THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

INSTITUTE OF SCIENCE AND TECHNOLOGY

AN EVALUATION OF THE BENEFITS OF SIMULATOR TRAININGS FOR PILOTS BY USING PHYSIOLOGICAL MEASUREMENTS

MASTER THESIS

İsmail KUMPAS

Electrical and Electronics Engineering Department

Master Thesis Program

FEBRUARY 2016

THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

INSTITUTE OF SCIENCE AND TECHNOLOGY

AN EVALUATION OF THE BENEFITS OF SIMULATOR TRAININGS FOR PILOTS BY USING PHYSIOLOGICAL MEASUREMENTS

MASTER THESIS

İsmail KUMPAS

1303630012

Electrical and Electronics Engineering Department

Master Thesis Program

Supervisor: Assist. Prof. Dr. M.Taylan DAŞ

İsmail KUMPAS, having student number 1303630012 and enrolled in the Master Program at the Institute of Science and Technology at the University of Turkish Aeronautical Association, after meeting all of the required conditions contained in the related regulations, has successfully accomplished, in front of the jury, the presentation of the thesis prepared with the title of “An Evaluation Of The Benefits Of Simulator Trainings For Pilots By Using Physiological Measurements”

Supervisor : **Assist. Prof. Dr. M.Taylan DAŞ**
Kırıkkale University

Jury Members : **Assist. Prof. Dr. M.Taylan DAŞ**
Kırıkkale University

: **Assist. Prof. Dr. Engin DEMİR**
The University of Turkish Aeronautical Association

: **Assist. Prof. Dr. Abdellatif BABA**
The University of Turkish Aeronautical Association

Thesis Defense Date: 10.02.2016

THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUTE OF SCIENCE AND TECHNOLOGY

I hereby declare that all the information in this study I presented as my Master's Thesis, called "An Evaluation Of The Benefits Of Simulator Trainings For Pilots By Using Physiological Measurements" has been presented in accordance with the academic rules and ethical conduct. I also declare and certify on my honor that I have fully cited and referenced all the sources I made use of in this present study.

10/02/2016
İsmail KUMPAS

FOREWORD

I had the opportunity to see closely simulator flight trainings received by pilots, because of working in HAVELSAN which designs, manufactures and operates full flight simulators. I had better understood that how hard, how serious and how necessary these trainings were. The point that attracted my attention was that pilots (no matter how experienced) are required to take a certain period of training in the full flight simulator. This ensures that the pilots always ready to face all kinds of dangers. This increases the awareness of just how dangerous jobs they have. Thus, pilots should be always mentally ready for the mission.

Well! In spite of receiving high-level training with well-equipped technological opportunities, why are the aircraft crashes increasing recently? Do the airways increase the number of aircraft in the fleet of the company or news on this topic began to attract my attention because of my business? After making a short research I observed that, pilots' cognitive emotions had a great impact on increasing the aircraft crashes. I decided to work on this subject.

First of all, I would like to thank my supervisor Assist. Prof. Dr. M.Taylan DAŞ for his guidance, broad vision and incredibly useful advice during the preparation of my thesis. I also owe thanks to all volunteer pilots and technical staff to help with the collection of necessary data for this thesis. Finally, although I allocated very little time to them; I would like to thank a lot to my family for providing moral support to me.

February 2016 İsmail KUMPAS

TABLE OF CONTENTS

TABLE LISTS

FIGURE LISTS

ABBREVIATIONS

AFCS : Automatic Flight Control System
ANOVA : Analysis of Variance
ATC : Air Traffic Control
DOF : Degree of Freedom
EASA : European Aviation Safety Agency
ECG : Electrocardiogram
EEG : Electroencephalogram
EMG : Electromyography
EOG : Electrooculography
FAA : Federal Aviation Administration
GSR : Galvanic Skin Response
HAVELSAN : Hava Elektronik Sanayi
HR : Heart Rate
I/O : Input / Output
ICAO : International Civil Aviation Organization
IG : Image Generator
IGE : In Ground Effect
JAR : Joint Aviation Requirements
NVG : Night Vision Goggles
OGE : Out of Ground Effect
QTG : Qualification Test Guide
SA : Situation Awareness
SAS : Stability Augmentation System
TCC : Tactical Control Center
TUAF : Turkish Air Force
WHO : World Health Organization

ABSTRACT

AN EVALUATION OF THE BENEFITS OF SIMULATOR TRAININGS FOR PILOTS BY USING PHYSIOLOGICAL MEASUREMENTS

KUMPAS, İsmail

Master of Science, Institute of Science and Technology,

Department of Electrical and Electronics Engineering

Thesis Supervisor: Assist. Professor M. Taylan DAŞ

February 2016, 78 pages

Simulation technology in the aviation industry is more critical than other technologies used in safety-critical industry. Previously, simulators in aviation training were used in order to train instrumentations (sticks, rudder and avionic instrument training). Today, a large part of aviation training (especially the new multi-crew pilot license training) is mostly based on the simulation of flight training. Although it seems that the most important reason for this is taking an effective training; the main reason is to save money, time and people's life.

The importance of full flight simulators in pilot trainings is increasing day by day for military use as well as civil use. This thesis is prepared to monitor changes that occur in cognitive status of pilots during the training received in a new generation simulator. For this purpose, heart rate data of the pilots are collected during the trainings and using this data anxiety of a pilot when faced with a malfunction is evaluated.

The simulator which is used in this thesis is designed and constructed with high technology. It includes a simulated cockpit which enables to generate dynamic effects of a real aircraft. In this simulator, tests were performed on pilots having different flight hours. During the experiments, measurement data was collected from 6 experienced pilots, 8 inexperienced pilots and 3 candidate pilots. With this context, quantitive data were obtained by heart rate measurement method which is one of the physiological test methods used in the simulators. The collected raw data is first processed by using different filters available in MATLAB signal processing toolbox. Following the filtering process, this data set is also evaluated statistically.

The data analysis enabled us to observe the difference between the response of new pilots and experienced pilots when faced with disruptive effects. Obtained results showed the impact of simulators on the process of pilot training and the effects of different malfunctions in the cognitive status of the pilot. It is expected that as a result of the experience gained in flight simulators, pilots would feel less anxious when they face dangerous situations in a real flight. It is hoped that this study would trigger the development of neurophysiology targeted and pilot-centered new generation intelligent simulators in the coming years.

Key Words: full flight simulator, cognitive status, dynamic effect, physiological test method, heart rate measurement, signal processing, anxiety, disruptive effect

ÖZET

PİLOTLAR İÇİN SİMÜLATÖR EĞİTİMİNİN FAYDASININ FİZYOLOJİK ÖLÇÜMLER KULLANILARAK DEĞERLENDİRİLMESİ

KUMPAS, İsmail
Yüksek Lisans, Fen Bilimleri Anabilim Dalı,
Elektrik ve Elektronik Mühendisliği Bölümü
Tez Danışmanı: Yrd. Doç. Dr. M.Taylan DAŞ
Şubat 2016, 78 sayfa

Simülasyon Teknolojisi, güvenlik açısından diğer kritik sanayilere nazaran havacılık endüstrisinde daha çok kullanılan bir teknolojidir. Önceleri simülatörler, havacılık eğitimlerinde yalnızca alet eğitimleri (lövye, dümen ve aviyonik cihazların eğitimi) amacıyla kullanılmaktaydı. Günümüzde ise, havacılık eğitiminin büyük bir kısmı (özellikle yeni çok-mürettebatlı pilot lisans eğitiminin) simülasyon tabanlı uçuş eğitimine dayanır. Bunun en önemli sebebi etkili eğitimin alınması gibi gözükse de; temel sebep para, zaman ve insan hayatının kurtarılmasıdır.

