of STM. Specifically, phonological STM is associated with posterior parietal for storage, and for rehearsal, Broca’s area, premotor cortex, and supplementary motor cortex. Spatial STM on the other hand is associated with inferior prefrontal, storage for spatial STM associated with anterior occipital, and for rehearsal of spatial STM is posterior parietal, and premotor cortex (Gathercole, 1999). As the regions associated with STM, and LTM are also different, LTM is highly associated with first hippocampus then the information is transferred to areas of cerebral cortex involved in language, perception for permanent storage. STM, and WM are found to display changes in cognitive functioning associated with ageing as observed in both longitudinal, and cross-sectional studies (Hoyer, Rybash, & Roodin, 1999).

A study by Coles and Tomporowski (2008), investigated the effects of aerobics exercise on short-term memory, and executive functions on 18 young adults that completed various neuropsychological tests. The results suggested that exercise did not facilitate short term memory, and it does not have impact on executive functions.

3.2.2. Working Memory

The concept of working memory (WM) is marks a strong emphasis on the notion of manipulating information rather than simple maintenance (Ma, Husain, & Bays, 2014). Furthermore, WM was originally adopted to convey the idea that active processing as well as passive storage is involved in temporary memory (Healy, 2001). This was hypothesized since the same region which serves as a temporary storage facility for STM is also essential part for manipulating the information. Additionally, the information that is in those cognitive systems are either encoded into LTM, decays, or replaced. Unless the information is actively attended,
or rehearsed, WM only has a duration around 10-15 seconds (Goldstein, Naglieri, Princiotta, & Otero, 2014).

The most accredited model that explains how WM works has been proposed by Baddeley, and Hitch (2000) describing WM as a system consisting of four components: two slave systems, the phonological loop, and the visuospatial sketchpad, a central executive, and an episodic buffer (see figure 1).

Their original model (1974) only consisted of the first three components: a) The phonological loop b) the visuospatial sketchpad c) the central executive.

Figure 1: Baddeley and Hitch’s (2000) model of Working Memory.

The phonological loop is the part of WM that deals with spoken, and written material. It consists of two parts 1. Phonological store, and 2. Articulatory control process. The phonological store is associated to speech perception, and is responsible for holding information in speech-based form for 1-2 seconds. As spoken words enter the store directly, written words on the contrary, must first be converted into an articulatory code before entering phonological store. Articulatory control process is associated with speech production, and is responsible for rehearsing information from phonological store. It circulates information, and as long as it is rehearsed, the information will be retained in WM.
The Visuospatial Sketchpad is responsible for visual, and spatial information. It keeps track of where we are in relation to other objects as we move through the environment. The visuospatial sketchpad is also responsible for displaying, and manipulating visual, and spatial information that are needed in the LTM.

The Central Executive is the most crucial component of WM as it is responsible for monitoring, and managing the visuospatial sketchpad, and the phonological loop, and also relates them to LTM. Central Executive manages the operation of which information is attended to, and which parts of the WM will receive that information. Consequently, it focuses on attention, and gives priority to particular activities.

In 2000, Baddeley, and Hitch updated the original model by introducing the Episodic Buffer as an additional component as the interaction between WM, and LTM had to be clarified. The Episodic Buffer acts as a ‘backup’ store, communicating with both LTM, and components of WM (i.e., the visuospatial sketchpad, and the phonological loop) in order to bind information into a unitary episodic representation.

Functional neuroimaging studies in humans have mapped WM, and STM related brain activity that require maintenance (related to STM concept), and manipulation (related to WM concept) of information to both sensory association cortices, and dorsolateral prefrontal cortex (Curtis & D’Esposito, 2003). Cabeza, and Nyberg's (2000) empirical review of studies using Positron Emission Tomography (PET), and fMRI techniques have concluded that the left dorsolateral prefrontal cortex activates when verbal WM tests are given, and the right dorsolateral prefrontal cortex for spatial WM tests. Other studies (Aguirre & D’Esposito, 1999; Druzgal & D’Esposito, 2003; Rypma, et al., 2002) have been consistent with the notion of association of verbal information mediated by unilateral ventral regions, specifically caudal left inferior frontal cortex (also known as Broca’s area, or BA 44) (Rypma, Prabhakaran, Desmond, Glover, & Gabrieli, 1999). Different trends were found between the
activated areas in young, and older adults in the prefrontal cortex suggesting that there is a primary deficit on right anterior prefrontal cortex function in older adults (Rajah & D’Esposito, 2005). An understanding of age-related neurophysiological changes may help to account for these variances. Age-related cognitive decline in WM may be caused by the deterioration of the frontal lobes as it is the first areas of the brain known to deteriorate with ageing (Grady & Craik, 2000).

A study by Sibley, and Beilock (2007) investigated the effects of acute aerobics exercise on working memory on healthy adults who also completed working memory tests. The results suggested improvements of working memory capacity for healthy adults whose cognitive performance is generally the lowest.

The most used neuropsychological assessment tasks of verbal STM, and verbal WM are the Digit Span Forward, and Backwards (Weschler, 2008). Digit Span tasks are the most commonly used test for memory span, partially because performance on a Digit Span task cannot be affected by factors such as semantics, frequency of appearance in daily life, and/or complexity (Jones & Macken, 2015). A study (Dobbs, Allen, Rule, 1989) investigating age differences in the Forward Digit Span task found significant declines between the ages of 60-69, and 70+ years compared to younger participant groups. It is suggested that the age differences may be due to a decrease in cognitive flexibility with ageing.

Another test that measures visuospatial WM as well as visuospatial STM is the Corsi Block-Tapping Task (Corsi, 1972). It requires the participant to observe the sequence of blocks lit up (on the computerised version), and repeat the sequence back in the same order. This task is given in forward, or backward manner. A study (Kessels, Van Den Berg, Ruis, & Brands, 2008a) investigating age differences in Corsi Block-Tapping task only observed minimal correlation between age, and performance on Corsi Block-Tapping backward, and no significant correlation between age, and the forward Corsi Block-Tapping task in their
Exercise and Memory

older sample. This is supported by Park et al. (2002) whom also observed small age effect in their study. Since the backward span task is more challenging as it requires to store the items in the correct order whilst simultaneously reorganizing the material in the reverse order (Bromley, 1958). This could be due to the information manipulation process, and therefore highlighting the role of WM in the backwards condition.

4. Aims of the study

The aims of the presents study were to:

1. Analyse the effects of aerobic exercise on performance in memory tests (SM, STM, and WM) on both active, and non-active young, and older adults.

2. Analyse the effects of aerobic exercise on memory self-evaluation measures on both active, and non-active young, and older adults.

