Effects of aerobic fitness and aerobic exercise on visual attention and working memory performance

A

Thesis submitted

in the partial fulfillment of the requirement for the degree of

MASTER OF ARTS
IN
PSYCHOLOGY
(CLINICAL)

Submitted By:
Eshwerjyot Singh

(861702005)

UNDER THE SUPERVISION OF

Dr. Naveen
Lecturer
School of Humanities & Social Sciences

THAPAR INSTITUTE OF ENGINEERING AND TECHNOLOGY, PATIALA-147004

CERTIFICATE

This is to certify that the thesis entitled **"Effects of aerobic fitness and aerobic exercise on visual attention and working memory performance"** being submitted in partial fulfilment of requirement for the award of degree of **Master of Arts in Psychology in the School of Humanities and Social Sciences, Thapar Institute of Engineering and Technology, Patiala** is a bonafide work carried out under the supervision of **Dr. Naveen**, Lecturer, School of Humanities and Social Sciences, Thapar Institute of Engineering and Technology (Deemed to be University),Patiala and that no part of this project has been submitted for the award of any other degree.

Eshwerjyot Singh
(ESHWERJYOT SINGH)

This is to certify that above statement made by the student concerned is correct and true to the best of my knowledge.

(Dr. NAVEEN)

Lecturer, School of Humanities and Social Sciences

Thapar Institute of Engineering and Technology,

(Deemed to be University)

Patiala

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this thesis entitled "**Effects of aerobic fitness and aerobic exercise on visual attention and working memory performance**" being submitted in partial fulfilment of requirement for the award of degree of **Master of Arts in Psychology**, in **the School Sciences, Thapar of Engineering and Technology, Patiala** is authentic record of my own work carried under the supervision of **Dr. Naveen**, Lecturer, School of Humanities and Social Sciences, Thapar of Engineering and Technology (Deemed to be University), Patiala and refers other researcher's work which are duly listed in the reference section.

The matter embodied in the thesis has not formed the basis for the award of any other degree of this or any other university.

Date:

Place: Patiala

(ESHWERJYOT SINGH)

This is to certify that above statement made by the student concerned is correct and true to the best of my knowledge.

(Dr. NAVEEN)

Lecturer, School of Humanities and Social Sciences

Thapar of Engineering and Technology,

Patiala

Acknowledgement

In the accomplishment of this project successfully, many people have best owned upon me their blessing and the heart pledged support, this time I am utilizing to thank all the people who have been concerned with this project.

Primarily I would thank god for being able to complete this project with success. Then I would like to thank my guide Dr.Naveen and other faculty members namely Dr.Sanathakumari, and Dr. Surinder Kaur whose valuable guidance has been the ones that helped me patch this project and make it full proof success. His suggedtions and his instruction have served as the major contributor towards the completion of the project.

Then I would like to thank my Mother and my frinds who have helped me with their valuable suggestion and guidance has been vary helpful in various phases of the completion of the project.

List of Tables

List of Figures

CONTENT

Abstract

The effect of physical exercise on barin and cognitive functioning have atteracted many reserchers in recent decades. The present investigation has examined the effect of physical exercise and aerobic fitness on visual attention and working memory performance. Sixty three participants between the age range of 18-30 years took part in this study All participants were healthy and had no records of medical history of cardiovascular disease, asthma, and brain injuries. A 2 (Exercise: No exercise and 1 mile running) × 2 (Aerobic Fitness: Low and High) mixed factorial design was used in this study. Aerobic fitness was determined by the VO2max score obtained through Rockport test. Aerobic fitness was between subject factor, whereas physical exercise used as within subject factor. There were two dependent variable visual attention and working memory. Performance on visual attention and working memory task was recorded in terms of reaction time on TMT-A and TMT-B..Analysis of variance results revealed significant effect of physical exercise on visual attention and working memory. Physical exercise improved their response time when compared to pre-exercise test. Results further revealed better performance on visual search and working memory among high aerobic fitness participants as compared to their counterpart low aerobic fit group. The obtained findings are in line with the previous research explain that exercise is a agent that can significantly affect the brain function. The findings of the present study can be useful in the are of sports and work settings where higher attention and working memory is required.

Key Words: Physical exercise, Aerobic Fitness, Visual Attention, Working Memory

CHAPTER 1 INTRODUCTION

People often report changes in their capacity to perform any cognitive task during or following physical exercise.For Instance, sports person knows well that warm up exercise improves their capacity to concentrate, whereas solders carrying heavy load complains about the debilitating effects of physical fatigue on their cognitive processing capacity such as decision making and attentional performance. Besides these general beliefs, researches also support that physiological and psychological changes induced by physical activity potentially affects human cognitive performance. Considerable empirical and theoretical research have been conducted in recent decades.

Aerobic Fitness

Aerobic fitness is a measurement of an individual’s capacity to uptake and consume oxygen from the environment and use it to produce muscular energy. It is a ability of an individual to consume and utilize oxygen. The primary measure of aerobic fitness is VO2max, an individual’s consumption of oxygen during physical activity. VO2max is influenced by several components primarily heart and vascular system capacity to deliver oxygen to the muscles through blood stream and the ability of an individual’s lungs. The secondary component of aerobic fitness includes the ability of muscle cells to take up oxygen from blood and use it to produce energy.Maximal oxygen uptake (VO2 max) is characterized by the highest rate of oxygen utilization by the muscles during an exercise and to exhaustion state. It isconsidered to be the best single for measuring aerobic fitness (Armstrong, N. & McManus, A. M.,)

Aerobic Exercise

Physical exercise includes any aerobic and anaerobic activities which results in energy expenditure. Studies focusing the effects of physical exercise or physical activity on human cognitive or brain function have used a various types of exercise protocols (Tomporowski& Ellis, 1986). According to Audiffren (2009), physical exercise can be classified through two general metabolic pathways that provides and supports the energy to muscle (i.e. aerobic and anaerobic).

The activities while performing require more oxygen are termed as aerobic activities (e.g., jumping rope, running, playing basketball, playing volley ball, football etc.). During aerobic exercise individual's body starts breakdown of glycogen available in the body. If there is not enough glycogen available in the body, individual's body start's using fat reserves which helps to lose weight (Mann, 2015). On the other hand,physicalactivities such as sprinting, weight lifting are termed as anaerobic. Anaerobic exercisesare short in session and initiates a breakdown of energy even in the absence of sufficient oxygen.

Visual Attention

"Attention refers to concentration on a mental task in which we select certain kind of perceptual stimuli for further processing, while trying to exclude other interfering stimuli" (Shapiro, 1994).Because in attention a limited mount of information is processed there2fore the perceptual system of visual attention is highly selective. This selective property of perception has long been termed as attention (Woodworth & Schlosberg, 1954).

In simple word we can define attention as a process or capacity of an individual to selectively focusing on one aspect of environment while ignoring others information at the same time. Attention has been divided into three categories: -

(1) **selective attention:**Itis the capacity of an individual to focus on relevant information and to ignore the irrelevant information. Sustained attention is influenced by the physical characteristics (i.e. size, intensity, motion etc.) and collative characteristics of the stimulus (such as novelty, incongruity, complexity) orientation response (Dember& Warm, 1979) of the individual.

(2) **Divided attention:** Divided attention is the capacity of an individual to attain the information from two or more sourcessimultaneously. The best example of divided attention is driving where a driver attends the vehicles coming from back and front-side and at the same time he/she listens to the music also.

(3) **Sustained attention:**According toDavies & Parasuraman, (1982) “Sustained attention or vigilance refers to the ability of observers to maintain their focus of awareness and remain alert to stimuli for prolonged period of time”

Working Memory

Working memory is a one of the cognitive process which is under the broad domain of human cognition. It is sub category of executive functions, this process includes the active storage of information, maintenance of information, and manipulation of information to be used or reterived within a short period of time. “Working memory plays an important role in supporting complex cognitive functions, such as reasoning and decision-making" (G. A. Miller, et al., 1960).

Baddeley and Hitch (1974) did extensive research of this topic and developed a model through to describe the basic processes involved in working memory performance. According to this model(Baddeley, 2000) working memory consists of a central executive as a primary component and three sub component or supporting components: (1) phonological loop, (2) visuo-spatial sketchpad, and (3) episodic buffer. The central executive operate head or supervisorysystem, it control and coordinate the flow of information among three other components. The first sub component phonological loopreceive and processes verbal information, while the second component visuo-spatial sketchpad incorporate and processes visual and spatial information. The their component episodic buffer plays an important role integrating information between other two components i.e. phonological loop, visuospatial sketchpad, and long-term memory systems (Baddeley, 2000). Working memory has been assessed in several studies using a variety of tasks (e.g. trail making test, n-back task etc.) and paradigms (Baddeley, 2003; Conway, et al., 2005)

Exercise and Cognition

The relationship of exercise and cognitive function is one of the most growing research areas in cognitive psychology. The impact of physical exercise on cognition and brain function has been extensively studied in several cognitive domains such as perception, attention, working memory and decision-making, reasoning and other related constructs (Brisswalter, Arcelin, Audiffren, &Delignières, 1997; Chamura, Nazar, &Kaciuba-Uscilko, 1994; Fleury, Bard, & Carriere, 1981;Greig, Marchant, Lovell, Clough,

&McNaughton 2007; Meyers, Zimmerli, Farr, &Baschnagel, 1969; McMorris, 2016; McMorris & Graydon, 1997; Sanabria, Morales, Luque, Galvez, Huertas, &Lupianez, 2010). Number of scientific research studies have investigated the effect of exercise on cognitive function in recent decades. The literature available on this topic have reported four kind of result: (1) an improvement in cognitive performance performance (2) an impairment in performance (3) changes in cognitive strategies to maintain optimum performance (4) no effects on human cognition.