Askeri amaçlı kullanımının yanı sıra sivil amaçlı kullanımlarda da pilot eğitimlerinde tam uçuş simülatörünün önemi gün geçtikçe artmaktadır. Bu tez pilotların yeni nesil simülatörlerde gördükleri eğitimler sırasında bilişsel durumlarında gerçekleşen değişimleri izlemek için hazırlanmıştır. Bu amaçla eğitimler sırasında pilotların kalp hızlarına ait verileri toplanmış ve bu very kullanılarak pilotun bir arıza ile karşılaştığında duyduğu endişede değerlendirilmiştir.

Bu tez çalışmasında en gelişmiş teknoloji ile tasarlanmış ve imal edilmiş bir simülatör kullanılmıştır. Simülatör, gerçek bir uçaktaki dinamik etkilerin üretilmesine olanak sağlayan bir kokpite sahiptir. Bu simülatörde farklı uçuş saatlerine sahip pilotlar üzerinde testler uygulanmıştır. Deneyler esnasında 6 tecrübeli pilot, 8 tecrübesiz pilot ve 3 pilot adayından veriler toplanmıştır. Bu kapsamda, nicel veriler simülatörlerde kullanılan fizyolojik test metodlarından biri olan kalp atış hızı ölçümü ile elde edilmiştir. Toplanan ham veri önce MATLAB

sinyal işleme araç kutusunda bulunan farklı filtreler ile işlenmiştir. Buveri seti filtreleme işlemini takiben istatistiksel olarak da değerlendirilmiştir.

Yapılan analiz, yeni pilotlar ile tecrübeli pilotların bozucu etkiler ile karşılaştıklarında verdikleri tepkilerdeki farkın gözlemlenmesine olanak sağlamıştır. Elde edilen sonuçlar, simülatörlerin pilot uçuş eğitimi süreçlerine katkılarını ve farklı arızaların pilotların bilişsel durumlarına etkisini göstermiştir. Uçuş simülatörlerinde kazanılan tecrübenin sonucunda pilotların gerçek uçuşta karşılaştıkları tehlikeli durumlarda daha az endişe duymaları beklenmektedir. Bu çalışmanın önümüzdeki yıllarda hedeflenen, nörofizyoloji temelli ve pilot-merkezli yeni nesil akıllı simülatörlerin geliştirilmesi için tetikleyici olacağı umit edilmektedir.

Anahtar Kelimeler: tam uçuş simülatörü, bilişsel durum, dinamik etki, fizyolojik test metodu, kalp atış hızı ölçümü, sinyal işleme, endişe, bozucu etki

CHAPTER ONE

1. INTRODUCTION

It is well-known that driving a car (and to a major extent, an aircraft) requires significant cognitive effort and attention for the drivers. According to the World Health Organization (WHO) the primary cause of death in adults from 18 to 29 years old, and the ninth cause of human death globally, is represented by car accidents (Preventing Road Traffic Injury: A Public Health Perspective For Europe, 2009). In fact, when an individual drives a car, this reality which is the brain's capacities of attention, memory and awareness are often ignored. By the way, all individuals can make even more mistakes when performing common everyday tasks. The main important thing is easy to quickly act to prevent repeating errors, and this is called a learning process [1].

In many complex command and control systems, the crucial point is mental workload. If performance failures occur this could result in catastrophic losses. Thus, understanding the operator's mental workload in these situations is the most critical point. Cognitive capacity of an individual could also be increased with training which would lead to gradual increase in experience. It is observed that experienced individuals can easily overcome unexpected disruptive effects. Therefore, training experienced operators for command and control system has more risk of catastrophic losses (i.e. Air Traffic Control (ATC) operators, Civilian Aircraft Pilots and - maybe the most important one - Warship Commander) has become much more important [2].

Aircraft pilots have to operate more complex vehicles with the risk of catastrophic losses. Therefore, before getting their flying license, pilots have to go through a severe training program. Nowadays, modern glass cockpits are more complex systems than analogue cockpits. They are designed to be as intuitive as possible for a new pilot. Although they look tidy, a huge and a very complex system is functioning behind the scenes of a cockpit. As a result, it becomes increasingly challenging for pilots to fully and continuously manage the display systems of the new models of modern aircrafts.

Why is it crucial for the pilot to command and manage the entire cockpit? In emergency situations the available time required to understand and solve the problem could be very short. Even though an aircraft has an excellent reliability, there is still great risks in actual flights related to emergency situations and situations that could occur because of pilot's mental workload. When an emergency situation occurs, the pilot's mental state – a construct including situation awareness (SA), mental workload and fatigue –plays a crucial role in solving the problems [1].

The description of the human behaviour during aircraft control and mental fatigue is a very crucial concept. In fact, mental fatigue is believed to be a gradual and cumulative process that reduced efficiency and alertness and also it is thought to be related to unwillingness for any effort, feelings of inhibition and impaired mental performance [1].

Mental fatigue does not fluctuate rapidly over periods of a few seconds. However drowsiness is totally different from mental fatigue, as it fluctuates rapidly over periods of a few seconds. Another major source of accidents is pilots' drowsiness. For example, in 2007 a commercial aircraft in India missed the target airport because both pilots were sleeping (http://articles.timesofindia.indiatimes.com/2009-12-23/india/280905141 air-traffic controllers-dgca-pilots) [1, 3].

According to Civil Aviation Annual Report which is published in 2008, in the period 1993–2007, 46% of the contributing factors that led to fatal accidents were related to cockpit crew SA. Another worldwide data published by Boeing (2015) showed that the in-flight loss of control and controlled flight towards the terrain caused the majority of fatalities in worldwide commercial jet accidents in the period 2005–2014. 46% of fatal accidents are related to mentioned situation [1]. Lately, Annual Safety Review 2014 published by European Aviation Safety Agency (EASA) indicated that inadequate SA has contributed to a number of severe accidents. According to accidents and serious incidents per occurrence category, the rate of fatal accidents related with cockpit crew is seriously big, 50%. When International Civil Aviation Organization's (2014) accident reports are examined, it appears that

5% of main factors of accidents are the factors affecting the cognitive status of the pilots. This rate is much greater in fatal accidents, it is 55%. Although pilots are normally trained to deal with system failures and emergency cases that were foreseen in the aircraft development phase [4], pilots' cognitive status is one of the causes of accidents.

Thus; the development of simulators that can follow the cognitive status of the pilot - to increase the effectiveness of the training procedure and to prevent such accidents - has the potential to make significant contributions to the aviation industry.

Nowadays, the importance of simulators is increasing both for military and civil training purposes. Simulators provide excellent flexibility in the training of normal, abnormal, and emergency procedures as well as flight maneuvers for initial training, recurrent training and type rating certification [5].

Flight simulators play a critical role in modern aviation training and give the perfect opportunity to the pilots training with realistic flight instruments like malfunctions. Flight simulators help new pilots to prepare real flights and gain experience on flight controls. Simulator help experienced pilots to refresh their flight procedures. In addition, pilots can try several malfunctions safely and low-cost that cannot be tested or difficult to try but possible to occur in real flight [5].