   Existing literature involving self-awareness studies in ageing have mostly focused in individual cognitive skills, such as memory, or executive functions (Souchay, 2007). Most of the studies demonstrate differences in self-evaluated memory, and actual memory performance, and therefore, self-reported memory information may not capture the actual memory status (Nilsson & Larsson, 2007; Rickenbach, Agrigoroaei, & Lachman, 2015; Sohel, Tuokko, Griffith, & Raina, 2016). Previous studies comparing young, and older adults’ performances in cognitive tasks were measured in conjunction with physical activity status (Bugg, DeLosh, & Clegg, 2006; Hayes et al., 2015; Tanigawa et al., 2014). However, to our knowledge, there is not known research comparing self-evaluative measures, and objective measures of cognitive capacity (such as memory), while assessing the influence of physical activity. Therefore, the aim of the present study was to investigate whether active adults would be better at evaluating their own abilities accurately than inactive adults, and if there are any differences.
We hypothesized that active young, and old adults would be better at self-evaluating their capacity to perform the SM, STM, and WM tasks than non-active young, and old adults due to the information gathered from the literature on physical activity. We also hypothesized age differences in regard to cognitive performance across memory functioning as we expected young adults to perform better than old adults regardless of activity status.

Finally, the present research would also enrich our knowledge on age-related cognitive decline. It would contribute to understand whether physical exercise can be used for prevention purposes of any early pathological cognitive decline.

5. Methodology

5.1. Active and non-active: The criteria

In the present study, active, and non-active criteria is sought to categorise participants. This categorisation process consists of active, and non-active young, and older adults. Three types of physical activity criteria have been considered in this study. These are: National Health Service (NHS) - Physical Activity Guidelines (NHS Choices, 2015) for adults to be healthy; American College of Sports Medicine (ACSM Guidelines, 2015) physically active criteria; Spanish Physical Activity criteria (Padilla, Pérez, & Andrés, 2014).

NHS’s criteria are for 19-64-year-old adults. NHS suggests adults to complete at least 150 minutes (2 hours, and 30 minutes) of moderate aerobic activity such as cycling, or brisk walking every week as well as strength exercises on two, or more days a week that works all major muscles or, 75 minutes (1 hour, and 15 minutes) of vigorous aerobic exercises such as running, hiking, fast swimming, gymnastics etc. The advantage of this criteria is that it is created for people living in United Kingdom (UK).

On the contrary, the guidelines that are currently in use in parts of United States of America (USA) are the ACSM guidelines, which defines being physically active as:
performing planned, structured physical activity at least 30 minutes on at least three days per week for at least the least three months. However, ACSM guidelines do not specify the type of activity that needs to be performed, suggesting that the activity should be performed at least at moderate intensity. This criterion recommends nearly as half of what NHS guidelines recommend to be healthy however this could be due to low level of physically activity in the USA population (Laskowski, 2012).

Finally, Padilla, Pérez, and Andrés (2014) differentiated the criteria for active, and non-active young adults. According to the researchers, active people should have been exercising for at least ten years following a minimum pattern of 360 minutes (6 hours) of aerobic/cardiovascular exercise a week, distributed across minimum of three days a week. Whereas the passive people should not have, practicing exercise more than two hours a week for at least four years, and should have not completed more than six hours of aerobic exercise per week during their childhood (0-12-year-old). An advantage of this criteria is that the researcher specifies every condition that they need for the study. However, as the previous two criteria, this is also dependent on the cultural factors. It requires twice as much physical activity than NHS guidelines.

As each criteria has its advantages, and disadvantages, in this study the categorization process will be done following NHS’s guidelines, since this study will be developed in the UK. Active participants are required to disclose the number of hours, and the type of physical activity they undertook in the present (i.e., last week) as well as in the past (i.e., past year). Active participants are expected to complete at least 150 minutes of moderate aerobic exercise (e.g., walking, running, cycling, swimming, etc). Active participants respond to a series of physical activity screening questions. The questions are a combination of modified versions of CHAMPS Physical Activity Questionnaire for older adults (Stewart, Mills, King, Haskell, Gillis & Ritter, 2001), and the Physical Activity Questionnaire created by Padilla,
Pérez, & Andrés (2014) developed by Guerrini and Aygun, (2016). The questionnaire is designed to identify the criteria needed to classify participants as physically active, or non-active. Examples of questions are: “What type of activities/exercises do you normally do?”; “How many hours a week do you do this activity?”, and “Since when have you started this activity?”. This questionnaire was also used to classify non-active participant recruitment process. Non-active participants should not have been practicing exercise more than 60 minutes a week for at least 4 years.

5.2. Participants

Studies investigating memory in older adults tend to use a sample age range between 55, and 85. Examples include: Voss et al. (2010) participant age range 55-80 years old investigating executive control functions, and spatial working memory; Erickson et al. (2009) participant age range 59-81 years old investigating spatial working memory; Gordon et al. (2008) participant age range 65-81 years old investigating working memory; Smith et al. (2013) participant age range 65-85 years old investigating semantic memory; and Szabo et al. (2011) participant age range 59-81 years old investigating spatial working memory.

In respect to young adults, studies investigating memory tend to use a sample age range between 18, and 35. Examples include: Chooi & Thompson (2012) using mean age of 20 years old participants, investigating training working memory to improve intelligence; Verburgh, Königs, Scherder, & Oosterlaan (2014) looked at effects of physical exercise enhancing executive functions with a sample age range between 18, and 35; Madore, Jing, & Schacter (2016) studied episodic specificity induction, and divergent thinking with 18 to 30 years old young adults; Pertzov, Heider, Liang, & Husain (2015) explored object location in visual short-term memory in 19 to 31 years old young adults; and Mohanty & Naveh-
Benjamin (2018) investigated differential effects of semantic memory support on item, and associative memory on participants (M = 27).

Four groups of 20 volunteers each took part in the present study: 1) 20 active young adults (12 females, 8 males), 2) 20 non-active young adults (11 females, 9 males), 3) 20 active older adults (13 females, 7 males), and 4) 20 non-active older adults (10 females, 10 males). Participants in the young groups were 18 to 33 years old (M = 20.28, SD = 2.47) with a mean level of education 14.42 years (SD = 0.84). Participants in the older groups were 59 to 84 years old (M = 72.10, SD = 6.27) with a mean level of education 15.86 years (SD = 3.92). Young adults were recruited through the student population at the University of Hull, and older adults were recruited from the Department of Psychology, University of Hull participants’ panel as well as from the general public, through advertisement, and announcements in Kingston upon Hull region. Due to linguistic contents of some tests, all participants were native English speakers. Participants with psychological, neurological, psychiatric disorders, and participants currently taking psychoactive medications were exclude from the study. The study was approved by the University of Hull Ethics Committee.

The sample size is 80 participants with 20 in each group. However, 47 participants had to be excluded from the study due to various exclusion criteria. Additionally, it is difficult to have more participants due to strict sample criteria. Nonetheless, same number of participants were chosen in each group balancing the gender, and age.