CHAPTER 2 REVIEW OF LITERATURE

Theoretical Development in Exercise and Cognition Interaction

The early research conducted in the area of physical exercise and cognitive and brain function was not based on theoretical support (Gutin& Di Gennaro, 1968; McAdam & Wang, 1967; Meyers et. al., 1969). The first theoretical support was provided by Davey (1973) for hypothesizing that physical exercise will have an effect on cognitive performance. He viewed physical exercise as being a stressor agent and same as anxiety, temperature, and noise etc., which have potential capacity to affect the arousal level among individuals (McMorris, 2016). To develop his first hypothesishe supported Yerks and Dodson (1908) inverted-U model of arousal and performance to develop his hypothesis. Yerks and Dodson model claims that human performance is good when arousal is optimum in an individual. In contrast, when arousal level is low or very high then human performance would become poorer.

Similarly,Easterbrook (1959) also developed his model according to him performance is poor when arousal level is low, which results that individual attentional focus is very wide and attend both related and unrelated information. Easterbrook further explained that as the arousal arise, individual process the information only relevant to the task, which results performanceefficiency.Severalother researcher's (Allard, Brawley, Deakin & Elliott, 1989; Isaacs & Pohlman, 1991) have supported Easterbrook's (1959) cue utilization theory to explained the physical exercise effects on cognition (McMorris, 2016). Yerks and Dodson Law and Easterbrook's cue utilization theories remained most popular theories among researchers to support their hypothesis till the late nineties (McMorris, 2016).

Several other later researchers' (Brisswalter et. al., 1997; Collardeau, Brisswalter, &Audiffren, 2001; McMorris & Keen, 1994) turned to support resource allocation theories of Kahneman (1973) and Sanders (1983). According to Kahneman an individualhave limited amount of resources to perform any task and the amount of resources are flexible not fixed. According to this theory as the arousal level arise the number of resource available in the brain to perform any task gets available, which results better performance on cognitive tasks. Kahneman further argued that performance gets improved only if individuals allocates the cognitive resources to the provided task. Kahneman also supported Yerks Dodson law and claimed that if arousal level is higher than optimum level, then person will not be able to allocate the mental resources to the task. Sanders (1983) also accepted almost parallel approach to Kahneman (1973). According to Sanders different stages of cognitive processing (i.e. arousal, activation, evaluation & effort) needed to be energized by various energetical mechanism. Arousal (phasic physiological response to input), Activation (physiological readiness to respond), Evaluation (executive control), and Effort (managing activity of the arousal and activation system).

In recent researches studies Audiffren (2009) and Audiffren, Toporowski and Zagrodnik (2009) supported Hockey's (1997) cognitive energetic model to explain the exercise- cognition interaction. According to Hockey's model there are two performance regulation loops:- (i) Automatic control loop: This mechanism regulate well-learned skills and function without effort. This loop monitors the action and compare the target outcome with actual outcome. If incongruity is perceived, adjustment in resourceallocation are made. (ii) Effortful control loop: This loop works in maintaining performance and includes effort monitor mechanism. This loop also sustains the task performance under disturbance from stressor and prevents the loss of task goals.

Researchers have used varities of models to explained and established their research hypothesis. However most of them have used or partially accepted Yerks and Dodson's inverted- U shaped approach. These theories were articulated to explain the effect of arousal and stress on overall performance in general, including human cognition. But none of theories are based on exercise only (McMorris, 2016). All the researchers who established their research hypothesis on the basis of above-mentionedtheories have assumed that, physical exercise is a kind of stressor (like noise, temperature etc.) and will affect human cognition in the same pattern of other stressors. Most of the theories are based on inverted-U shaped hypothesis, but these theories also demonstrated some differences from one another. Kahneman (1973) saw arousal as one-dimensional but Sanders (1983) divided arousal into two level arousal and activation. However, both believed that effort is vital forassigningmentalresources to the task.

Exercise and Cognitive Performance Interaction

It has been known that physical exercise is linked with fitness and healthy cardiovascular system. However, recently the researchers have understood that physical exercise is also very important for sustaining cognitive health. Researches have well established that keeping yourself physically active have sereal benefits and it protects your brain from expectedcognitive decay (Erikson & Kramer, 2009; Erickson et. al., 2011). According to recent reviews (Lambourne &Tomporowski, 2010; Mozrall& Drury, 1996; Tomporowski, 2003) physical exercise improves mental processing, clarity of thought and improve performance on some cognitive tasks, however it also inhibitperformance on other tasks or on the same tasks under dissimilar conditions. Moreover, the effect of physical exercise on cognitive performance is broad research area, including multiple domain related to memory, processing speed, executive control, learning, attention and perception, and overall cognitive performance (Churchill, Galvez, Colcombe, Swain, Kramer, & Greenough, 2002; Coteman&Berchtold, 2002; Erikson & Kramer, 2009; Erickson et. al., 2011).

Number of the researchesstudies conducted on the relationship between physical exercise and cognition have developed and tested their hypothesis based on “arousal” theories (Hockey, Gaillard, & Coles, 1986; Kahneman, 1973; Yerkes and Dodson, 1908). Common assumption to these theories is that to meet cognitive task demands, cognitive performance is reliant on distribution of energetically physiological and psychological resources.The evaluation of exercise induced arousal stands as central point for the vast literature regarding exercise and cognition. In exercise research scientists have investigated the effect of physical exercise during and after the cessation of exercise interventionon cognitive function. Research Studies measuring cognitive performance during physical exercise are majorly based on arousal theories, expecting physical exercise will increase arousal state among individuals. On the other hand, investigation measured cognitive performance following physical exercise are groundedon the expectation that exercise intervention will induce a state of fatigue or change in arousal level among individuals. Number of studies have been conducted in last five decades. The early researches do not establish the effect of physical exercise on human cognition performance during exercise intervention (Bard & Fleury, 1978; Fleury, Bard, Jobin, & Carriere, 1981). However, the later researches reported facilitation in performance on various cognitive domains.

The studies based on the behavioural measures (i.e. accuracy and reaction time) have reported different results on various cognitive domains. Number of studies have taken reaction time as performance measure along with performance efficiency. Reaction time has been recognized as an efficient indicative of performance efficiency and individual's ability to process visual information (Welford, 1968). Nanda, Balde, and Manjunatha (2013) examined the effect of thirty minutes aerobic exercise at 70% heart rate reserve on different cognitive tests (i.e. Spatial Span, Odd One Out, Feature Match, Polygon, Spatial Search, and Spatial Slider). Participants reported significant improvement in performance on Paired Associates, Odd One Out and Spatial Slider test the tests of memory, reasoning and planning respectively. On the other hand nosignificant improvement was found for the tests assessing concentration (Feature Match, Polygon). Although, the reaction time improved following exercise on all the cognitive tests than at the pre-test time.

In a recent study Davranche and Audiffren (2004) examined the effect of aerobic exercise on attentional discrimination task. Subjects performed attentional task under three experimental conditions, at resting state while exercising on cycle ergometer at 20% maximum aerobic power (MAP) and at 50% MAP. Participants reported fastest response time during exercising at 50% MAP followed by 20% MAP and resting state. The facilitation in performance has been also observed on visuospatial attentional task, participants under exercise condition (60% VO2max for 30 min.) reported better reaction time on visuospatial attention task as compared to non-exercise group (Tsai, Chen, Pan, Wang, Huang, & Chen, 2014).

Mild intensity physical exercise also improve visual attentional search task performance. Several studies have report better performance efficiency andimproved reaction time on visual search, visual feature and conjunction task performance. In a study by Allard, Brawley, Deakin, and Elliot (1989) examined the effect of cycling at 0%, 30% and 60 % maximal oxygen consumption (VO2 max) on visual search task during exercise intervention. Participants reported better performance at high level cycling workload s compared to low levels of cycling. In an another study Aks (1998) evaluated the performance of participants on visual feature and conjunction search. Participants exercised on visual search task after 10 minutes cycling exercise protocols at low level exertion (65% workload) and after then high level exertion(8 min. at 65% plus 2 min.at 80% workload). Results revealed better visual search speed and decreased error frequency. Performance was best under high level exertion protocols conditions. Improvement in choice reaction time has been also reported following exercise. Ellemberg and St-Louis-Deschenes (2010) observed better reaction time on choice reaction time and simple reaction time task under aerobic exercise condition following exercise intervention. One group of participants exercised on cycle ergometer for 30 minutes while the other group rested and did nothing. Participants under exercise group reported fastest response time on both the tasks than no exercise group. Arcelin, Delignieres and Brisswalter (1998) measured choice reaction time of participants while exercising on cycling ergometer at 60% VO2 max. The decision-making task was administered after three minutes of exercise and again after eight minutes of exercise. Participant's response time were significantly faster in exercise conditions than resting condition. Further, the reaction time was fastest at the cessation of the physical exercise period as compared to the beginning.