Flight hours on modern simulators are considered as actual flight hours beacause they make the pilot feel almost all effects on aircraft. So that the actual flight hours revised in pilot flight training and some of these hours are applied on simulators. For instance; Turkish Air Force (TUAF) revised initial flight training on training aircraft (before fighting aircraft). Normally new pilots need 85 actual flight sorties to get the flight certification or flight license. After TUAF's modification of using simulators, in initial flight training new pilots needs 69 actual flight sorties and the remainings are on 10 modern simulators (that are developed and produced by Hava Elektronik Sanayi (HAVELSAN)) for getting the flight certification. The training is applied in this situation nearly one year ago and since then 30.000 hours simulator training is performed. As a result, TUAF not only saves money (around 190M TL - http://www.milscint.com/tr/simulator-egitim-merkezi-kazandirdi/ -) from this type of training but also increases the effectiveness and safety of flight training [6].

Simulator training provides especially new pilots to improve the readiness of cognitive situations and train behaviours about what to do during unexpected cases. Because simulator training provides flexibility in training of normal, abnormal, and emergency procedures as well as flight maneuvers for pilots that they cannot try or having great risk to try them during actual flight. Therefore; to decrease the risk of any accident, simulator training is more safe, effective and economic training method [7].

In the second chapter of this thesis, literature review is presented and aim of this study is explained. A literature review is achieved for types of simulators and to understand a full flight simulator. The review of cognitive processes on human factors in aviation is also achieved and explained in this chapter. Physiological effects on cognitive processes used for research studies are also classified into two groups and explained in this chapter. In this thesis one of the indirect method variations of heart rate (HR) is observed. Therefore, the main reason for variations of HR during simulator flight anxiety is explained in the second chapter.

In chapter three, test materials are described. First of all, the features of three group of participants are explained in detailed. Then the apparatus of test environment are described. Especially the used simulator which is designed with high technology and modelled of the dynamic effects and simulation of the real aircraft is described in detailed. In addition to the known disruptive effects which are widely used by commercial simulators, AS 532 Cougar Helicopter simulator designed by HAVELSAN has 9 types and 420 malfunctions/disruptive effects. Malfunctions that are applied during tests are explained briefly. In addition, the HR sensor is used in the experiments as a measurement device. Different filtering methods are applied on raw HR data to eliminate noise and disturbances. Detailed information about filtering is explained in this chapter.

In this thesis; the variation of pilots' HR which is one of the physiological test methods used during the flights is evaluated. The HRs of pilots which are trained on simulator is compared in terms of disruptive effects and the experience of the pilots. Tests are applied and evaluated in chapter four. After the filtering process, this data set is also evaluated statistically.

The results showed that pilot flight training by simulator training could be improved using the physiological test method. The analysis enabled us to observe the difference between the response of new pilots and experienced pilots when faced with disruptive effects. Results showed the impact of simulators on the process of pilot training and the effects of different malfunctions in the cognitive status of the pilot. As a result of the experience gained in flight simulators, pilots would feel less anxious when they face dangerous situations in a real flight.

CHAPTER TWO

2. LITERATURE AND CONCEPTS

2.1 Flight Simulators

The flight simulator is a system that tries to simulate as closely as possible and in a realistic manner just like an actual flight. Flight simulators have great wide-concept from computer games to Full Mission / Full Flight Simulators that can be controlled by advanced computer technology and have an exactly same cockpit mounted on the hydraulic or electromechanical actuators [8].

Flight simulation can be defined as a representation of the dynamic characteristics of vehicles and systems that have different realities with the purpose of research, design, development, training or entertainment.

Flight simulation should be real time during training. Real time means all temporal relationship on simulator should be same on aircraft. For instance; weather situation, terrain situation, aerodynamics effects, sound effects on simulator should be same as a real aircraft.

Flight simulators used especially for type-rating training in civil aviation. It is also widely used for refreshment training. Federal Aviation Administration (FAA) approves all type-rating training on the simulator if the simulator meets the requirements of Airplane Simulator Qualification AC120-40C published by FAA. Like FAA, the other authority European Aviation Safety Agency (EASA) also accepts all type-rating training on the simulator if the simulator has the certification of JAR-FSTD-A (for airplane) or JAR-FSTD-H (for helicopter) published by EASA. With reference to this certification, there are four levels (A-B-C-D) according to maturity and realistic level. Level D is the highest full flight simulator qualification. If a simulator has Level D certification, it means it is equipped with high technological systems.

Flight simulation requires high technology. In addition, it is about high-quality and well-regulated training for pilots [9].

Pilots realize the importance of training and learning to overcome problems such as unusual and unanticipated situations during time pressure constraints and complex group interaction, which are rarely encountered in regular operator training on flight simulators [1].

Tests of this thesis are performed in a simulator with Level-D certification.

2.1.1 Full Flight Simulators (FFS)

Full Flight Simulators (FFS) are the simulators composed of many sub-systems such as; a cockpit exactly like the real helicopter / aircraft cockpit, a high-fidelity visual system which is very close adapting the outside world images, a main simulation software which simulates the aerodynamic model and the behaviour of the flight system of helicopter / aircraft, 6-axis motion system (6 DOF motion system) and control loading system which provide accurate physical sensations [8].

Either full flight simulators satisfy to feel inside the cockpit environment, or you consider you are actually flying.

The pilot can interact with the simulator in real time since the simulation software is in real time. All displays which are generated by very complicated computers called Image Generators (IG) are an almost real world that you cannot recognize you are in the simulator. All instruments, avionics and hardware in the cockpit are real or simulated equipment. All sound effects and communications are simulated.

In the full flight simulator, the pilot could observe the velocity, altitude of the aircraft in the cockpit instruments. Orientation changes could be observed in the visual system and seen again in cockpit indicators. Calculated accelerations and changes in these calculated values are added to simulator by the help of the motion system. Control loading system provides pilots an accurate force feedback of flight controls. High-frequency vibration effects are given to the pilot via vibration system. The aircraft position on the earth could be exactly observed from navigation instruments. By means of these, pilots could feel all aircraft effects on a full flight simulator [10].

During this study, tests are performed on the full flight simulator of AS-532 Cougar Helicopter Platform.

2.2 Cognitive Processes

Basic cognitive processes that play a decisive role in the literature on human factors in aviation pilot performance are:

- cognitive workload
- situational awareness
- divided attention
- mental fatigue & incapacitation and,
- drowsiness [11].

The assessments in the simulator environment for these concepts are done mainly through behavioural data. These data are usually based on;

- the flight scenario of instructor pilots by stopping the current status of the pilot to test, observe the level of awareness to the questions posed responses accuracy rate,
- the recorded flight data to observe the amount of deviation from the ideal performance model or,
- the pilot of a questionnaire after virtual office using subjective assessments about what is the degree of difficulty [12].

Mainly; neurophysiological projection of cognitive processes used in the literature can be handled in two main groups:

- direct methods (Electroencephalogram (EEG)) which are focused on brain activity and,
- indirect methods (Electrocardiogram (ECG), Electromyography (EMG), Electrooculography (EOG) and Galvanic Skin Response (GSR)) which are following the physiological effects on the body caused by the nervous system. In such studies using the indirect method; increased HR, reduction in the blink frequency and length, increased focus on eye were observed in cases where the negative effects are given to the pilots [1].