5.3. Materials and Procedure

5.3.1. Initial Assessment

All participants were informed about the purpose of the study, and asked to complete a consent form (Appendix A). Then the participants were required to fill out a health, and demographics questionnaire (Appendix B), and to respond to the Mini Mental State
Examination (MMSE) (Appendix C) (Folstein, Folstein, & McHugh, 1975) to detect the presence of significant cognitive impairment due to neurological, psychiatric, and/or psychological disorders. Participants then completed a short-form of the Geriatric Depression Scale (15-item) (Yesavage & Sheikh, 1986) which is sensitive to any age form of depression. Depression can compromise the results of self-evaluation of cognitive abilities, and test performance (Appendix D). The score for this scale ranges from 0-15. 0-4 is considered to be within the normal range, 5-9 indicates mild depression, and 10-15 indicates moderate to severe depression (Almeida & Almeida, 1999). Exclusion criteria for the present study requires GDS scores no to be higher than 10 indicating moderate to severe depression.

5.3.2 Physical Activity Questionnaire

A Physical Activity Questionnaire was completed to determine the baseline of participants’ physical activity status. The test is a combination of modified versions of CHAMPS Physical Activity Questionnaire for older adults (Stewart, Mills, King, Haskell, Gillis & Ritter, 2001), and the Physical Activity Questionnaire created by Padilla, Pérez, & Andrés (2014) e.g. “What types of activities/exercises do you normally do?”; “How many hours a week do you do this activity?”. The questionnaire designed to individuate physically active, and non-active participants was developed by Guerrini and Aygun, (2016). Active participants are expected to complete at least 150 minutes of moderate aerobic exercise (e.g., walking, running, cycling, swimming, etc). The main outcome measure is the minutes of physical activity a week that the participant completes. Additionally, the other questions are asked to understand what type of physical exercise they complete, and generally understanding the participants’ exercise pattern. There is not any time restriction on answering the questions (see Appendix E).
5.3.3 Self-Evaluation Measures

After completing the initial assessment, and the physical activity questionnaire, the participant then be given a series of self-evaluative questionnaires for each cognitive domain under investigation (Semantic Memory, Short-term Memory, and Working Memory) (adapted from Barber, Snowden, & Craufurd, 1995). Participants are asked to evaluate how they feel about their memory, and predict how they feel they would perform in a specific memory task e.g. Face Recognition, Corsi span, and Digit span for Semantic Memory (SM). They were asked to complete questionnaires of: Semantic Memory (SM) (e.g., “Do you usually find it difficult recognising faces, and names of well-known people?”); Short-Term Memory (STM) (e.g., “Imagine that you are participating in a testing session. You are asked to repeat a series of 7 digits after you have listened to them. Do you think you would ever find this task difficult to perform?”); and Working Memory (WM) (e.g., “Imagine that you are participating in a testing session. On the table front of you there are 10 cubes placed in random order, the examiner taps a sequence of 6 cubes, and you are asked to repeat the sequence backwards. Do you think you would ever find this task easy to perform?”). After completing the questionnaires, participants were asked to complete the SM, STM, and WM tasks separately (see Appendix F, and G).

Predictions be provided on a 9-point Likert scale (from “I never feel like it’s difficult to perform this task” to “I always feel like it's very difficult to perform this task”). These self-evaluations are completed before performing each of the neuropsychological tests in order to provide a prediction of their own abilities, and performance according to each cognitive domain. Finally, the total score of 9 as a raw data to be treated in the analysis.
5.3.4 Neuropsychological tests

Short-term Memory, and Working Memory - The objective test selected to measure the verbal STM span was the forward Digit Span task (Weschler, 2008) whilst the forward span of the Corsi Block-Tapping task (Corsi, 1972) was chosen to measure the visuo-spatial STM. The objective test selected to measure the verbal WM span was the backward Digit Span task (Weschler, 2008) whilst the backward span of the Corsi Block-Tapping task (Corsi, 1972) was chosen to measure the spatial WM.

In the Digit Span task, participants hear a sequence of numerical digits, and are instructed to recall the sequence correctly, it starts with two digits with increasingly longer sequences being tested in each trial. The participant's span is the longest number of sequential digits that can accurately be remembered. Digit Span tasks can be administrated in two versions: forward, or backward. Once the sequence is presented, the participant is asked to either recall the sequence in normal (i.e., forward), or reverse order (i.e., backward). An example sequence of six digits forward Digit Span used was “619472”. Whereas an example sequence of five digits backward Digit Span used was “15286”. The experimenter pronounces the digits with a monotone voice, and with a same amount of time pause in between to restrict the participant to chunk the digits, instead to learn the digits individually to get the correct Digit Span.
In the Corsi Block-Tapping task (Corsi, 1972), participants are asked to observe the sequence of blocks lit up (on the computerised version), and repeat the sequence back in the same order by clicking on the mouse. This task is also given in forward, or backward versions. It starts with two blocks being lit up, and gradually increases in length up to nine blocks (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000).

Semantic Memory - An updated, and computerized version (Guerrini et al in preparation) of the Face Recognition Task (Albert, Butters, & Brandt, 1980b) was used. The pictures for this task shown on a laptop, and the participants are asked to name 26 public faces (film stars, singers, public figures, political figures) presented individually, or to provide any information about the public character that they recognize. The reason is that, the older adults might struggle to name the famous person although hold relevant information about the character. A performance that may be due to lexical retrieval rather than semantic memory (Stuart-Hamilton, 2000).

The pictures were selected on three conditions: 7 pictures of particular public faces that older adults would recognise (e.g. Doris Day), 7 pictures of public faces that younger adults would recognise (e.g. Kate Moss), and 12 pictures of public faces that both generations would recognise (e.g. Marilyn Monroe). The testing sessions run individually in a quiet room. The experiment approximately lasted one hour for young, and older participants.
Examples chosen to represent three conditions: faces that older generation would recognise, younger generation would recognise, and both generations would recognise.

5.4. Data Analysis Plan

In the present study, data analysis were conducted in four phases. Firstly, exclusion criteria applied on all raw data. Secondly, descriptive analysis were conducted to understand the basic features of the data, and measures. Comparisons using one-way ANOVA used to reveal any differences between young, and the old groups on the variables of age, years of education, GDS, MMSE, and minutes of physical activity. Thirdly, a series five 2 (Activity level [active vs non-active]) x 2 (Age [young vs old]) ANOVA analysis were run to compare the effects of aerobic exercise on performance scores in SM, verbal STM, Visuo-spatial STM, verbal WM, and Visuo-spatial WM between groups of Active Young, Non Active Young, Active Old, and Non Active Old. Then another five, 2 (Activity level [active vs non-active]) x 2 (Age [young vs old]) ANOVA analysis were run to compare the effects of aerobic exercise on self-evaluation scores in SM, verbal STM, Visuo-spatial STM, verbal WM, and Visuo-spatial WM between groups of Active Young, Non Active Young, Active Old, and Non Active Old. Finally, Pearson correlation coefficient were run to model better understanding of the relationships between self-evaluations, and performance levels in
comparison to Young, and Old groups. All data used in the analysis is the raw data collected, and has not been transformed into different datasets before treated. Finally, all post-hoc tests were run to confirm where the differences occurred between groups, and were only run when there was shown statistical significant differences.