In sum of above mention research, the studies of Aks (1998), Allard et. al. (1989), Ellemberg and St-Louis-Deschenes (2010) and Arcelin, Delignieres and Brisswalter (1998) reported better reaction time on different cognitive task. In contrast, some studies including the intense exercise protocol conditions have reported delayed response time on many cognitive tasks. McMorris & Keen (1994) found delayed reaction time on 100% maximum poweroutput (MPO) cycle ergometer protocols as compared to 70% and 0% MPO. Moore, Romine, O'connor, and Tomporwski, (2012) also reported similar results, delayed reaction time on visual vigilance task.

In a recent study Legrand et. al .(2018) evaluated the effects of acute exercise on attentional control and working memory. Participants were tested on trail making test before and after exercise while the control group rested during the exercise session. Improvement in visual attentional control and working memory performance were evident among exercise groups when compared to the controls. In addition, Tom Bullock and Berry Giesbrecht (2014) examined the effect of acute aerobic fitness on cognitive performance. Participants with high aerobic fitness performed better on selective attention during visual search task. Similarly Concepcion Padilla, Laura Perez and Pilar Andres (2014) also evaluated the effect of aerobic fitness on working memory and inhibitory capacity. Results revealed active participants performed better on working memory than less active one. In addition active participants reported high capacity to manage two simultaneous two verbal task performance.

The recent exercise studies that used transcranial magnetic stimulation (TMS) and twitch interpolation techniques have well established that intense exercise also induce fatigue in the brain neurons (Amann & Dempsey, 2008; Gandevia, 2001). In addition, a different perspective emerges with narrative and meta-analytic reviews exploring the impact of physical exercise on cognitive performance (Chnag, Labban, Gapin, &Etnier, 2012; Tomporwski, 2003; Lambourne &Tomporwski, 2010). These reviews have reported some contradictory results and concluded that the effect of physical exercise on cognitive function totally depends upon the intensity of exercise, medium of exercise intervention and duration of physical exercise.

Majority of studies have used behaviouralresponse measures to examine the effect of acute exercise on cognitive function, however, a number of resent researchers have also incorporated the neuroelectric approaches for better fundamental understanding of exercise and cognition interaction (Hillman, Snook, & Jerome, 2003; Hillman, Kamjio, & Pontifex, 2012; Scudder, Drollette, & Pontifex, & Hillman, 2012). Gutmann, Mierau, Hülsdünker, Hildebrand, Przyklenk, Hollmann, and Strüder (2015) observed improved alpha peak frequency (iAPF) among individuals following exercise interventions. Alpha peak frequency is considered to be a recognized marker of better arousal and attention (Jann, Koeing, Dierks, Boesch, Federpiel, 2010). Alpha peak frequency is also positively correlated with better information processing and efficiency (Klimesch, 1999). The studies based on event-related potential (ERP) have reported increased P3 amplitude and shorted P3 latency following aerobic exercise (Kamijo, Nishihira, Higashiura, &Kuroiwa,

2007; Nakamura, Nishimoto, Akamatu, Takahashi, Maruyama, 1999). P3 is a standard primary ERP component, P3 amplitude reflects the attentional resource allocation dedicated to given task (Chang, 2016; Polich, 2007; Wickens, Kramer, Vanasee, &Donchin, 1983), whereas P3 latency is reflects speed of detecting and processing the stimulus (Chang, 2016; Magliero, Bashore, Coles, &Donchin, 1984; Polich, 2007). Increased P3 amplitude and shortened P3 latency represents the better amount of resource allocation and stimulus evaluation, respectively..Aberge et .al. (2009) aerobic fitness also improve cognitive function and influence brain health . Studies conducted on longitudinal design have well established that exercise programs improve both the cardiovascular capacity and cognitive function. Recent studies have also provided preliminary evidence that high aerobic fitness is associated with greater brain volume and better functional connection (Chaddock, 2010; Erikson, 2009). Therefore, in the light of these reported findings it can be concluded that aerobic exercise may leads to greater resource allocation and better information processing and stimulus evaluation

Rationale of the Study

Several neurological research have established that exercise affect human cognition. Preliminary evidence has been also found that regular exercise improves cardiovascular fitness which results increase in the greater brain volume and better information processing. Number of behavioral studies also have supported these changes induced through acute and chronic level of physical exercise. Previous behavioral research have incorporated the acute effect of exercise on cognitive performance. But very few studies have incorporated chronic effects of physical exercise on human cognition. Therefore, the present study have incorporated both chronic and acute effects of physical exercise on human cognition.

Objectives

1. To study the effect of physical exercise on visual search.
2. To study the effect of aerobic fitness on visual search.
3. To study the effect of physical exercise on working memory.
4. To study the effect of aerobic fitness on working memory.

Hypotheses

1. Participants would perform better after exercise intervention as compared pre-exercise performance on visual search test.
2. High aerobic fitness level participants would perform better than low fit on visual search test.
3. Participants would perform better after exercise intervention as compared pre-exercise performance on working memory test.
4. High aerobic fitness level participants would perform better than low fit on working memory test.

CHAPTER 3 METHODOLOGY

Sample

Sixty-three participants within the age range of 18 -30 (M = 21.11 years; SD= 3.02) years, weight (M= 68.94; SD= 15.28), BMI (M= 23.42; SD= 4.47) participated in this study. People with any known medical condition like cardiovascular disease, asthma or brain injury were not included in the sample. Further participants were divided into low aerobic fit and high fitness level on the basis of VO_{2max}score. Median analyses were used to categorize participants into low and high aerobic fitness groups. Details of demographic variables are presented in table 3.1

Table 3.1 Demographical information of participants

	Low Aerobic Fit	High Aerobic Fit
Age	22.68 (3.59)	19.64 (1.40)
Weight (in kg)	68.30 (17.33)	67.37 (11.25)
Height (cm)	104.15 (79.32)	158 (52.20)
BMI	24.48 (4.86)	21.99 (3.18)
VO_{2max}	44. 70 (9.87)	65.51 (4.44)

Design

A 2 (Exercise: No exercise and 1 mile running) × 2 (Aerobic Fitness: Low and High) mixed factorial design was used in this study. Aerobic fitness was determined by the VO2max score obtained through Rockport test. Aerobic fitness was considered as a between subject factor and exercise was used as within subject factor. There were two dependent variable visual attention and working memory. Visual attention and working memory task performance was recorded in terms of reaction time.

Tools

Trail Making Test (TMT)

The TMT is a well-known neuropsychological test which has been included in many neuropsychological batteries. The TMT measures several cognitive faculties such as visual search, scanning, mental flexibility, executive function and speed of information processing. The TMT consists two parts: Part -A and Part -B. Both the test were administered on A4 size paper.

TMT-A

Participants visual search performance was measured through TMT-A. TMT -A consists circled number from 1 to 25 which are randomly distributed on A4 size paper. Participants were required to connect the number in ascending order (for instance, 1,2,3,4, 5...25) by drawing a line. Participants were also asked to join the numbers as quickly as possible without compromising accuracy.

TMT- B

Performance on working memory was measured through TMT-B. TMT-B consists both number (from 1 to 12) and letters (A to L). These numbers and letters are also randomly distributed on the paper. TMT-B also required same process to perform except participant have to connect the number by alternating the latter (e.g. 1, A, 2, B, 3, D, 5, E………...12, L). TMT -B is a multifaceted neuropsychological test but the competition reaction time measures primarily working memory (Sanchez-Cubillo et. al. 2009).

Rockport Test

The Rockport is a famous aerobic fitness test which required the participants to run/ walk for 1 mile.Hear rate are being measured at the end of the one-mile walk. Weight of the person is also required to calculate the Rockport test.

Polar OH1+

Polar OH1+ is an optical hear rate monitor and provides records of every second's heart rate. This instrument was used to measure heart rate during all session (i.e. pre-TMT, Rockport test, cooldown, and post-TMT).

Procedure

Participants were provided information about the purpose of the study and informed consent were taken from them. Polar OH1+ monitor were placed on their arm to measure heart rate. Sample of TMT test were given to all the participants and they practice on the sample on test. Participants firstly performed on TMT -A and then on TMT -B. Task completion time of TMT A and B were recorded through stopwatch to the nearest of 00.01 seconds. On the completion of TMT participants performed 1-mile Rockport test, they were asked to run for 1 mile at their comfortable level pace. The Vo2max score for all participants were obtained through Rockport test. After Rockport test each participant were provided 10 minutes rest for cool down which followed TMT post-test. Hear rate was measured during all the session (i.e., pre TMT, Rockport test, Cooldown and post TMT). Participants were debriefed thanked for their participation.