Active cognition is a crucial point for success in complex command and control systems such as military operations, ATC operations and flight operations.

Objective judgment and decision-making are critical operational functions which depend on high-order cognitive processes. Cognitive processes can be overwhelmed by emotions such as fear and anxiety [13]. The ability of control emotion varies from person to person and generally related to the experience of the individual. An expert operator/pilot can be viewed as having developed his/her level of skill required to control his/her emotions during high-stress operations through experience. The response of situational awareness caused by anxiety is analyzed in this thesis.

2.3 Anxiety on Pilots' Performances

An experienced pilot should be self-confident that he/she can control his situational awareness and emotions, such as anxiety, in a way that allows him/her to effectively assure the demands of his/her job. Simulation flight training for pilots has been training individuals to improve to control their awareness to be a helpful optimal performance for many years. Since the pilots perform tasks under the high-stress situation, flight simulators facilitate their jobs. Emotion prepares individuals to respond to eliciting stimuli by coordinating a system for responses: Anger prepares the body to fight, and fear prepares it for flight. Simulation flight training eases that pilots' confidence in their ability to control anxiety can be improved through training on simulator whereby there has the opportunity to work through anxiety and perform their tasks many times until they are successful [13].

In the field of professional sport, the ability to control one's emotions is a requirement of performance. Effective intelligence is as an indicator to measure 'Mental toughness' in athletes and also it becomes aware of optimal performance in the sports. It is dependent on an athlete being able to stay in control of his/her emotions, even several obstacles he/she faces with and to be actively overcome his/her emotions into play to facilitate optimal performance [13].

Daniels et al. have studied positive emotions have been found to facilitate the retrieval of positive self- and task-related information, whereas negative emotions have been found to facilitate the retrieval of negative self- and task-related information [13]. Anxiety which is one of the undesired emotion affects too much before individuals start to lose motivation to perform their tasks. The amount of the affect can vary pilot by pilot. One of the purposes of flight training simulation is to teach trainees to control higher levels of anxiety, where the level of disruptive effects gradually increases until their performance starts to get worse.

2.4 Training to Control Anxiety

There are several advantages to train individuals in order to strengthen his/her emotion to control anxiety. Military reports remark that the severe number of combat people is crushed by anxiety and fear before or during battle. Because of these emotions, physical symptoms often occur such as nausea and heart palpitations. Anxiety and fear are natural emotions and often important for the survival of the individual. However, it cannot be allowed to display a critical role that it interferes with and reduces combat effectiveness. Military people must give crucial battlefield decisions under difficult or dangerous conditions. Highly trained individual has the ability to control his or her emotions no matter how difficult conditions he/she is facing with to carefully think about how to proceed [13].

In aviation, flight simulators help pilots to be trained to stay calm under difficult or dangerous conditions. One of the advantage of training for safety-critical situations via simulation is that pilots can repeat same training several times in order to increare their response against extreme disruptive effects; such as engine malfunction, tail rotor malfunction, electrical malfunction, hydraulic malfunction and extreme case scenarios; such as flying in storm weather, flying in heavy clouded or foggy weather, twilight or night time and so on. While improving their technical skills, simulator helps pilots to improve their emotional control which is nearly as important as technical skill. They learn how to control negative emotions in the safety critical fraught situations and how to give a quick response and give complicated decisions under these situations [13].

The analysis of HR waveforms and their decomposition in different frequency bands has often been employed in the assessment of the variation of the cognitive processes. Previously, it has been already demonstrated by several studies that show performance degradation because of cognitive processes by different measurements. In addition, this thesis demonstrates the performance degradation of the pilot due to anxiety which is observed with the changes in the HR.

CHAPTER THREE

3. TEST MATERIALS

3.1 Introduction to Test

Tests were conducted between September 2015 and December 2015 and were undertaken at the flight training facility located at Turkish Army Aviation School, Güvercinlik, Ankara in Turkey. The main aim of the test is to obtain simultaneous physiological and subjective measures of anxiety during the training received by the pilots in a new generation simulator. Meanwhile, changes in the pilots' behaviours were observed and evaluated by the test pilot from flight video records. Additionally, it is provided as a source of data for trainee's flight records.

Indirect measurements of the pilots' behaviours could be observed by analyzing the movement of the eye. Eye blinks and eye movements (electrooculogram, EOG) could supply valuable information. Measurement of the HR (the electrocardiogram, ECG) could also supply valuable information like the measurement of the eye blinks and the eyes movements. However, the variation of the brightness of light in the simulator causes a negative effect on the eye blinks [1]. Due to limitation, only HR data was collected in this study.

HR was recorded during one sortie of a pilot program. HR of the pilots were recorded while participants undertook a flight scenario designed to increase the difficulty over a 15 or 45 minutes period. The flight scenarios are obtained from Army Aviation School pilot training program.

All pilots' resting HR data is recorded regularly by Pilot Medical Center at Turkish Army Aviation School. Normal resting HR data for participants is taken from Medical Center. The participants' features (their height, weight and HR) are given in Table 3.1, Table 3.2 and Table 3.3.

3.2 Participants

This study was applied on seventeen participants who are taking pilot training in Turkish Army Aviation School. Participants are divided into three groups. The pilots in the first and second groups were AS 532 Cougar Helicopter pilots and the pilots in the third group were candidate pilots. They voluntarily took part in the study and their consents were taken. The photo of a volunteer participant is shown in Figure 3.1.

Figure 3.1 Participant (Volunteer Helicopter Pilot)

3.2.1 First Group

In the first group, six pilots were selected as experienced helicopter pilots. They were all male pilots. They had minimum 350 total flight hours on several aircrafts. All of them has experience on this platform. Only the first pilot is not as experienced on AS-532 Cougar Helicopter as the others. He had 55 flight hours on AS-532 Cougar Helicopter. The others had minimum 250 flight hours on the related platform. Each participant's features are given in Table 3.1. These pilots aged from

26 to 33 years old with a mean age of 29 years. Their HR during the rest position are given in Table 3.1. The average HR for first group is 74 according to Table 3.1.

Table 3.1 Experienced AS-532 Cougar Helicopter Pilots

S/N	WEIGHT	HEIGHT	AGE	TYPE OF TRAINING	TOTAL FLIGHT (hr)	AS-532 FLIGHT (hr)	Resting HR
1	84	181	26	REFRESHER	550	55	73
2	80	173	31	REFRESHER	1500	900	78
3	82	179	26	REFRESHER	600	250	79
4	70	174	27	REFRESHER	750	250	64
5	88	178	31	REFRESHER	2200	300	77
6	72	170	33	REFRESHER	2800	350	73

3.2.2 Second Group

In the second group, eight pilots were selected as helicopter pilots. They have at least 150 hours flight experience on other platforms. However, they are all new on AS-532 Cougar Helicopter. They have just started to the initial flight training program where they had 13 flight hours on AS-532 Cougar Helicopter. They also took the first simulation flight training on AS-532 Cougar Helicopter simulator during this study. They are all male pilots. All participants' features are given in Table 3.2. These pilots all aged 23 years old. Their HR values are given for the rest position in Table 3.2. The average resting HR for the second group is 76.