6. Results

In the present study, we aimed to investigate whether aerobic exercise has any effect on memory performance, and self-evaluations in young, and old participants. We firstly present a descriptive statistics table with the characterization of our sample. An attempt was made to balance the four groups (active young, non-active young, active old, non-active old) in respect to gender, and education. Additionally, the two young adults groups, and two old adults groups were balanced in respect to age. The exclusion criteria included: any psychological, neurological, psychiatric disorders; psychoactive medications intake; GDS scores higher than 10 indicating severe depression; MMSE scores lower than 25 indicating cognitive impairment due to neurological, psychiatric, and/or psychological disorders; and physical activity information not adequate to classify participants as active, or non-active.

Table 1. Demographic variables of means, and standard deviations between subject groups.

<table>
<thead>
<tr>
<th></th>
<th>Active Young N=20</th>
<th>Non-Active Young N=20</th>
<th>Active Old N=20</th>
<th>Non-Active Old N=20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age</td>
<td>19.80**</td>
<td>1.10</td>
<td>20.75**</td>
<td>3.29</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>12</td>
<td>0.48</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>8</td>
<td>0.80</td>
<td>9</td>
</tr>
<tr>
<td>YoE</td>
<td>14.30</td>
<td>0.80</td>
<td>14.55</td>
<td>0.88</td>
</tr>
<tr>
<td>Mini Mental State Examination (MMSE)</td>
<td>28.85</td>
<td>1.14</td>
<td>28.95</td>
<td>1.23</td>
</tr>
<tr>
<td>Geriatric Depression Scale (GDS-15)</td>
<td>1.30</td>
<td>1.45</td>
<td>2.75</td>
<td>2.57</td>
</tr>
<tr>
<td>Minutes of Exercise</td>
<td>492.25**</td>
<td>257.14</td>
<td>0.00**</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Comparisons using one-way ANOVA analysis revealed differences between the four groups (active young, non-active young, active old, non-active old) in regards to age \( F(3, 76) = 821.40, p < .0001, \eta^2 = .97 \). Post-hoc comparisons using the Bonferroni test indicated that the mean score for the Active Young group (M = 19.80, SD = 1.10), and Non Active Young group (M = 20.75, SD = 3.30) do not differ (95% CI [-4.95, 3.05], \( NS \)). Mean score for the Active Old group (M = 70.50, SD = 5.55), and Non Active Old group (M = 73.70, SD = 6.67) also do not differ (95% CI [-7.20, 0.80], \( NS \)). However, the young, and the old groups showed significant differences regarding age across the two (\( p < .0001 \)).

There were no differences between the groups regarding years of education \( F(3, 76) = 1.75, p = .163, \eta^2 = .06 \). Also, no differences were found between the groups in their MMSE scores \( F(3, 76) = 1.28, p = .29, \eta^2 = .05 \) neither in their GDS scores \( F(3, 76) = 1.54, p = .21, \eta^2 = .05 \). This was expected as all participants had a criteria of GDS scores no more than 10, and MMSE scores no less than 25 to be included in the data. There was a difference between the groups considering minutes of physical activity \( F(3, 76) = 54.61, p < .0001, \eta^2 = .68 \), with the active young group exercise level being considerably higher than the active older group.

### 6.1 Performance analysis

To compare the effects of aerobic exercise on performance scores in SM, verbal STM, visuo-spatial STM, verbal WM, and visuo-spatial WM between groups of Active Young, Non Active Young, Active Old, and Non Active Old, a series of five 2 (Activity level [active vs non-active]) x 2 (Age [young vs old]) ANOVA analysis were conducted. Bonferroni adjusted pairwise comparisons were also conducted, where required, to clarify the nature of the significant effects (\( p < 0.5 \)).

**Semantic Memory** – The Face recognition task was measured to assess SM, and the total of 26 public faces were used. There was no statistical significant effect of the age factor.
on the performance levels of SM as young, and old groups did not differ, $F(3, 76) = 1.97$, NS, $\eta^2_p = .02$. However, there was a significant statistical effect of activity level factor as active participants scored higher on the SM task than non-active participants, $F(3, 76) = 4.70, p = .03, \eta^2_p = .06$. Additionally, a significant interaction was observed between groups of age (young, and old), and groups of activity level (active, and non-active) on the effects of exercise on Semantic memory performance, $F(3, 76) = 6.99, p = .010, \eta^2_p = .08$. Post-hoc comparisons using the Bonferroni test indicated that the mean score for the Active Young group ($M = 18.05, SD = 3.33$) was significantly higher than Non Active Young group ($M = 14.27, SD = 3.41$) (95% CI [1.56, 5.89], $p < .01$). However, there were no differences between the Active Old group ($M = 17.07, SD = 3.26$), and the Non-Active Old group ($M = 17.45, SD = 3.98$) (95% CI [-2.58, 1.83], NS). Furthermore, Non Active Young group ($M = 14.27, SD = 3.41$), and the Non Active Old group ($M = 17.45, SD = 3.98$) also showed a significant effect (95% CI [0.97, 5.38], $p = .005$), with the performance of Non Active Old group in the SM task being significantly higher than the Non Active Young group. Finally, there were no differences between the Active Young group ($M = 18.05, SD = 3.33$), and the Active Old group ($M = 17.07, SD = 3.26$) (95% CI [-1.23, 3.18], NS).

**Verbal Short-Term Memory** – The Forward Digit Span task was used to assess verbal STM with maximum of 9 digits being recalled. There was no statistical effects of the age factor as young, and old groups did not differ, $F(3, 76) < 1$, NS. There was no significant statistical effect of activity level factor on the verbal STM task performance, $F(3, 76) = 1.54$, NS, $\eta^2_p = .02$. Additionally, a non-significant interaction was also observed between groups of age (young, and old), and groups of activity level (active, and non-active) on verbal STM performance, $F(3, 76) < 1$, NS.

**Visuo-spatial Short-Term Memory** - The Forward Corsi Span task was used to assess visuo-spatial STM with maximum sequence of 9 blocks being remembered, and tapped. There was
a statistical significant effect of age factor on the visuo-spatial STM Corsi task performance, $F(3, 76) = 25.83, p < .0001, \eta^2 = .25$, with the young group (active: $M = 5.75, SD = 0.44$, non-active: $M = 5.60, SD = 0.68$) overall scoring higher than the old group (active: $M = 4.85, SD = 0.87$, non-active: $M = 5.00, SD = 0.56$) (95% CI [0.46, 1.04], $p < .001$). There was no statistical significant effects of the activity level factor on the visuo-spatial STM task performance, $F(3, 76) < 1$, NS. Additionally, no significant interaction was observed between groups of age (young, and old), and groups of activity level (active, and non-active) on visuo-spatial STM performance, $F(3, 76) = 1.03$, NS, $\eta^2 = .01$.

**Verbal Working Memory** - The Backwards Digit Span task was used to assess verbal WM with maximum of 9 digits being recalled in a backward manner. There was no statistical significant effect of the age factor as young, and old groups did not differ, $F(3, 76) = 1.09$, NS, $\eta^2 = .01$. There was no statistical significant effect of activity level factor on the verbal WM task performance, $F(3, 76) < 1$, NS. Additionally, a non-significant interaction was also observed between groups of age (young, and old), and activity level (active, and non-active) on the verbal WM performance, $F(3, 76) = 1.09$, NS, $\eta^2 = .01$.