CHAPTER 4 RESULTS

Manipulation check

To ensure that our first factor exercise had its effects on performance one-way repeated measure analysis of variance (ANOVA) were computed on heart rate among four phases (pre-exercise TMT session, after exercise, during cooldown and during post-exercise TMT). Mean results are presented in Table 3.1. ANOVA results revealed significant effect of phases, $F(3, 186) = 789.17$, $p = 0.000$, partial eta squared = .927 (see figure 3.1)

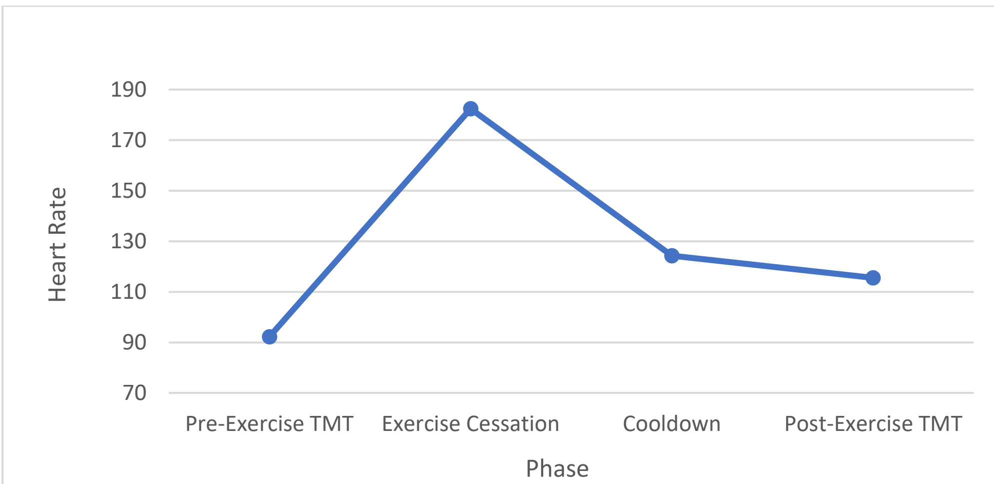

Figure.4.1 Mean hear rate across various time phases.

Table 4.1 *Means Standard Deviation (in parenthesis) heart rate during pre-exercise TMT, exercise, cool down and post-exercise TMT*

Pre-Exercise TMT	Exercise	Cooldown	Post-Exercise TMT
92.23 (12.71)	182.41 (15.89)	124.25 (11.98)	115.59 (12.42)

Performance Measures

Means and Standard deviation were computed for all performance measures. Means results are presented in table 4.2and 4.3. A 2 (Exercise: No exercise and 1 mile running) × 2 (Aerobic Fitness: Low and High)mixed factorial analysis of variance were computed. ANOVA results are presented in table 4.4 and 4.5.

Table 4.2 *Means and Standard Deviation (in parenthesis) of pre and post exercise among low and high aerobic fitness participants on visual search performance.*

		Pre-Exercise	Post- Exercise	Total
Visual search	Low Aerobic Fitness	20.67(7.37)	17.67(4.32)	19.16 (6.14)
	High Aerobic Fitness	18.64(4.57)	15.05(4.51)	16.78 (4.84)
	Total	19.64 (6.15)	16.34 (4.57)	

Table 4.3 *Means and Standard Deviation (in parenthesis) of pre and post exercise among low and high aerobic fitness participants on working memory performance.*

		Pre-Exercise	Post- Exercise	Total
Working memory	Low Aerobic Fitness	43.08(16.77)	34.87(10.28)	39.47 (14.57)
	High Aerobic Fitness	33.84(10.17)	30.57(11.75)	31.48 (10.17)
	Total	38.39 (14.48)	32.69 (11.13)	

TMT-A

First part of TMT results revealed that participants took less time to complete TMT-A after exercise (M= 16.34; SD= 4.57) as compared to pre-exercise session (M=

19.64; SD= 6.15). The main effect of exercise phase was found significant, F (1, 61) = 19.82, p= 0.000, partial eta square = .245 (see figure 4.2).

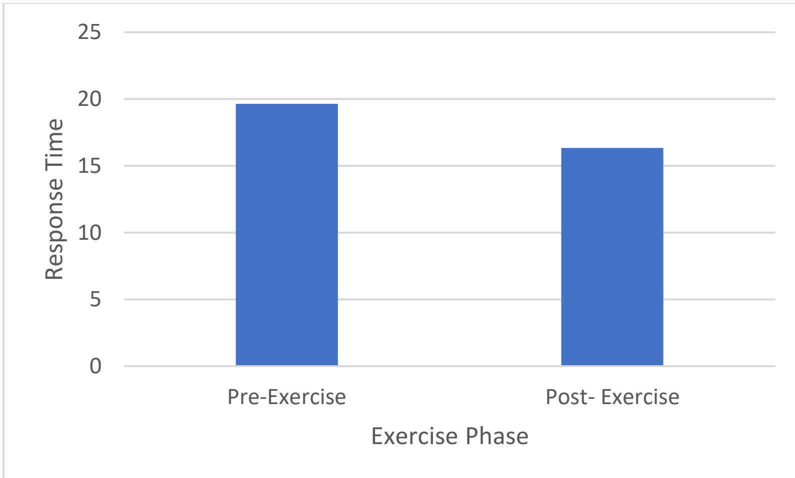

Figure.4.2 Mean response time for two different exercise phases on visual search performance

Results further revealed that high aerobic fit participants took less time to complete the task (M= 16.78, SD = 4.84) as compared to low aerobic fit (M= 19.16, SD =6.14). The main effect of aerobic fitness was also found significant, F (1, 61)= 4.274, p = 0.43, partial eta square = .065(see figure 4.3).

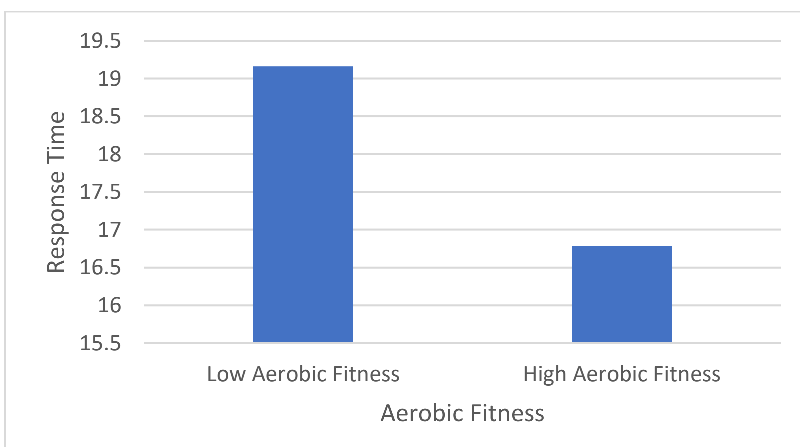

Figure.4.3 Mean response time for two different aerobic fitness level on visual search performance

The obtained results further revealed that there was similar change in performance of exercise intervention among both the groups. The interaction effect between exercise and aerobic fitness was not found significant, $F(1, 61) = 0.156$, $p = 0.694$, partial eta squared = .003 (see figure 4.4).

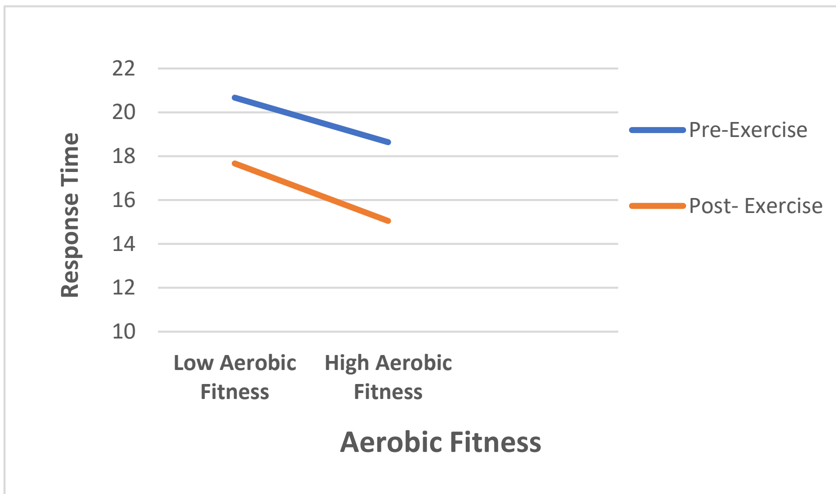

Figure.4.4 Response time as function of aerobic fitness and exercise phase on visual search performance

Table 4.4.*Summary of 2 × 2 analysis of variance of exercise and aerobic fitness on visual search performance*

Source of Variance	df	Sum of Square	Mean Square	F	Significance level	Partial eta squared
Within Subject Factor						
A: Exercise	1	341.06	341.06	19.82	0.000	.254
Error	61	1049.37	17.20			
Between Subject Factor						
B: Aerobic Fitness	1	169.83	169.83	4.27	0.04	.065
Error	61	2423.79	39.73			
Interaction Effects						
A × B	1	2.683	2.683	.156	.69	.003
Error	61	1049.37	17.20			

TMT – B

The obtained TMT-B results revealed that participants took less time to complete the task after exercise intervention (M= 32.69; SD= 11.13) as compared to pre-exercise intervention (M= 38.39; SD= 14.48). The main effect of exercise was found significant, F (1, 61) = 20.68, p = 0.000, partial eta square = .253 (see figure 4.5).