3.2.3 Third Group

In the third group, three candidate pilots were selected as participants. They have flown neither on AS 532 Cougar helicopter nor on an one-engine helicopter. They are all male pilots. All participants' features are given in Table 3.3. These candidate pilots aged from 28 to 36 years of age with a mean age of 32 years. Their

HR values are given for the rest position in Table 3.3. The average HR for the third group is 78.

Table 3.2 Inexperienced AS-532 Cougar Helicopter Pilots

S/N	WEIGHT	HEIGHT	AGE	TYPE OF TRAINING	TOTAL FLIGHT (hr)	AS-532 FLIGHT (hr)	Resting HR
7	84	185	23	INITIAL	160	3,5	75
8	54	169	23	INITIAL	180	6	80
9	72	180	23	INITIAL	160	6	76
10	80	184	23	INITIAL	150	3,5	78
11	85	187	23	INITIAL	170	6	73
12	74	177	23	INITIAL	160	8	76
13	82	185	23	INITIAL	150	6	77
14	68	174	23	INITIAL	170	13	73

Table 3.3 Candidate Helicopter Pilots

S/N	WEIGHT	HEIGHT	AGE	TYPE OF TRAINING	TOTAL FLIGHT (hr)	AS-532 FLIGHT (hr)	Resting HR
15	75	180	36	INITIAL	0	0	82
16	67	178	32	INITIAL	0	0	74
17	74	170	28	INITIAL	0	0	78

3.2.4 Test Pilot

Test Pilot was retired from Turkish Army. He has an instructor, examiner and test pilot licenses for several platforms (i.e., AS-532 Cougar, UH-1H, AB-206, AB-212, H-300 Helicopters). He has an experience of 11500 total actual flight hours plus

3700 simulator flight plus 750 actual NVG (Night Vision Goggles) hours. 4000 hours of actual flights were only on AS-532 Cougar Helicopter. He participated in the design, development, integration, validation & verification tests and acceptance test phase of AS-532 Cougar helicopter simulator which all the tests for this study applied on. Because of having very huge flight hours on AS-532 helicopter and simulator and was present in all production phases of this simulator; he is the most experience AS-532 simulator pilot in the world. He attended all tests during collecting the data for observation and analysis of the behaviour of the pilots throughout this study. Obtained data presented in chapter 4 is evaluated with him.

3.3 Apparatus

3.3.1 Simulator

The Eurocopter AS-532 Cougar is a twin-engine, medium-weight, multi-purpose helicopter shown in Figure 3.2. All tests for this thesis were realized in the full flight simulator of AS-532 Cougar Helicopter Platform having Level-D certification shown in Figure 3.3.

Figure 3.2 AS-532 Cougar Helicopter

This full flight simulator has been designed and manufactured in order to create the highly-accurate and zero-risk training environment for orientation, emergency, refresher, combat readiness & maintenance / testing pilot training of AS-532 Cougar helicopter pilots. It is designed in HAVELSAN, one of Turkish Defense Companies. The simulator provides experience and capabilities required for each pilot with the most realistic training on a six-axis motion platform. It includes an unlimited variety of scenarios with effects created by a computer. Simulator environment of the AS-532 Cougar flight missions is produced by using realistic three-dimensional modelling.

Figure 3.3 AS-532 Cougar Helicopter Full Flight Simulator

3.3.1.1 Simulator Technical Specifications:

The full flight simulator of Cougar helicopter basically includes main software simulation, instructor operation station, input/output (I/O) system, visual system, motion system, control loading system, sound system and vibration system. All related software and hardware work compatible with each other.

The main software contains high-fidelity helicopter flight and mission subsystems models. The core of the flight related subsystems is 6-DOF (Degree of Freedom) flight dynamics modelling with rigid body assumption. The translational and rotational equations of motion are derived by using Newton-Euler formulation. These calculations are used to support profile phases of all missions. These phases are taxi, take-off, IGE (In Ground Effect) hover, OGE (Out of Ground Effect) hover, low and high-speed cruise, climb, descent, vertical climb, autorotation, and landing. Detailed Stability Augmentation System (SAS) and Automatic Flight Control System (AFCS) modelling are also embedded in the simulator. High fidelity aerodynamic modelling for main rotor, tail rotor, and fuselage are realized. Simulator also includes detailed engine and transmission system modelling, other flight related subsystems physical models such as electrics, hydraulics, and fuel system. Besides, related sensor and navigation models are available.

In brief, simulator has the following technical specifications;

- JAR Level D qualification in international (EASA) standards
- Six-Axis hydraulic motion system
- Three-axis vibration platform
- 220 ° horizontal x 60 ° vertical visual system
- 5-Channel image generator and projectors

3.3.1.2 Mathematical Modelling of Simulator

The mathematical modelling of the helicopter flight dynamics is built-up by using superimposing the component effects. The forces and moments that are affecting on the related component such as the main rotor, tail rotor, fuselage, propulsive subsystem, and landing gear subsystem are calculated and then these calculated forces and moments are transported to the center of gravity of the helicopter. The equations of motions including translational and rotational manner are written and by solving these equations related accelerations, velocities and positions of the helicopter are obtained. During this calculation, the effect of altitude, air pressure and temperature change are also included into model. Ground effect is added in the aerodynamic calculations especially in the hover modelling. The helicopter and surface type interactions are taken into account during taxi, take-off and landing phases.

The force and moment equations in body axis system (shown in Figure 3.4) is as follows;

Force Equations : $\vec{F} = m \cdot \frac{d\vec{V}}{dt}|_B + m \cdot \vec{\omega} x \vec{V}$ **(Equation 3.1)**

Moment Equations : $\vec{M} = \frac{d\vec{H}}{dt}|_B + \vec{\omega} x \vec{H}\, ,\, \vec{H} = I\vec{\omega}_E$ **(Equation 3.2)**