**Visuo-spatial Working Memory** - The Backwards Corsi Span task was used to assess visuo-spatial WM with maximum sequence of 9 blocks being remembered, and tapped in a backwards manner. There was a statistical significant effect of age factor on the visuo-spatial WM Corsi task, $F(3, 76) = 5.56, p = .02$, $\eta^2 = .07$ as Young groups (active: $M = 4.95, SD = 0.39$, non-active: $M = 5.00, SD = 0.72$) scored higher on the Backward Corsi task than Old groups (active: $M = 4.55, SD = 0.89$, non-active: $M = 4.65, SD = 0.74$) (95% CI [0.06, 0.69], $p = .02$). However, there was no significant statistical effect of activity factor on the visuo-spatial WM task performance, $F(3, 76) < 1$, NS. Additionally, no significant interaction was also observed between groups of age (young, and old), and activity (active, and non-active) on the visuo-spatial WM performance, $F(3, 76) < 1$, NS.
6.2 Self-evaluation analysis - Bonferroni adjusted pairwise comparisons were also conducted, where required, to clarify the nature of the significant effects ($p<0.5$). The questionnaire used for SM consisted of four questions with 9-point Likert scale with a total of 36 scores as a raw data point.

**Semantic Memory** – There was a statistically significant effect of age factor on the self-evaluations of SM, $F(3, 76) = 6.60, p = .01, \eta_p^2 = .08$. To explore the effects of age further, post-hoc comparisons using the Bonferroni test was carried out. The results indicated that the Young (active: $M = 23.00$, $SD = 4.83$, non-active: $M = 22.6$, $SD = 5.83$) groups’ self-evaluation scores were higher than Old (active: $M = 20.1$, $SD = 5.23$, non-active $M = 19.05$, $SD = 6.34$) groups’ (95% CI [0.72, 5.70] $p = .01$). There was no significant statistical effect of activity factor on the participants self-evaluation scores for SM, $F(3, 76) <1$, NS. Additionally, no significant interaction was observed between groups of age (young, and old), and activity (active, and non-active) on SM self-evaluations scores, $F(3, 76) <1$, NS.

**Verbal Short-Term Memory** – There was a statistical significance for the age factor, and self-evaluating verbal STM capacity, $F(3, 76) = 15.50, p <.001, \eta_p^2 = .17$. Post-hoc revealed that young group ($M= 5.02$, $SD = 1.69$) rated their self-evaluations higher than old group ($M = 3.45$, $SD = 1.95$) (95% CI [0.78, 2.37] $p<.001$). There was also a significant statistical effect of activity factor on the verbal STM self-evaluations, $F(3, 76) = 4.78, p = .03, \eta_p^2 = .06$. Post-hoc revealed that active group ($M= 4.67$, $SD = 1.02$) rated their self-evaluations higher than non-active group ($M = 3.80$, $SD = 1.20$) (95% CI [0.78, 1.67] $p = .03$). However, a non-significant interaction was observed between groups of age (young, and old), and activity (active, and non-active) on verbal STM self-evaluations, $F(3, 76) <1$, NS.

**Visuo-spatial Short-Term Memory** - There was a statistically significant effect of age factor on the self-evaluations of visuo-spatial STM, $F(3, 76) = 24.93, p <.001, \eta_p^2 = .25$. To
explore the age factor further, post-hoc comparisons Bonferroni test was used. The results indicated that there was a significant main effect on the ratings for self-evaluation scores as for Young group (active: M = 5.15, SD = 1.22, non-active: M = 5.05, SD = 1.54) rated their visuo-spatial STM capabilities higher than Old group (active: M = 3.35, SD = 2.34, non-active: M=2.90, SD = 1.77) (95% CI [1.19, 2.76] p<.001). There was no significant statistical effect of activity factor on the participants self-evaluation scores for visuo-spatial STM, $F(3, 76) <1$, NS. Additionally, no significant interaction was observed between groups of age (young, and old), and activity (active, and non-active) on visuo-spatial STM self-evaluations scores, $F(3, 76) <1$, NS.

Verbal Working Memory - Young, and old groups did not differ on the self-evaluation scores for verbal WM, $F(3, 76) <1$, NS. There was not a significant statistical effect of the activity factor on the verbal WM self-evaluations, $F(3, 76) <1$, NS. Additionally, a non-significant interaction was observed between groups of age (young, and old), and activity (active, and non-active) on verbal WM self-evaluations scores, $F(3, 76) <1$, NS.

Visuo-spatial Working Memory – Young, and old groups did not differ on the self-evaluation scores for visuo-spatial WM, $F(3, 76) <1$, NS. There was not a significant statistical effect of the activity factor on the visuo-spatial WM self-evaluations, $F(3, 76) <1$, NS. Additionally, a non-significant interaction was observed between groups of age (young, and old), and activity (active, and non-active) on visuo-spatial WM self-evaluations scores, $F(3, 76) <1$, NS.

Table 2. Summarised results of 2x2 ANOVA for performance, and self-evaluation on age factor, activity factor, and the interaction between groups.
### Exercise and Memory

#### 6.3 Correlations between self-evaluations, and performance levels in comparison to Young and Old groups

In order to analyse if participants were able to predict their performance, self-evaluations questions were conducted. Self-evaluations, and performance scores were analysed through correlations in each group respectively to memory domains.

**Semantic memory**

Results of the Pearson correlation indicated that Semantic memory self-evaluation scores was not statistically correlated with performance scores for the young group, \( r (40) = .24, p=.13 \). Also, no correlation was found between old group while analysing self-evaluation, and performance scores, \( r (40) = .26, p=.09 \).
Exercise and Memory

**Verbal STM**

Results indicate that self-evaluation regarding the verbal STM was not statistically correlated with performance of Forward Digit Span task scores in the young group, $r (40) = .07, p = .65$. Also, no correlation was found between the old group while analysing self-evaluation, and performance scores, $r (40) = .15, p = .36$.

**Visuospatial STM**

Pearson correlation indicated that the self-evaluation was not statistically correlated with performance on the visuospatial STM task (Forward Corsi Span task) for the young group, $r (40) = .17, p = .29$. Also, no correlation was found between the old group while analysing both self-evaluation, and performance scores, $r (40) = .07, p = .65$.

**Verbal WM**

Results indicate that self-evaluation, and the verbal WM (Backward Digit Span task) performance was not statistically correlated in the young group, $r (40) = -.29, p = .06$. Also, no correlation was found between old group while analysing both self-evaluation, and performance scores, $r (40) = -.11, p = .51$.

**Visuospatial WM**

Results of the Pearson correlation indicated that there was no significant relationship between the self-evaluation, and the performance score on the Backward Corsi Span task for the young group, $r (40) = -.04, p = .82$. Also, no correlation was found between the old group while analysing both self-evaluation, and performance scores, $r (40) = -.16, p = .30$.