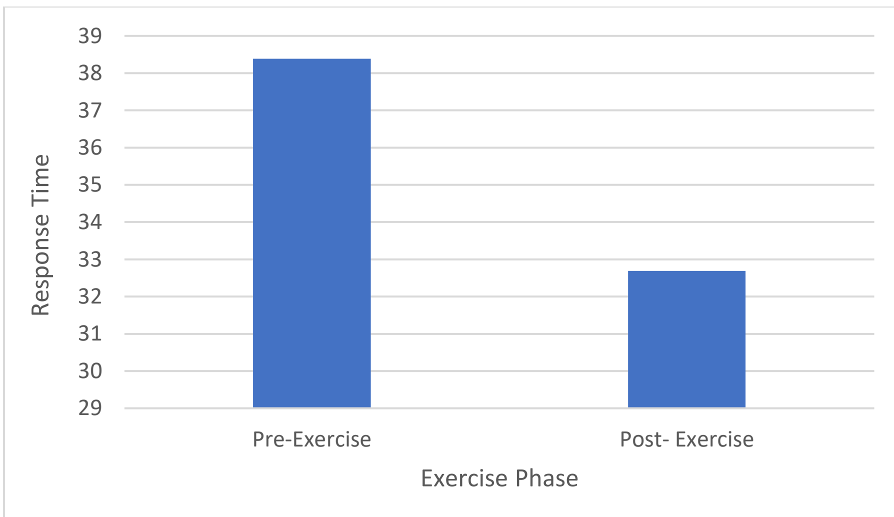

Figure.4.5 Mean response time for two different exercise phases on working memory performance

ANOVA results further revealed high aerobic fit participants took less time to complete the task (M = 31.48, SD = 10.17) as compared to low aerobic fit (M = 39.47, SD = 14.57). The main effect of aerobic fitness was also found significant, F (1, 61) = 5.51, p = 0.02, partial eta squared = .083 (see figure 3.6).

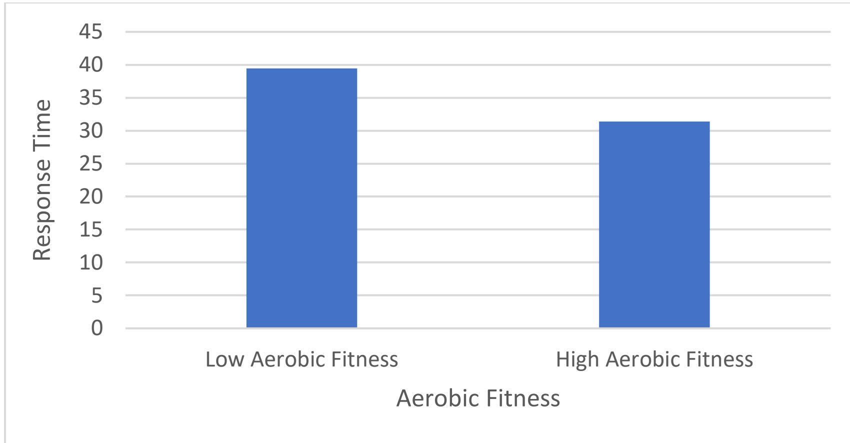

Figure.4.6 Mean response time for two different aerobic fitness levels on working memory performance

Means results further revealed that low aerobic fit participants showed better improvement of exercise intervention (pre-exercise: M = 43.08, SD = 16.77 to post exercise: M = 34.87, SD = 10.28)as compared to high aerobic fit (pre-exercise: M = 33.84, SD = 10.17 to post exercise: M = 30.57, SD = 11.75). The interaction effect of exercise and aerobic fitness was also found significant, F (1, 61) = 3.84, p = .05, partial eta squared = .059 (see figure 4.7).

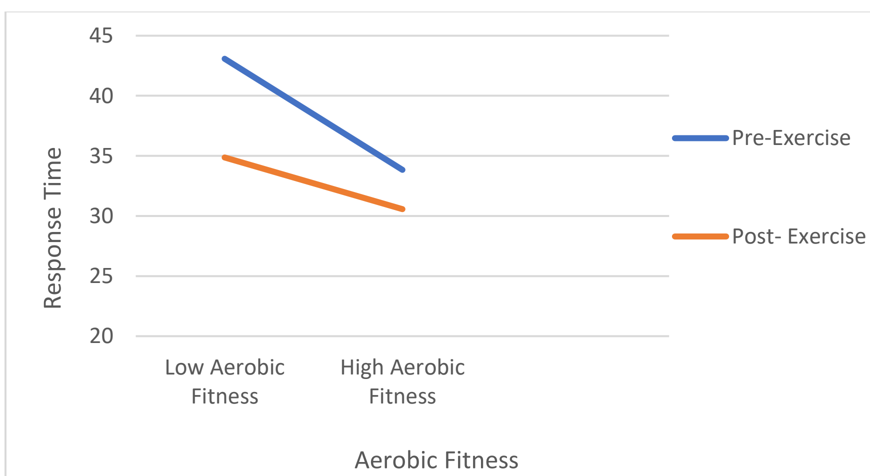

Figure.4.7 Response time as function of aerobic fitness and exercise phase on working memory

Table 4.5. *Summary of 2 × 2 analysis of variance of exercise and aerobic fitness on working memory performance*

Source of Variance	df	Sum of Square	Mean Square	F	Significance level	Partial eta squared
Within Subject Factor						
A: Exercise	1	1036.97	1036.97	20.68	0.000	.253
Error	61	3058.28	50.13			
Between Subject Factor						
B: Aerobic Fitness	1	1444.86	1444.86	5.51	0.02	.083
Error	61	15992.82	262.17			
Interaction Effects						
A × B	1	192.59	192.59	3.84	0.05	.059
Error	61	3058.28	50.13			

CHAPTER 5 DISCUSSION

The present study examined the effect of aerobic fitness and aerobic exercise on visual search and working memory performance. Visual search and working memory performance was measures with the help of TMT-A and TMT –before and after 1 mile jogging/running exercise among sixty three participants. Four hypotheses were framed (1) Participants would perform better after exercise intervention as compared pre-exercise performance on visual attention (2) High aerobic fitness level participants would perform better than low fit on visual attention (3) Participants would perform better after exercise intervention as compared pre-exercise performance on working memory test (4) High aerobic fitness level participants would perform better than low fit on working memory test

Our first hypothesis stated that participants would perform better after exercise intervention on visual attention test (TMT-A). The obtained findings revealed that participants took less time to complete visual search task after exercise intervention as compared to pre exercise session. Hence, our first hypothesis stands accepted. Second hypothesis stated that High aerobic fitness level participants would perform better than low fit on visual search test. Results revealed that high aerobic fitness level participants took less time to complete the task. Therefore, our second hypothesis also stands accepted.

Third hypothesis stated that participants would perform better after exercise intervention as compared pre-exercise performance on working memory test. Our obtained results clearly indicated that participants took less time to complete working memory task (TMT-A) after exercise interventions as compared to pre-exercise session.

Hence our third hypothesis also stands accepted. Fourth hypothesis stated that High aerobic fitness level participants would perform better than low fit on working memory test. Obtained findings demonstrated that high aerobic fit participants took significantly less time to complete the task (TMT-B) as compared to low fitness participants group. Therefore our fourth hypothesis also stands accepted.

Similar results have also been reported by Aks (1998). She found improvement in performance on visual search and conjunction task at high level exercise exertion. Further these results can be attributed to Yerks Dodson law which claims an optimum increase in arousal level can improve performance. One mile exercise was also with the prior expectation that this will increase an arousal level among individuals.

In a recent study Legrand et. al .(2018) found improvement in visual attentional control and working memory performance exercise 2 mile jogging exercise when compared to the their controls. In addition, Tom Bullock and Berry Giesbrecht (2014) reported that high aerobic fitness improves selective attention during visual search task. Similarly Concepcion Padilla, Laura Perez and Pilar Andres (2014) also found that active participants performed better on working memory than less active one. In addition active participants reported high capacity to manage two simultaneous two verbal task performance.

In addition, neurological studies also have established that exercise improves alpha peak activities in the brain (Gutmann, Mierau, Hülsdünker, Hildebrand, Przyklenk, Hollmann, Strüder, 2015). Alpha peak frequency is considered to be a recognized marker of better arousal and attention (Jann, Koeing, Dierks, Boesch, Federpiel, 2010)andalso found positively correlated with better information processing and efficiency (Klimesch, 1999).The studies based on event-related potential (ERP) have reported increased P3 amplitude and shorted P3 latency following aerobic exercise (Kamijo, Hayashi, Sakai, Yahiro, Tanaka, &Nishihira, 2009). P3 is a primary ERP component, and measures attentional resource allocation dedicated to given task (Chang, 2016; Polich, 2007). In addition P3 latency measures the speed of detecting and processing the stimulus (Chang, 2016; Polich, 2007). Increased P3 amplitude and shortened P3 latency represents the better amount of resource allocation and stimulus evaluation. According to Abergeet .al. (2009) aerobic fitness also improve cognitive function and influence brain health . Studies conducted on longitudinal design have well established that exercise programs improve both the cardiovascular capacity and cognitive function. Recent studies have also provided preliminary evidence that high aerobic fitness is associated with greater brain volume and better functional connection (Chaddock, 2010; Erikson, 2009).

Conclusion

The current study investigated the effect of physical exercise and aerobic fitness level on human cognition. The obtained findings have well established that physical exercise improves visual attention and working memory. In addition, the current research also established the that aerobic fitness improves working memory. The present findings provide behavioral support to the previous neurological studies, which have provided the evidences that exercise improves neuroelectric activities in human brain. These behavioral results also in line with the fMRI studies claiming that aerobic fitness is associated with high brain volume and better information processing.

Implication

The findings of the present study may be applied in the area of sports, military, hospital and other area of function where attention and working memory plays an important role. The current study clearly recommend that war-up exercise can improve attention and other cognitive area of function. This study also recommend that regular physical exercise can not only improve your cardiovascular fitness but it also facilitate several cognitive domains such as attention, working memory, processing speed, motor response.