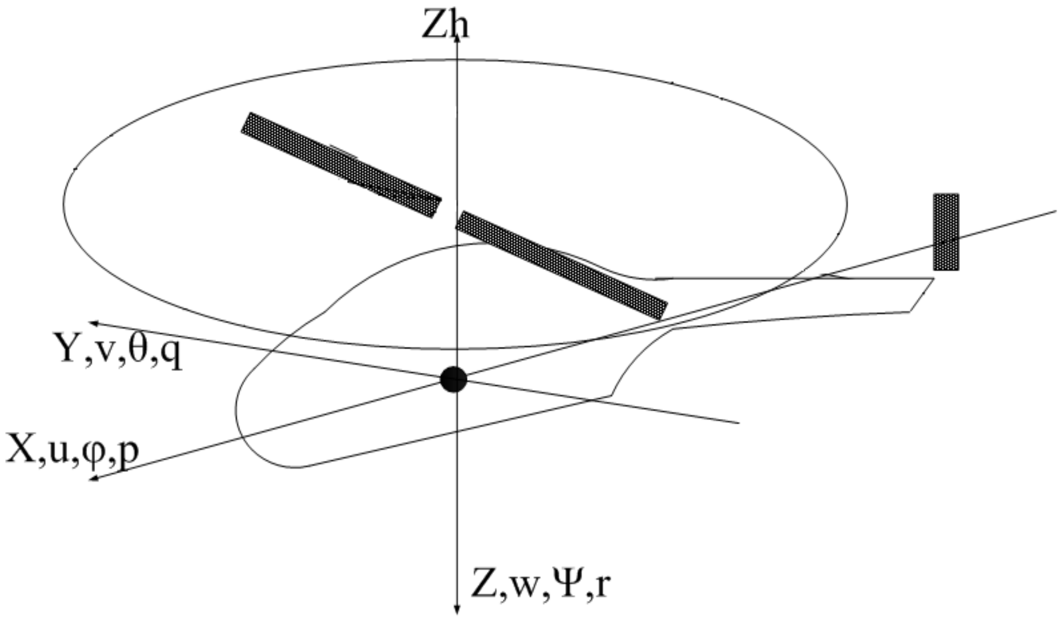


Figure 3.4 Body Axis System Representation

where F is the total force vector, M is the total moment vector. The force components in the body axis system are X, Y, Z; and moment components in body system axis are L, M, N. Translational velocity components are u, v, w; and rotational velocity components are p, q, r. The helicopter mass is m and $\vec{\omega}$ the angular velocity, $\vec{V}$ the translational velocity, $\vec{H}$ the angular momentum and I represented as the inertia matrix. ϕ, θ, ψ are a roll, pitch, and yaw Euler angles respectively. Subscript B refers to body axis system, subscript E refers to Earth-Fixed axis system.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = m \begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{w} \end{bmatrix} + m \cdot \det \begin{bmatrix} \vec{i} & \vec{j} & \vec{k} \\ p & q & r \\ u & v & w \end{bmatrix} \qquad \textbf{(Equation 3.3)}$$

Then, by re-arranging the equations;

$$\dot{u} = \frac{X}{m} + rv - qw$$

$$\dot{v} = \frac{Y}{m} - ru + pw \qquad \textbf{(Equation 3.4)}$$

$$\dot{w} = \frac{Z}{m} + qu - pv$$

When you integrate Equation 3.4 [13, 14], translational velocity components in body axis are obtained. Then, by performing a transformation to earth-fixed axis system and integrating, positions are calculated in the earth-fixed axis systems.

Similarly, moment equations are given as follows;

$$\begin{bmatrix} L \\ M \\ N \end{bmatrix} = \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{xy} & I_{yy} & -I_{yz} \\ -I_{xz} & -I_{yz} & I_{zz} \end{bmatrix} \begin{bmatrix} \dot{p} \\ \dot{q} \\ \dot{r} \end{bmatrix} + \vec{\omega} x \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{xy} & I_{yy} & -I_{yz} \\ -I_{xz} & -I_{yz} & I_{zz} \end{bmatrix} \begin{bmatrix} p \\ q \\ r \end{bmatrix} \qquad \textbf{(Equation 3.5)}$$

Then, by re-arranging the Equation 3.5 [13, 14] and assuming $I_{xy} = 0$ and $I_{yz} = 0$ since exact values are really small,

$$\dot{p} = \left(I_{xz}[I_{xx} - I_{yy} + I_{zz}]pq - [I_{zz}(I_{zz} - I_{yy}) + I_{xz}{}^2]qr + I_{zz}L + I_{xz}N \right) / \left(I_{xx}I_{zz} - I_{xz}{}^2\right)$$

$$\dot{q} = \frac{1}{I_{yy}}[(I_{zz} - I_{xx})pr - I_{xz}(p^2 - r^2) + M] \qquad \textbf{(Equation 3.6)}$$

$$\dot{r} = \left([(I_{xx} - I_{yy})I_{xx} + I_{xz}{}^2]pq - I_{xz}[I_{xx} - I_{yy} + I_{zz}]qr + I_{xz}L + I_{xx}N \right) / \left(I_{xx}I_{zz} - I_{xz}{}^2\right)$$

When you integrate Equation 3.6 [13, 14], angular velocity components in body axis are obtained. Euler orientation angles are obtained with the help of the below equations;

$$\dot{\phi} = p + \sin\phi \tan\theta\, q + \cos\phi \tan\theta\, r$$
$$\dot{\theta} = \cos\phi\, q - \sin\phi\, r$$
$$\dot{\psi} = \sin\phi \sec\theta\, q + \cos\phi \sec\theta\, r$$

(Equation 3.7)

When you integrate Equation 3.7 [14, 15], Euler angles are determined. Simulator was modelled according to these assumptions and derivations. After the design and integration phases, QTG tests were applied to the simulator under the observations of EASA certifiers and simulator has taken Level-D certification from EASA.

3.3.1.3 Simulator Capabilities:

In order to support the pilot training, there are approximately 271 (if sub-malfunctions included it will be approximately 420) defined malfunctions available in the Cougar helicopter flight simulator. Malfunctions are identified for different subsystems such as engine, electrics, hydraulics, fuel, sensor & navigation and automatic flight control system. Malfunctions are presented in detail in **Appendix-A** AS-532 Cougar Helicopter Simulator Training Tasks. These malfunctions are given from the instructor operation station and all defined effects are seen, heard and felt by the trainee pilot in the cockpit, flight characteristics, sound, visual and motion system where it is applicable. The cockpit view of AS-532 Cougar Helicopter simulator is shown in Figure 3.5.

The main training capabilities of simulator are listed below:

-Cockpit Procedures;

-Engine Start-Up,

-Taxi Controls and Taxiing,

-Landing, Take-off,

-Normal and Emergency Procedures;

-Engine Stop and Rotor Stop

-Search & Rescue Training

-MFD / CDU/DTU Tactical Menus

-TACAN, VOR, ILS, IFF

Figure 3.5 AS-532 Cougar Helicopter Full Flight Simulator Cockpit View

3.3.2 Heart Rate Sensor

Polar HR Sensor is used for collecting the data of pilots during their simulator flights. Initially, both HR and iris change are planned to be collected as an indicator physiological data. However, specialist physchiatrists offer that both iris change and HR change are related with same cardiac outputs caused by situational awareness. Therefore, only HR is collected as an indicator of physiological data.

Figure 3.6 illustrates the extracted data from the sensor by the aid of Polar watch M400. Pairing Polar Watch M400 with HR sensor via Bluetooth, the HR data can be easily seen on the watch simultaneously. The sensor collects the HR in each four seconds.

Figure 3.6 HR Sensor and Polar Watch

HR sensor can be adjusted comfortably on a strap which tied around the pilots' chest. Application of adjustment is shown in Figure 3.7. Polar watch should be put on the pilots' wrists as shown in Figure 3.7.

Figure 3.7 HR Sensor on Participant

HR sensor and Polar watch does not have a negative effect during the flight training. They are not disturbing test instruments. So, the participants didn't feel as they are tested. They performed normal flight training as shown in Figure 3.8.

Figure 3.8 Participant fly with HR Sensor

3.3.2.1 Signal Processing on HR Data

The HR frequency is extracted from the sensor by the aid of Polar watch shown in Figure 3.9. There was some noise in the extracted raw data. Its interference with noisy signals is shown in Figure 3.9. These signals should be removed via digital signal processing with digital filters.