In conclusion, there were no significant correlations found between self-evaluations, and actual performance, regardless of the participants’ age. The results suggest that neither of the groups could correctly predict their performance in any of the domains.
7. Discussion

The aim of this study was to investigate the extent to which aerobic exercise affects self-evaluation, and performance levels in SM, STM, and WM in young, and old participants. Consequently, besides neuropsychological tests, self-evaluation questionnaires were given to physically active, and non-active participants to understand the effects of exercise on their self-belief. Additionally, we explored the relationship between the actual performance levels of neuropsychological tests in comparison to self-evaluation in physically active, and non-active young, and old participants. Taking into account of our results, we wanted to examine related predictions (Nilsson & Larsson, 2007) for self-evaluation in comparison to performance, and for the effects of physical exercise on age-related cognitive decline (Bherer et al., 2013). The results will be discussed in concordance with each related memory domain (SM, STM, and WM).

7.1. Semantic Memory

The results show clear significance for activity factor, and the interaction between age, and activity, however no significance for age. The results revealed that aerobic exercise did have an effect on semantic memory performance independently of age, moreover, active young participants achieved higher on the SM task than non-active young. Considering other studies investigating SM, Smith et al., (2013) was particularly interested in the effects of exercise on SM. Their findings determined that exercise has an effect on improvement of neural efficiency during semantic memory information retrieval process, and leads to improvement in overall cognitive functioning. Our results on the age, and activity factor supports Smith’s findings on exercise having an effect on SM.
In regards to self-evaluation in the SM domain, on average, young participants rated their self-evaluations’ higher for recognising famous faces than old participants with absence of statistical significance.

In an attempt to provide additional theoretical basis of the findings, Schank’s script theory can provide a great insight (Schank & Abelson, 1975). The central focus of the theory proposes that knowledge of objects, persons, locations, and events are recorded in semantic memory in scripts, and forms basic level of dynamic memory system that learns from personal experience (Schank & Abelson, 1975). This simply suggests that our SM continuously learns, and grows as we experience new information. Findings from the current study suggesting young participants scoring higher in semantic memory task could be explained by this theory on the basis of young adults’ ability, and higher capacity for organising, and processing new information, and data (Funnell, 2001). As a younger adult constantly saves new personal experiences, they are more likely to keep their system more dynamic in comparison to older participants. Consequently, the interaction between the groups could account for it, however more studies needs to be conducted to verify this theory.

7.2. Short-term Memory

7.2.1. Verbal Short-term Memory

The results show clear insignificance for age factor, activity factor, and the interaction between age, and activity. Despite not reaching statistical significance, active, and non-active young groups scored higher than active, and non-active old groups in the verbal STM task, the Forward digit span. This insignificant age differences could be due to a decrease in cognitive flexibility supported by Dobbs, Allen, & Rule, (1989) who found significant decline in older participant groups compared to young subjects. Cognitive flexibility is the capacity to adjust behaviour according to environmental change (Scott, 1962). It enables to
efficiently disengage from previous work, reconfigure response system, and implement new response for the current task (Dajani & Uddin, 2015). This system is important in the Forward Digit Span task as the participant is asked to repeat the given sequence of numbers in the same order, and if they succeed, the next sequence is one digit longer. This process requires the participant to ultimately remove/disengage from the previous sequence to be able to recall the current sequence given to be able to succeed onto the next sequence.

Consequently, an indirect contribution of the Central Executive in the verbal STM can be derived for the Forward Digit Span task (Monaco, Costa, Caltagirone, & Carlesimo, 2013). The non-significant results of age, and activity factor including the interactions between the two could be due to the decrease in cognitive flexibility, thus, the role played by executive functions.

Self-evaluation results in the verbal STM domain suggests that young participants rated their self-evaluations’ significantly higher than older participants demonstrating more self-belief. Young participants reporting higher self-evaluations could be due to older adults having over-pessimistic beliefs about their declining memory (Hultsch et al., 1992), and lacking metacognitive ability (realistically evaluating own cognitive abilities) (McCallum et al., 1985).

7.2.2. Visuospatial Short-term Memory

The results show no significance effect of physical exercise on visuospatial STM performance scores for activity factor, and the interaction between, age, and activity. However, there is a clear significance for the age factor, with young adults scoring better on the forward Corsi task than the older adults. These results suggest that there is an age effect but not a physical exercise effect. Other studies in the literature did not find age differences
while investigating differences in Corsi block-tapping task (Kessels, Van Den Berg, Ruis, & Brands, 2008; Lezak & Lezak, 2004).

In regards to the self-evaluation in the visuospatial STM domain, there was a statistical significance found on the age factor. On average, young participants rated their self-evaluations’ significantly higher than older participants.

7.3. Working Memory

7.3.1. Verbal Working Memory

The results show no significance for age factor, activity factor, and the interaction between age, and activity for the effects of physical exercise on verbal WM performance.

There were also no differences for the age factor, activity factor, and the interaction between age, and activity for verbal WM task, and the self-evaluation scores either.

7.3.2. Visuospatial Working Memory

The results show clear insignificance for activity factor, and the interaction between age, and activity for the effects of physical exercise on visuospatial WM performance.

On average, for the age factor, young groups performed significantly better on the backwards Corsi span task than the old groups. Results suggest that active, and non-active groups did not differ in the visuospatial WM task of backwards Corsi span. This could be explained as it is more challenging to complete backward span as it requires to store the items in the correct order whilst simultaneously reorganising the material in the reverse order (Bromley, 1958). Literature determines that performance in executive tasks involving WM may slow down with aging (Salthouse, 1994; Rhodes & Katz, 2017; Park & Payer, 2012), as with the current study showing signs of differences in age.
The processing-speed theory could also explain the deterioration of cognitive functioning related to aging, as it elaborates the association of decrease processing speed, and impairments of cognitive functioning (Salthouse, 1996). A longitudinal study also supported the notion of processing speed as a leading indicator of age changes in memory, and spatial ability (Finkel, Reynolds, McArdle, & Pedersen, 2007).

There were also no differences for the age factor, activity factor, and the interaction between age, and activity for visuo-spatial WM task, and the self-evaluation scores either. Therefore, self-evaluations cannot be a reliable source to predict performance on visuospatial WM objectively.

### 7.4. Association between self-evaluation, and performance

The current study was interested in determining whether young, and old adults accurately predict their performance in SM, STM, and WM. To fully understand the association, a series of Pearson correlation coefficient analysis was carried out between self-evaluation predictions, and performance levels across all domains studied. In general, neither of the variables correlated with each other. The results suggests that neither of the groups could correctly predict their performance in any of the domains similarly to two meta-analysis in the literature (Beaudoin & Desrichard, 2011; Crumley, Stetler, & Horhota, 2014). As most of the studies in the literature suggested, there are differences in self-evaluations, and actual performance, and due to this, as predicted, self-reported memory information may not capture the actual memory status (Nilsson & Larsson, 2007; Rickenbach et al., 2015; Sohel et al., 2016).
7.5. Limitations and Future Directions

Some limitations of the current study deserve discussion. Firstly, although this thesis investigated the self-evaluation prediction of performance across domains of SM, STM, and WM, there is little control over what people actually thought when the questions were asked. The complexity of some of the questions may have confused the participants. A possibility to avoid this problem could entail simplifying the questions, repetition of the questions when needed, and making sure that the participant fully understands, and have enough time to imagine themselves performing the task to be able to correctly predict their actual performance.