Limitation

There are several limitations of this research. Rockport test was used to measure the fitness level of participants. To get the accurate Vo2mx value popper oxygen consumption test should be used. In the current study maximum participants were high aerobically fit according to Rockport as we did not get very low fit participants. The ssample size was relatively small and the number of male and female participants were unequal in the study. There is a possibility of gender effects on the response measures.

Scope for future Research

Vo2max value was measure with Rockport test which is believed to highly valid and reliable test for aerobic fitness. However, the accurate fitness level can only beobtained by using physiological measures. Therefore current study open an area to explore this relationship extensively by using physiological recordings such as VO2max, SpO2 etc. The current study has not assessed the possible gender and age difference, therefore future studies may incorporate these variable to explore this relationship.

References

Aks, D. J. (1998). Influence of exercise on visual search: Implications for mediating cognitive mechanisms. *Perceptual and Motor Skills*, *87*, 771-783. doi: 10.2466/pms.1998.87.3.771

Allard, F., Brawley, L. R., Deakin, J., & Elliott, D. (1989). The effect of exercise on visual attention performance. *Human Performance, 2*, 131-145.

Amann, M., & Dempsey, J. A. (2008). Locomotor muscle fatigue modifies central motor drive in healthy humans and imposes a limitation to exercise performance. *The Journal of Physiology, 586*(1), 161-173. doi: 10.1113/jphysiol.2007.141838

Arcelin, R., Delignières, D., &Brisswalter, J. (1998). Selective effects of physical exercise on choice reaction processes. *Perceptual and Motor Skills, 87*(1), 175-185. doi: 10.2466/pms.1998.87.1.175

Audiffren, M. (2009). Acute exercise and psychological functions: A cognitive-energetics approach. In T. McMorris, P. D. Tomporowski, & M. Audiffren (Eds.), *Exercise and cognitive function* (pp. 3-39). Chichester: Wiley-Blackwell.

Audiffren, M., Abou-Dest, A., &Possamai, C.A. (2007). Steady-state exercise aerobic increases sensory sensitivity. Paper presented at 12th ACAPS Conference, Leuven, Belgium.

Audiffren, M., Tomporowski, P. D., &Zagrodnik, J. (2009). Acute exercise and information processing: modulation of executive control in a Random Number

Generation task. *Acta Psychologica, 132,* 85-95. doi: 10.1016/j.actpsy.2009.06.008

Baken, P. (1959). Extraversion-introversion and decrement in an auditory vigilance task. *British Journal of Psychology, 50,* 325-332. 90

Baker, C. H. (1963). Further toward a theory of vigilance. In D. N. Buckner & J. J. McGrath (Eds.), *Vigilance: A symposium* (pp. 127-170). New York: McGraw-Hill.

Ballard, J.C. (1996). Computerized assessment of sustained attention: A review of factors affecting vigilance performance. *Journal of Clinical and Experimental Neuropsychology, 18*(6), 843-863. doi: 10.1080/01688639608408307

Bard, C., & Fleury, M. (1978). Influence of imposed metabolic fatigue on visual capacity components. *Perceptual and Motor Skills, 47,* 1283-1287. doi: 10.2466/pms.1978.47.3f.1283

Berger, B. G., Pargman, D., & Weinberg, R. S. (2014). *Foundations of exercise psychology*. Morgantown, WV: Fitness Information Technology.

Brisswalter, J., Arcelin, R., Audiffren, M., &Delignières, D. (1997). Influence of physical exercise on simple reaction time: Effect of physical fitness. *Perceptual and Motor Skills, 85,* 1019-1027. doi: 10.2466/pms.1997.85.3.1019

Broadbent, D. E. (1958). *Perception and Communication*. London: Pergamon Press.

Broadbent, D. E. (1971). *Decision and stress*. New York: Academic Press.

Broadbent D. E., & Gregory M. (1963). Vigilance considered as a statistical decision. *British Journal of Psychology, 54*(4), 309–323. doi: 10.1111/j.2044-8295.1963.tb00886.x

Buckworth, J., Dishman, R., O'Connor, P. J., &Tomporowski, P. (2013). *Exercise Psychology*. Champaign, IL: Human Kinetics.

CardiVision Stress Test System [Computer software]. (2007). Chandigarh, India: Medicaid Systems.CardiVision Treadmill [Apparatus]. (2007). Chandigarh, India: Medicaid Systems.

Chaddock, L., Hillman, C. H., Buck, S. M., & Cohen, N. J. (2011). Aerobic fitness and executive control of relational memory in preadolescent children. *Medicine and Science in Sports and Exercise, 43*(2), 344-349. doi: 10.1249/MSS.0b013e3181e9af48

Chang, Y. K. (2016). Acute exercise and event-related potential: Current status of future prospects. In McMorris, T. (Ed.), *Exercise-Cognition Interaction* (pp. 105-130). Oxford: Elsevier.

Chang, Y. K., Labban, J. D., Gapin, J. I., Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research, 1453,* 87-101. doi: 10.1016/j.brainres.2012.02.068

Chmura, J., Nazar, H., &Kaciuba-Uścilko, H. (1994). Choice reaction time during graded exercise in relation to blood lactate and plasma catecholamine thresholds. *International Journal of Sports Medicine, 15,* 172-176. doi: 10.1055/s-2007-1021042

Chu, C.J., & Jones, T.A. (2000) Experience-dependent structural plasticity in cortex heterotopic to focal sensorimotor cortical damage. *Experimental Neurology, 166,* 403- 414. doi: 10.1006/exnr.2000.7509

Churchill, J. D., Galvez, R., Colcombe, S., Swain, R. A., Kramer, A. F., & Greenough, W. T. (2002). Exercise, experience and the aging brain. *Neurobiology of Aging, 23*(5), 941-955.

Collardeau, M., Brisswalter, J., &Audiffren, M. (2001). Effects of a prolonged run on simple reaction time of well-trained runners. *Perceptual and Motor Skills, 93*(3), 679-689. doi: 10.2466/pms.2001.93.3.679

Colquhoun, W. P. (1961). The effect of unwanted signals on performance in a vigilance task. *Ergonomics, 4,* 42-51. doi: 10.1080/00140136608964402 92

Colquhoun, W. P. (1969). Effects of raised ambient temperature and event rate on vigilance performance. *Aerospace Medicine, 40*(4), 413-417.

Cote, J., Salmela, J. H., &Papthanasopoloulu, K. P. (1992). Effects of progressive exercise on attentional focus. *Perceptual and Motor Skills, 75*(2), 351-354. doi: 10.2466/pms.1992.75.2.351

Cotman, C. W., &Berchtold, N. C. (2002). Exercise: A behavioral intervention to enhance brain health and plasticity. *Trends in Neurosciences, 25*(6), 295-301.

Davey, C. P. (1973). Physical exertion and mental performance. *Ergonomics, 16,* 595-599. doi: 10.1080/00140137308924550

Davies, D. R., & Tune, G. S. (1970). *Human Vigilance Performance*. London: Staples.

Davies, D.R. &Parasuraman, R. (1982). *The Psychology of Vigilance*. London: Academic Press.

Davranche, K., &Audiffren, M. (2004). Facilitating effects of exercise on information processing. *Journal of Sports Science, 22,* 419–428. doi: 10.1080/02640410410001675289

Deese, J. (1955). Some problems in the theory of vigilance. *Psychological Review, 62*(5), 359-368.

Dember, & Warm, J. S. (1979). *Psychology of Perception*. New York: Holt, Rinehart and Winston.

Easterbrook, J. A. (1959). The effect of emotion cue utilization and the organization of behavior. *Psychological Review, 66*(3), 183-201. doi: 10.1037/h0047707 93

Egan, P. J., Greenberg, Z. G., & Schulman, A. I. (1961). Operating characteristics, signal detectability, and the method of free response. *The Journal of the Acoustical Society of America, 33,* 993-1007. doi: 10.1121/1.1908935

Ellemberg, D., Deschenes, M. St-Louis. (2010). The effect of acute physical exercise on cognitive function during development. *Psychology of Sports and Exercise*, *11,* 122-126. doi: 10.1016/j.psychsport.2009.09.006

Erickson, K. I., & Kramer, A. F. (2009). Aerobic exercise effects on cognitive and neural plasticity in older adults. *British Journal of Sports Medicine, 43*, 22-24. doi: 10.1136/bjsm.2008.052498

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., Kim, S. J., ….Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the National Academy of Sciences of the United States of America*, *108*, 3017-3022. doi: 10.1073/pnas.1015950108

Fleury, M., Bard, C., &Carrière, L. (1981). Effects of physical or perceptual workloads on a coincidence/anticipation task. *Perceptual and Motor Skills*, *53*(3), 843-850. doi: 10.2466/pms.1981.53.3.843

Fleury, M., Bard, C., Jobin, J., &Carrière, L. (1981). Influence of different types of physical fatigue on a visual detection task. *Perceptual and Motor Skills*, *53*(3), 723–730. doi: 10.2466/pms.1981.53.3.723

Gandevia, S.C. (2001). Spinal and supraspinal factors in human muscle fatigue. *Physiological Reviews, 81*(4), 1725-1789.