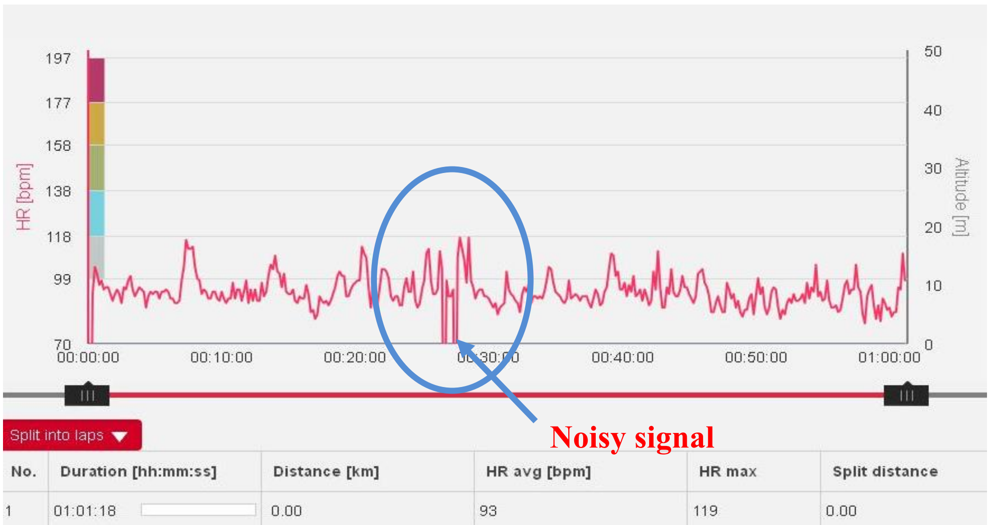
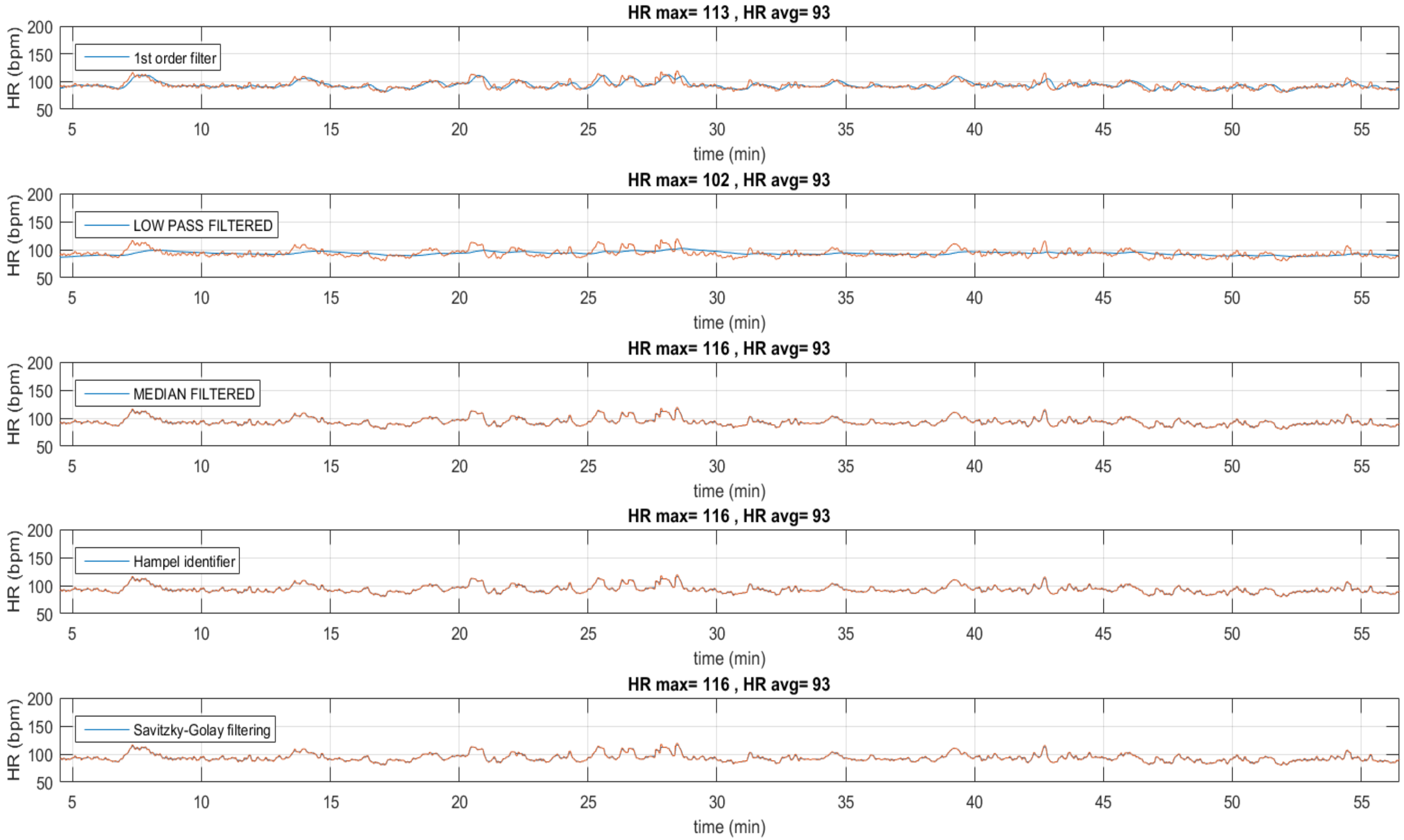


Figure 3.9 Raw Data From HR Sensor

While recording the ECG signals, data is contaminated by several noises. Thus, it is necessary to preprocess the signals prior to classification. Digital filters are used to remove noise from the raw signal [16]. In the literature, there are several algorithms to filter the ECG signals. In this study, five different algortihms are tested on the same data in order to select the best one. These algorithms are first order high pass filter [16, 17], low pass filter, median filter, Hampel identifier and Sawitzky-Golay filtering respectively. Since the main aim of this study is not to compare different filters, only the best filter among them is selected.

First order high pass filtering is required when the main source of noise is below the frequency range of the signals of interest. This is most commonly used method to filter signals obtained from ECG [16, 17, 18]. A low pass filter is a filter that rejects signals with frequencies higher than the cutoff frequency and passes signals with a frequency lower than a certain cutoff frequency. A low pass filter is one of the mostly used digital signal filters for ECG [16, 17, 18]. Generally, median filtering is used as a smoothing technique. It is also used for digital signal filtering on ECG signals [19]. In many applications, Hampel identifier gives much better overall results than median filtering [20]. Therefore, Hampel filter is also tested. Noise elimination is a challenging task with contaminated background noise when data is collected from ECG signals. Savitzky Golay filter works well in noise elimination [21, 22]. All of these methods are available in MATLAB toolbox. The data is processed with these filters and the obtained results are shown in Table 3.4. The MATLAB code that compares the filters is presented in **Appendix-B**.

Table 3.4 Comparison Of Processing Algorithms



There are severe differences on these five methods as it can be seen from the results. As can be seen form the figure, last three algorithms (median filter, Hampel identifier and Sawitzky-Golay filtering) could not smooth the frequency. The maximum and average HR results on frequency graphics are nearly same. According to the results, the algorithms do not filter data as expected. Low pass algorithm makes the HR frequency smoothed and it is also an easy to use method. However, it filtered the data properly too. First order high pass algorithm makes the frequency smoothed and keeps the significant data. It is a simple method to implement on data. It saves the computing time compared to the other methods. Therefore, the first order high pass algorithm is used in this study. The filtered HR data for the raw signal (stated in Figure 3.9) is shown in Figure 3.10.