Secondly, in our sample there were 80 participants with 20 in each group. However, 47 participants had to be excluded from the study due to various exclusion criteria. Potential participants could go through an initial telephone assessment to be accepted as a participant in the future to avoid high number of excluded participants. The smaller sample size could have been the reason why it was difficult to find significant relationships between some variables in the dataset to ensure representative distribution of the groups to be generalised to the population.

Lastly, since this study only relied on subjective statements of participants declaring their physical activity status, and how many minutes a week they exercise as well as what kind of exercises that completed; an objective measure might be more suitable for future researches in the field e.g. ActiGraph. This is a non-invasive method of monitoring, and recording continuous human rest/activity cycles. It is a sensor that is worn for a week to measure gross motor activity, with the unit usually worn on a wrist, or waist. It is a useful and efficient way to classify the physical activity status of participants within participants. In this way, we can: 1) understand the true physical activity status of the person; 2) understand whether the person is actually over, or under estimating their physical activity status; and 3)
research the association between physical activity, and performance in more reliable technique.

7.6. Conclusion

Findings from the study demonstrate mixture of results. We can conclude that Active Young adults were better at the SM task, than Non-active Young adults, suggesting the presence of an exercise effect but not of an age effect. On the contrary, an ageing effect was found between Non-active Young, and Non-active Old adults in the visuospatial STM task. The age effect is also present while for the self-evaluations in STM memory domain as young adults had a higher self-belief than old adults when they predicted their own performance. There were no differences in performance in verbal STM, but age differences in self-evaluations as Young participants rated their self-evaluations higher than Old participants due to older adults’ over-pessimistic beliefs about their declining memory. There were no age, or exercise effects for the performance in verbal WM between young, and old adults. Finally, there were no exercise effects found for the visuospatial WM, however, age effects were found as young participants scored higher than the old participants on the visuospatial WM performance task.

Overall, self-evaluations, and performance levels did not correlate across all memory domains studied in the current thesis between young, and old groups due to self-reported memory predictions not capturing actual memory status as expected.

As the present study investigated the literature for the studies that has used older adults as their sample to base it on, it was found that most studies in the field of memory tend to use the age range of 55 to 85. Consequently, ages of 59 to 84 years old older participants were studied. However, the age classifications for older generations are moving to later age, and therefore, the sample age range might need to be reconsidered for future researches.
Future experiments, and studies need to be conducted to clarify the age effects, and physical exercise effects. Objective measures need to be used to permit the complete understanding of the physical activity level effect.
8. References


study of their validity for the diagnosis of a major depressive episode according to ICD-10 and DSM-IV. *International Journal of Geriatric Psychiatry*, 14(10), 858–865.


Exercise and Memory

Psychology and Aging, 29(2), 250–263. https://doi.org/10.1037/a0035908


cognition. *Current Opinion in Behavioral Sciences.*

https://doi.org/10.1016/j.cobeha.2015.01.005


https://doi.org/10.1073/pnas.1015950108


https://doi.org/10.1016/B978-0-323-09138-4.00047-4


https://doi.org/10.1037/0003-066X.34.10.906


https://doi.org/10.1007/978-3-642-45190-4


Exercise and Memory


https://books.google.co.uk/books?hl=en&lr=&id=FroDVkVKA2EC&oi=fnd&pg=PA3&dq=lezak+&ots=q6UnYRTi3R&sig=alNlwEhEslnqbsvij8pgNbdG38#v=onepage&q=lezak&f=false


Ruscheweyh, R., Willemer, C., Krüger, K., Duning, T., Warnecke, T., Sommer, J., … Flöel,
Exercise and Memory


https://doi.org/10.1123/jsep.29.6.783

https://doi.org/10.1249/01.MSS.0000058366.04460.5F


https://doi.org/10.1093/ageing/afv163


Sternberg, R. J. (1999). *The nature of cognition*. MIT Press. Retrieved from https://books.google.co.uk/books?hl=en&lr=&id=Mehu2cpozSUC&oi=fnd&pg=PR7&dq=sternberg+1999+memory&ots=ph4G_Kpn7O&sig=zfiogdp4fDv6OzsDMd-4xLb-ZO#v=onepage&q=memory means by which we draw on our past experiences in order to use this information present&q=false


9. Appendix

9.1 Appendix A- Consent Form

University of Hull
Department of Psychology

Principal investigator: Deniz Aygun
Supervisor: Dr Chiara Guerrini

Consent by volunteer to participate in psychometric testing

Name of Study: Self-awareness of cognitive capacity in young and older adults

➢ The researcher has explained to me the purpose of the study as it has been outlined here.  

YES/NO

➢ I agree to take part in this study which is designed to promote knowledge and may be of no benefit to me personally.  

YES/NO

➢ I understand that I am completely free to withdraw from any part of the study at any time I wish.  

YES/NO

➢ I understand that part of the testing session will be tape recorded simply to make it easier for the examiners to follow my oral production during some tests. Once the material has been transcribed the tape will be destroyed.  

YES/NO

➢ I agree my personal details will be kept on your records in order to be contacted for future testing sessions.  

YES/NO

Name of the volunteer: ____________________________________________________________

Signature of the Volunteer: ______________________________________________________

Date: ________________________________________________________________________

I have explained the study to the above participant and he/she has agreed to take part.

Signature of researcher _________________________________________________________

Date ________________________________________________________________________
9.2 Appendix B – Health and Demographics questionnaire

Health and Demographics Questionnaire

Date of Examination__________________

Participant Number: ________________

Examiner____________________________

For experimental reasons we need some more generic details about our participants. For this reason, we really appreciate if you can fill the following form. If, for some reason, you do not want to fill the questionnaire, it will not compromise the execution of the rest of the experiment.

Gender________ Age________ Date of birth________________________

From the age of 5 (typical school starting age) please state your number of years of education____________________________________________________

Left/Right Handed __________________________________________________________________

If currently working, please indicate what is your job

_____________________________________________________________________________

If retired, please indicate your job before retirement

_____________________________________________________________________________

What is your main physical complaint, or health issue?

_____________________________________________________________________________

_____________________________________________________________________________

____
Are you currently taking any medication? Yes  No

If yes, please give details.

___________________________________________________________________________

___________________________________________________________________________

Have you ever had a stroke? Yes  No

If yes, please give details.

___________________________________________________________________________

___________________________________________________________________________

Have you ever had a head injury? Yes  No

If yes, please give details.

___________________________________________________________________________

___________________________________________________________________________

Have you ever had seizures, convulsions? Yes  No

If yes, please give details.