Green, D. M., &Swets, J. A. (1966). *Signal Detection Theory and Psychophysics*. New York: Wiley.

Greig, M., Marchant, D., Lovell, R., Clough, P., & McNaughton, L. (2007). A continuous mental task decreases the physiological response to soccer- specific 94 intermittent exercise. *British Journal of Sports Medicine, 41,* 908-913. doi: 10.1136/bjsm.2006.030387

Guralnick, M. J. (1972). Observing response and decision processes in vigilance. *Journal of Experimental Psychology, 93*(2), 239-244.

Gutin, B., &DiGennaro, J. (1968). Effect of one-minute and five minutes step-ups on performance of simple addition. *Research Quarterly for Exercise and Sport, 39*(1), 81-85. doi: 10.1080/10671188.1968.10616533

Gutmann, B., Mierau, A., Hulsdunker, T., Hilderband, C., Prazyklenk, A., Hollman, W., &Struder, H. K. (2015). Effects of physical exercise on individual resting state EEG alpha peak frequency. *Neural Plasticity*, *2015*, (2015:717312). doi: 10.1155/2015/717312

Hamilton, G. F., & Rhodes, J. S. (2016). Animal models of exercise-brain interactions. In Terry McMorris (Ed.). *Exercise-Cognition Interaction* (pp. 43-63). West Sussex: Elsevier

Hancock, P. A., & Hart, G. (2002). Defeating terrorism: What can human factors/ergonomics offer? *Ergonomics and Design, 10,* 6-16. doi: 10.1177/106480460201000103

Head, H. (1923). The conception of nervous and mental energy. II. Vigilance: A physiological status of nervous system. *British Journal of Psychology*, *14,* 126-147. doi: 10.1111/j.2044-8295.1923.tb00122.x

Hebb, D. O. (1955). Drives and the CNS (conceptual nervous system). *Psychological Review, 62*(4), 243-254. doi: 10.1037/h0041823

Helton, W.S., Dember, W.N., Warm, J.S., & Matthews, G. (2000). Optimism, pessimism, and false failure feedback: Effects on vigilance performance. *Current Psychology, 18,* 311-325. doi: 10.1007/s12144-999-1006-2 95

Helton, W.S., Hollander, T.D., Warm, J.S., Tripp, L.D., Parsons, K.S., Matthews, G., Dember, W. N., ….. Hancock, P. A. (2007). The abbreviated vigilance task and cerebral hemodynamics. *Journal of Clinical and Experimental Neuropsychology, 29,* 545-552

Hillman, C. H., Kamijo, K., & Pontifex, M. B. (2012). The relation of ERP indices of exercise to brain health and cognition. In H. Boecker, C. Hillman, L. Scheef, & H. K. Struder (Eds.), *Functional Neuroimaging in Exercise and Sport Sciences* (pp. 419-446). New York: Springer.

Hillman, C. H., Snook, E. M., & Jerome, G. J. (2003). Acute cardiovascular exercise and executive control function. *International Journal of Psychophysiology, 48*(3), 307-314.

Hockey, G. R. (1997). Compensatory control in the regulation of human performance under stress and high workload: A cognitive-energetical framework. *Biological Psychology, 45,* 73-93. doi: 10.1016/S0301-0511(96)05223-4

Hockey, R. J., Gaillard, A.W.K., & Coles, M.G.H. (1986). *Energetic Aspects of Human Information Processing*. Netherlands: MartinusNijhoff.

Humphreys, M.S., Revelle, W. (1984). Personality, motivation, and performance: A theory of the relationship between individual differences and information processing. *Psychological Review, 91*, 153-184. doi: 10.1037/0033-295X.91.2.153

Isaacs, L. D., & Pohlman, R. L. (1991). Effects of exercise intensity on an accompanying timing task. *Journal of Human Movement Studies, 20*, 123-131.

Jann, K., Koenig, T., Dierks, T., Boesch, C., & Federspiel, A. (2010). Association of individual resting state EEG alpha frequency and cerebral blood flow. *NeuroImage, 51*, 365-372. 96

Jerison, H. J. (1970). Vigilance: A paradigm and some physiological speculations. *Acta Psychologica, 33*, 367-380.

Jerison, H. J., & Pickett, R. M. (1964). Vigilance: The importance of the elicited observing rate. *Science, 143*, 970-971.

Jhonson, A. & Proctor, R.W. (2004). *Attention: Theory and Practice*. London: Sage.

Johnston, W. A., Howell, W. C., & Goldstein, I. L. (1966). Human vigilance as a function of signals frequency and stimulus density. *Journal of Experimental Psychology, 72*(5), 736-743.

Kahneman, D. (1973). *Attention and effort.* Englewood cliffs, NJ: Prentice-Hall.

Kamijo, K., Hayashi, Y., Sakai, T., Yahiro, T., Tanaka, K., &Nishihira, Y. (2009). Acute effects of aerobic exercise on cognitive function in older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 64,* 356-363.

Kamijo, K., Nishihira, Y., Higashiura, T., &Kuroiwa, K. (2007). The interactive effect of exercise intensity and task difficulty on human cognitive processing. *International Journal of Psychophysiology, 65*(2), 114-121. doi: 10.1016/j.ijpsycho.2007.04.001

Klimesch, W. (1999). EEG alpha and theta oscillation reflects cognitive and memory performance: A review and analysis. *Brain Research Review, 29*, 169-195. doi: 10.1016/S0165-0173(98)00056-3

Lambourne, K., &Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive performance: A meta-regression analysis. *Brain Research, 1341,* 12-14. doi: 10.1016/j.brainres.2010.03.091

Mackworth, J. F. (1968). Vigilance, Arousal and Habituation. *Psychological Review, 75*, 308-322. 97

Mackworth, J. F. (1969a). *Vigilance and habituation*. New York: Penguin Books.

Mackworth, J. F. (1969b). *Vigilance and Habituation: A Neuropsychological Approach*. Harmondsworth: Penguin.

Mackworth, N. H. (1950). Research on the measurement of human performance. *Medical Research Council Special Report No. 268.* London: H.M.S.O.

Mackworth, N.H. (1948). The breakdown of vigilance during prolonged visual search. *Quarterly Journal of Experimental Psychology*, *1,* 6-21. doi: 10.1080/17470214808416738

Magliero, A., Bashore, T., Coles, M. G. H., &Donchin, E. (1984). On the dependence of P300 latency on stimulus evaluation processes. *Psychophysiology*, *21*(2), 171-186.

Mann, J. (2015) *Aerobic exercise: The fitness through aerobics bible*. Morrisville: Lulu Press, Inc.

McAdam, R. E., & Wang, Y. K. (1967). Performance of a simple mental task following various treatments. *Research. Quarterly for Exercise and Sport, 38,* 208-212.

McGrath, J. J., & O'Hanlon, J. (1967). Temporal orientation and vigilance performance. In A. F. Sanders (Ed.), *Attention and Performance* (pp. 410-419). Amsterdam: North Holland Publication.

McMorris, T. (2016). History of research into the acute exercise-cognition interaction: A cognitive psychology approach. In McMorris, T. (Ed.), *Exercise-Cognition Interaction* (pp. 1-28). Oxford: Elsevier.

McMorris, T., & Graydon, J. (1997). Effect of exercise on cognitive performance in soccer-specific tests. *Journal of Sports Sciences*, *15,* 459-468. 98

McMorris, T., & Keen, P. (1994). Effect of exercise on simple reaction times of recreational athletes. *Perceptual and Motor Skills*, *78,* 123-130.

Meyers, C. A., Zimmerli, W., Farr, S. D., &Baschnagel, N. A. (1969). Effect of strenuous physical activity upon reaction time. *Research Quarterly for Exercise and Sport, 40,* 333-337.

Moore, R. D., Romine, M. W., O'connor, P. J., &Tomporwski P. D. (2012). The influence of exercise-induced fatigue on cognitive function. *Journal of Sports Sciences, 30* (9), 841-850. doi: 10.1080/02640414.2012.675083

Moray, N. (1967). Where is capacity limited? A survey and a model. *Acta Psychologica, 27,* 87-92. doi: 10.1016/0001-6918(67)90048-0

Mozrall, J. R. & Drury, C. G. (1996). Effects of physical exertion on task performance in modern manufacturing: A taxonomy, a review, and a model. *Ergonomics, 39*(10), 1179-1213. doi: 10.1080/00140139608964539

Nakamura, Y., Nishimoto, K., Akamatu, M., Takahashi, M., & Maruyama, A. (1999). The effect of jogging on P300 event related potentials. *Electromyography and Clinical Neurophysiology, 39*(2), 71-74.

Nanda, B., Balde, J. S., &Manjunatha, S. (2013). The acute effects of a single bout of moderate-intensity aerobic exercise on cognitive functions in healthy adult males. *Journal of Clinical and Diagnostic Research, 7,* 1883-1885.

Naveen, Mishra, T., Tiwari, T., Singh, I. L., Singh, A. L., & Singh, T. (in press). Effect of aerobic exercise on reaction time during vigilance task performance. *Journal of the Indian Academy of Applied Psychology, 43*(2).

Naveen, Mishra, T., Tiwari, T., Singh, I. L., Singh, T., & Singh, A. L. (2017). Effect of single bout of aerobic exercise on vigilance task performance. *Asian Journal of Research in Social Science and Humanities*, *7* (9), 253-263. doi: 10.5958/2249-7315.2017.00459.2 99

Navon, D., & Gopher, D. (1979). On the economy of the human information processing system. *Psychological Review, 86* (3), 214-255. doi: 10.1037/0033-295X.86.3.214

Norman D. A., &Bobrow, D. G. (1975). On data-limited and resource-limited processes. *Cognitive Psychology, 7*(1), 44-64. doi: 10.1016/0010-0285(75)90004-3

Parasuraman, R. (1979). Memory load and event rate control sensitivity decrements in sustained attention. *Science, 205,* 924-927.

Parasuraman, R. (1987). Human-computer monitoring. *Human Factors, 29,* 695-706.

Parasuraman, R., & Davies, D. R. (1977). A taxonomic analysis of vigilance performance. In R. R. Mackie (Ed.), *Vigilance: Theory, Operational Performance, and Physiological Correlates* (pp. 559-574). New York: Plenum.

Parasuraman, R., Warm, J. S., &Dember, W. N. (1987). Vigilance: Taxonomy and utility. In L. S. Mark, J. S. Warm, & R. L. Huston (Eds.), *Ergonomics and human factors: Recent research*. New York: Springer-Verlag.

Parasuraman, R., Warm, J. S., & See, J. E. (1998). Brain systems of vigilance. In R., Parasuraman (Ed.), *The attentive brain* (pp. 221-256). Cambridge, MA: MIT Press.

Pesce, C., Capranica, L., Tessitore, A., &Figura, F. (2003). Focusing of visual attention under submaximal physical load. *International Journal of Sport and Exercise Psychology, 1,* 275-292. doi: 10.1080/1612197X.2003.9671719

Piehl, K. (1974). Glycogen storage and depletion in human skeletal muscle fibers. *Acta PhysiologicaScandinavica, 402* (Suppl.), 1-33. 100

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*(10), 2128-2148.

Posner, M. I. (1978). *Chronometric explorations of mind*. Hillsdale, N. J.: Lawrence Erlbaum.

Rodriguez, J. J., &Verkhratsky, A. (2011). Neurogenesis in Alzheimer's disease. *Journal of Anatomy, 219*(1), 78-89. doi: 10.1111/j.1469-7580.2011.01343.x

Rose, C. L., Murphy, L. B., Byard, L., &Zikzad, K. (2002). The role of the big five personality factors in vigilance performance and workload. *European Journal of Personality*, *16*, 185-200.

Sanabria, D., Morales, E., Luque, A., Galvez, G., Huertas, F., &Lupianez, J. (2010). Effects of acute aerobic exercise on exogenous spatial attention. *Psychology of Sport and Exercise, 12* (2011), 570-574. doi: 10.1016/j.psychsport.2011.04.002

Sanders, A. F. (1983). Towards a model of stress and human performance. *Acta Psychologica, 53*(1), 61-97.

Satchell, P. M. (1993). *Cockpit monitoring and alerting systems*. Brookfield, VT: Ashgate.

Scudder, M. R., Drollette, E. S., Pontifex, M. B., & Hillman, C. H. (2012). Neuroelectric indices of goal maintenance following a single bout of physical activity. *Biological Psychology, 89*(2), 528-531.

Shapiro, K.L. (1994). The attentional blink: The brain's "eyeblink." *Current Directions in Psychological Science, 3*(3), 86-89.

Sharpless, S., & Jasper, H. H. (1956). Habituation of the arousal reaction. *Brain, 79*, 655-680. 101

Sheridan, T. B. (1970). On how often the supervisor should sample. *IEEE Transactiond on Systems Science and Cybernetics SSC, 6*(2), 140-145.

Sheridan, T. B. (1987). Supervisory control. In G. Salvendy (Eds.). *Handbook of human factors* (pp. 1243-1268). New York: Wiley.

Sibley, B. A, Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science, 15*(3), 243-256.

Singh, I. L., Greenwood, P. M., & Parasuraman, R. (2006). Cued vigilance performance in young and old adults. *Psychological Studies, 51*(1), 7-11.

Singh, I. L., Singh, A. L., & Tiwari, T. (2004). Discrimination type and sustained attention task performance. *Journal of the Indian Academy of Applied Psychology, 30*, 58-62.

Smith, R. L. (1966). *Monotony and motivation: A theory of vigilance*. Los Angeles, California: Dunlop and Associates, Inc.

SuperLab (Version 4.0.5) [Computer software]. (1992). San Pedro, CA: Cedrus Corporation.

Swain, R. A., Harris, A. B., Wiener, E. C., Dutka, M. V., Morris, H. D., Theien, B. E., Konda, S., Engberg, K……Greenough, W. T. (2003) Prolonged exercise induces angiogenesis and increases cerebral blood volume in primary motor cortex of the rat. *Neuroscience, 117*(4), 1037-1046.

Swets, J. A. (1977). Signal detection theory applied to vigilance. In R. R. Mackie (Eds.), *Vigilance: Theory operational performance and physiological correlates* (pp. 705-718). New York: Plenum.

Swets, J. A., & Kristofferson, A. B. (1970). Attention. *Annual Review of Psychology, 21*, 339-366. 102

Szalma, J. L. (1999). *Sensory and temporal determinants of workload and stress in sustained attention*. Unpublished doctoral dissertation, University of Cincinnati, Cincinnati, OH.

Szalma, J.L., & Hancock, P.A. (2002). *On mental resources and performance under stress*. Unpublished white paper, MIT2 Laboratory, University of Central Florida. Available at www.mit.ucf.edu

Taub, H. A., & Osborne, F. H. (1968). Effects of signals and stimulus rates on vigilance performance. *Journal of Applied Psychology, 52*(2), 133-138.

Teichner, W.H. (1974). The detection of a simple visual signal as a function of time on watch. *Human Factors, 16,* 339-353

Tiwari, T., Singh, A. L., & Singh, I. L. (2009). Task demand and workload: Effect on vigilance performance. *Journal of Indian the Academy of Applied Psychology, 35*(2), 265-275.

Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta Psychologica, 112*(3), 297-324.

Tomporowski, P. D., & Ellis, N. R. (1986). The effects of exercise on cognitive processes: A review. *Psychological Bulletin, 99,* 338-346. doi: 10.1037/0033-2909.99.3.338

Travlos, A. K., &Marisi, D. Q. (1995). Information processing and concentration as a function of fitness level and exercise induced activation to exhaustion. *Perceptual and Motor Skills, 80,* 15-26. doi: 10.2466/pms.1995.80.1.15

Tsai, C. L., Chen, F. C., Pan, C. Y., Wang, C. H., Huang, T. H., & Chen, T. C. (2014). Impact of acute aerobic exercise and cardiorespiratory fitness on visuospatial attention performance and serum BDNF levels. *Psychoneuroendocrinology, 41,* 121-131. 103

Van Praag, H., Christie, B. R., Sejnowski, T. J., Gage, F. H. (1999). Running enhances neurogenesis, learning, and long-term potentiation in mice. *Proceedings of the National Academy of Sciences of the United States of America, 96*(23), 13427-13431.

Van Praag, H., Kempermann, G., & Gage, F. H. (1999). Running increases cell proliferation and neurogenesis in the adult mouse dentate gyrus. *Nature Neuroscience, 2*(3), 266-270. doi: 10.1038/6368

Varela-Nallar, L., Aranguiz, F. C., Abbott, A. C., Slater, P. G., &Inestrosa, N. C. (2010). Adult hippocampal neurogenesis in aging and Alzheimer's disease. *Birth Defects Research Part C - Embryo Today: Reviews, 90*(4), 284-296. doi: 10.1002/bdrc.20193

Warm, J. S. (1977). Psychological processes in sustained attention. In R. R. Mackie (Ed.), *Vigilance: Theory, operational performance, and physiological correlates* (pp. 623-644). New York: Plenum.

Warm, J. S. (1984). An introduction to vigilance. In J. S. Warm (Ed.), *Sustained attention in human performance*. (pp. 1-14). Chichester, UK: Wiley.

Warm, J. S., &Dember, W. N. (1998). Tests of vigilance taxonomy. In R. R. Hoffman, M. F. Sherrick, & J. S. Warm (Eds.), *Viewing psychology as a whole: The* *integrative science of William Dember*(pp. 87-112). Washington, DC: American Psychological Association.

Warm, J. S., Dember, W. N., & Hancock, P. A. (1996). Vigilance and workload in automated systems. In R. Parasuraman & M. Mouloua (Eds.), *Automation and human performance: Theory and applications* (pp. 183-200). Mahwah, NJ: Erlbaum. 104

Warm, J.S., &Jerison, H. J. (1984). The psychophysics of vigilance. In J. S. Warm (Ed.), *Sustained attention in human performance* (pp. 15-59). Chichester, UK: Wiley.

Welford, A. T. (1968). *Fundamentals of skill*. London: Methuen.

Wickens, C. D., Hollands, J. G. (2000). *Engineering psychology and human performance*. Upper Saddle River, NJ: Prentice-Hall.

Wickens, C., Kramer, A. F., Vanasse, L., &Donchin, E. (1983). The performance of concurrent tasks: A psychophysiological analysis of the reciprocity of information processing resources. *Science, 221*, 1080-1082.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to the rapidity of habit formation. *Journal of Comparative Neurology and Psychology, 18*, 459-482. doi: 10.1002/cne.920180503