___________________________________________________________________________

___________________________________________________________________________

Do you have or have you had Alcohol or Drug Usage problems? Yes  No

If yes, please give details.

___________________________________________________________________________

___________________________________________________________________________
### Mini Mental State Examination (MMSE) Questionnaire

#### 1. Orientation
- What is the year we are in?
- What season is it?
- What is today's date?
- What day of the week is it today?
- What month are we in?
- What county are we in?
- What country are we in?
- What town are we in?
- Can you tell me the name of this place?
- What floor of the building are we on?

#### 2. Registration
Ask the subject if you may test his/her memory. Then say the names of 3 unrelated objects, clearly and slowly, about one second from each: “Lemon, Key, Ball”. After you have said all 3, ask him/her to repeat them. This first repetition determines their score (0-3) but keep saying them until they can repeat all 3, up to 5 trials. If they do not eventually learn all 3, recall cannot be meaningfully tested.

#### 3. Attention and Calculation
Ask the subject to begin with 100 and subtract 7 from 100, and keep subtracting 7. Stop after 5 subtractions (93) (86) (79) (72) (65). Score the total number of correct answers. Ask the subject to spell the word ‘World’ backwards. The score is the number of letters in the correct order. (e.g., dlrow = 5, dlorw = 3). The highest score will be recorded.

#### 4. Recall
Ask the subject if they can recall the 3 words you previously asked them to recall. Score

<table>
<thead>
<tr>
<th>Screening No.</th>
<th>ID Centre No.</th>
<th>Randomisation No.</th>
<th>Subjects Initials</th>
<th>Screening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Code:** 1 = Correct 0 =

<table>
<thead>
<tr>
<th>Was this test performed?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Score**

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Score</th>
<th>0-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Registration</th>
<th>Score</th>
<th>0-5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attention and Calculation</th>
<th>Score</th>
<th>0-5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recall</th>
<th>Score</th>
<th>0-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-3</td>
<td></td>
</tr>
</tbody>
</table>
Exercise and Memory

Mini-Mental State Examination  (Folstein et al. 1975)  Continued

5. Naming
   a. Show the subject a wristwatch and ask them what it is.
   b. Repeat for a pencil.

   Score 0-2

6. Repetition
   Ask the subject to repeat this sentence after you - “No ifs, Ands or Buts”
   Allow only one trial.

   Score 0-1

7. 3-Stage Command
   Have the subject follow this command – “Take a piece of paper with your right hand; fold it in half and put it on the floor”.
   Score one point for each part correctly executed.

   Score 0-3

8. Reacting
   On a blank piece of paper print the sentence “Close your eyes” in letter large enough for the subject to see clearly. Ask them to read it and do what it says.
   Score one point only if they actually close their eyes.

   Score 0-1

9. Writing
   Give the subject blank piece of paper and ask them to write a sentence for you. Do not dictate a sentence; it is to be written spontaneously. It must contain a subject and a verb and be sensible. Correct grammar and punctuation are not necessary.

   Score 0-1

10. Copying
    On a clean piece of paper, draw intersecting Pentagons. Ask the subject to copy it exactly as it is. All 10 angles must be present and 2 must intersect to score one point. Tremor and rotation are ignored.

    Score 0-1

Total Score
10. Copying
CLOSE YOUR EYES
9.4 Appendix D - Geriatric Depression Scale questionnaire

GDS

Choose the best answer for how you have felt over the past week:
Please circle Yes or No

1. Are you basically satisfied with your life? Yes/No

2. Have you dropped many of your activities and interests? Yes/No

3. Do you feel your life is empty? Yes/No

4. Do you often get bored? Yes/No

5. Are you in good spirits most of the time? Yes/No

6. Are you afraid something bad is going to happen to you? Yes/No

7. Do you feel happy most of the time? Yes/No

8. Do you often feel helpless? Yes/No

9. Do you prefer to stay at home rather than going out and doing new things? Yes/No

10. Do you feel you have more problems with memory than most? Yes/No

11. Do you think it is wonderful to be alive now? Yes/No

12. Do you feel pretty worthless the way you are now? Yes/No

13. Do you feel full of energy? Yes/No

14. Do you feel that your situation is hopeless? Yes/No

15. Do you think that most people are better off than you are? Yes/No
9.5 Appendix E – Activities questionnaire

Activities Questionnaire

What types of activities/exercises do you normally do? ..............................................................
......................................................................................................................................................
........................................................................................................................................................

Since when have you started this activity? .................................................................................
......................................................................................................................................................
........................................................................................................................................................

How many hours a week do you do this activity? ........................................................................
......................................................................................................................................................
........................................................................................................................................................

What other activities have you pursued in the past? ...................................................................
......................................................................................................................................................
........................................................................................................................................................
........................................................................................................................................................

Did you undertook this activity in the past (e.g. when you were a child)?
Yes.............. No..............

What level at you at now? (Tick the appropriate answer)
Beginner .............
Intermediate .........
Advance .............
9.6 Appendix F – Semantic memory self-evaluation questionnaire

**Semantic memory**

*refers to the ability to remember concepts and retain general knowledge like for example the concept of what an animal is, the idea of what a car is, the knowledge that London is the capital of England, the name of the Queen, ...*

0. Do you usually feel that your memory for general information for famous people’s names or details (example: Queen) within recent years, is not as good as it once was?

1. Do you usually find it difficult recognizing faces and names of well-known people?

2. Do you usually find it difficult remembering details or information associated with well-known people? (Examples: you can’t remember the name of the person on TV but you can remember that he’s a political and spiritual leader; or you can’t remember the name of the person on TV but you know that he’s a political Italian leader ...).

3. Imagine that a series of pictures of well-known people are presented to you on a computer screen. Your task is to name the person represented on the picture (for example: the Prime Minister) or mention characteristics that define the picture you have been presented. Do you think you would ever find this task hard to perform?
Short term memory/Working Memory is the ability for holding a small amount of information in mind for a very short period of time. For example, a phone number, a list of names, a series of images ...

We can hold this information if we keep repeating it (for example we keep repeating the digits of the phone number) and it disappears when other information arrives and interferes with the rehearsal (somebody calls us). This information usually disappears but sometimes is stored in our memory indefinitely.

0. Do you usually feel that your short-term memory, within recent years, is not as good as it once was?

1. Imagine that you are participating in a testing session. You are asked to repeat a series of 7 digits after you have listened to them. Do you think you would ever find this task difficult to perform?

2. Imagine that you are participating in a testing session. On the table in front of you there are 10 cubes placed in random order. The examiner taps a sequence of 7 cubes and you are asked to repeat the sequence after the examiner. Do you think you would ever find this task difficult to perform?
3. Imagine that you are participating in a testing session. On the table in front of you there are 10 cubes placed in random order. The examiner taps a sequence of 6 cubes and you are asked to repeat the sequence backwards. Do you think you would ever find this task easy to perform?

4. Imagine that you are participating in a testing session. You are asked to repeat a series of 6 digits backwards after you have listened to them. Do you think you would ever find this task easy to perform?