Figure 3.10 Filtered HR Data

3.3.3 Cockpit Camera

There is a cockpit camera in the simulator. With the aid of this camera, the pilots' behaviours can be observed online and recorded in TCC (Tactical Control Center) simultaneously. Cockpit camera is used to evaluate the test pilot comments according to pilots' physical behaviours, using instruments and commanding controls during the flight. Using this camera, the pilots' behaviours during the flight are also investigated by the test pilot. In the debriefing (after flight briefing) session, each pilot can see his/her physical habits. The test pilot could explain his/her faults (about using instruments and commanding controls) during the flight according to this recorded video. After analyzing HR measurements, the test pilot can comment on the anxiety level of a pilot with these data.

Figure 3.11 Image From Cockpit Camera

Figure 3.12 Cockpit Camera View

CHAPTER FOUR

4. DATA COLLECTION METHOD

4.1 Collection of the Test Data

Once HR sensor on the strap and Polar watch had been safely attached to the participant, simulation flight training was applied. The length of the flight training is minimum 40 minutes. All participants were given 15 minutes for a pre-flight briefing for the related sortie and an additional 5 minutes to familiarize themselves with the aircraft instruments, controls, and systems during taxiing undertaken. Then, pilots were required to take over the controls of all commands and apply the following maneuvers which were explained to them during the pre-flight briefing session:

1. Manual take-off
2. Level off at 1,000~1,200 feet
3. Thirty degree turns, in both directions
4. Climbing and descending turns and 30 degrees, at 100 knots (due to the level of participant's previous flight experience, it can be quite difficult to complete this maneuver)
5. Struggling malfunctions at unexpected time (for each participant)

Standard malfunction for all pilots was a twin-engine failure. Additional malfunctions were also applied for experienced pilots.

6. Landing on the runway

Two of experienced pilots were retested with the same maneuvers and same malfunctions again at the unexpected time. Three of inexperienced pilots were retested with the same maneuvers and same (twin-engine) malfunction. The reason and the results of the retests were found to be totally different. They are explained in the following test applications.

The simulator has an auto-pilot system but the participants are not allowed to use that system. The scenario which is arranged for flight training is not also suitable for steady state situation (auto-pilot system). It is observed from the cockpit camera that the participants are always cautious during their flight. In addition, the test pilot was observing the instant behaviours of the participants during the flight. Therefore, it is expected to observe greater HR of the participants during flight.

4.1.1 Tests for the First Group

In the first group, tests were applied to six experienced Cougar pilots. They all performed standard maneuvers mentioned in section **4.1**. For disrupted effect; twin-engine malfunction was a common malfunction for the first group. Other than this, one more malfunction is given to the participants in line with the refreshment training program. The additional malfunctions will be explained in detail in this section. All data was analyzed one by one with a test pilot. Data is analyzed by considering different sections during the flight; normal flight section, extra malfunction section and common malfunction section.

-S/N 1 Pilot's Test:

The first pilot is an experienced pilot but he is not experienced in Cougar platform. He had only 55 flight hours on Cougar Helicopter. Normal resting HR of the pilot is 73, which is shown in Table 3.1. During the refreshment training program, the test pilot gave him hydraulic system failure following the 12th minutes of take-off. Then, standard twin-engine malfunction is given to him during 65th minutes of the flight. HR data for the first pilot during the flight in the simulator is shown in Figure 4.1. According to these data, it is observed that HR reached maximum at 203. The average HR for the pilot is 116 after these malfunctions were applied. Even he has only 55 flight hours on this platform, the average and maximum HR was higher than expected. Furthermore, the cause of anxiety observed in the figure where the pilot's HR reached a value of 200 when the malfunctions were applied. Increase in HR values was expected result, but it was high for an experienced pilot. It means that, he should get more training related to these malfunctions. Thus, an additional test should be applied to him.

Figure 4.1 S/N 1st Pilot's First HR Data

HR data for the first pilot during the second flight in the simulator is shown in Figure 4.2 below. According to the data, average HR was 78 and HR reached maximum at a value of 112.

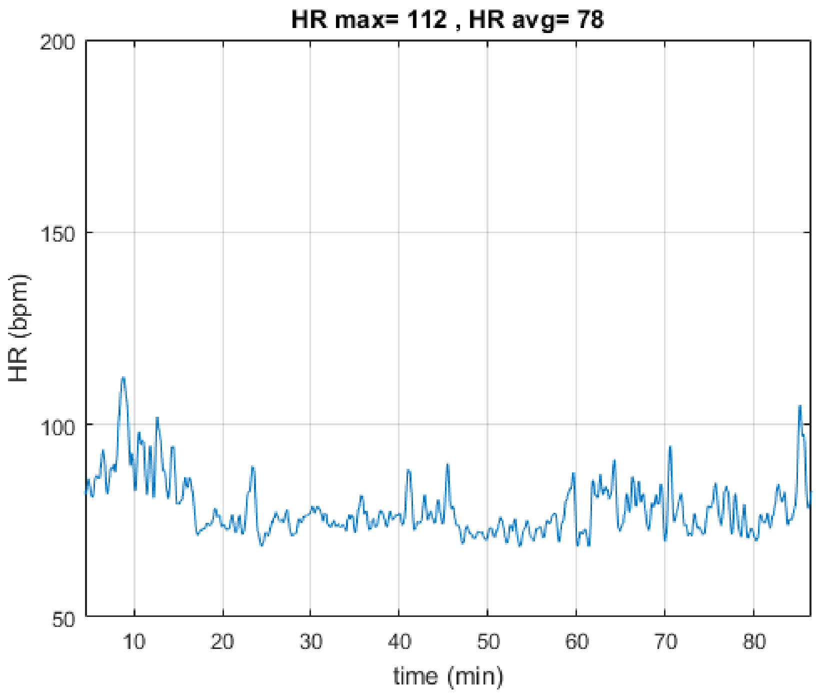


Figure 4.2 S/N 1st Pilot's Second HR Data

The first section of the flight was extra malfunction section. 8 minutes after the take-off, the hydraulic system malfunction was applied to the first pilot. The second section was normal flight section and it started 15 minutes after take-off. Standard twin-engine malfunction was given to him at the 60th minute of the flight and then third common malfunction section started. All of these data was found to be normal for an experienced pilot. It shows that this pilot is trained for these malfunctions. Difference in average HR between these two tests shows the benefits of simulator training. This is discussed in detail in Chapter 5.

-S/N 2 Pilot's Test:

The second pilot was a very experienced pilot for Cougar platform as it can be seen from Table 3.1. Normal resting HR of the pilot was 78 which is shown in Table 3.1. HR data for the second pilot during the flight in the simulator is shown in Figure 4.3.

Figure 4.3 S/N 2nd Pilot's HR Data

According to the data, it is observed that the average HR for the pilot wass 87 and maximum HR reached 102. The first section of the flight was normal flight section. During the refreshment training program, the test pilot gave him electrical system failure 12th minutes after take off. The unexpected common twin-engine malfunction was given at 30th minutes of the flight. In these sections, maximum HR reached 97, 97, 102 and average HR were 89, 87, 87 respectively. There were not vast differences on maximum and average HR. This was an expected result for an experienced pilot.

-S/N 3 Pilot’s Test:

The third pilot was also an experienced pilot and normal HR of him was 79 which is shown in Table 3.1. HR data for the third pilot during the flight in the simulator is shown in Figure 4.4.

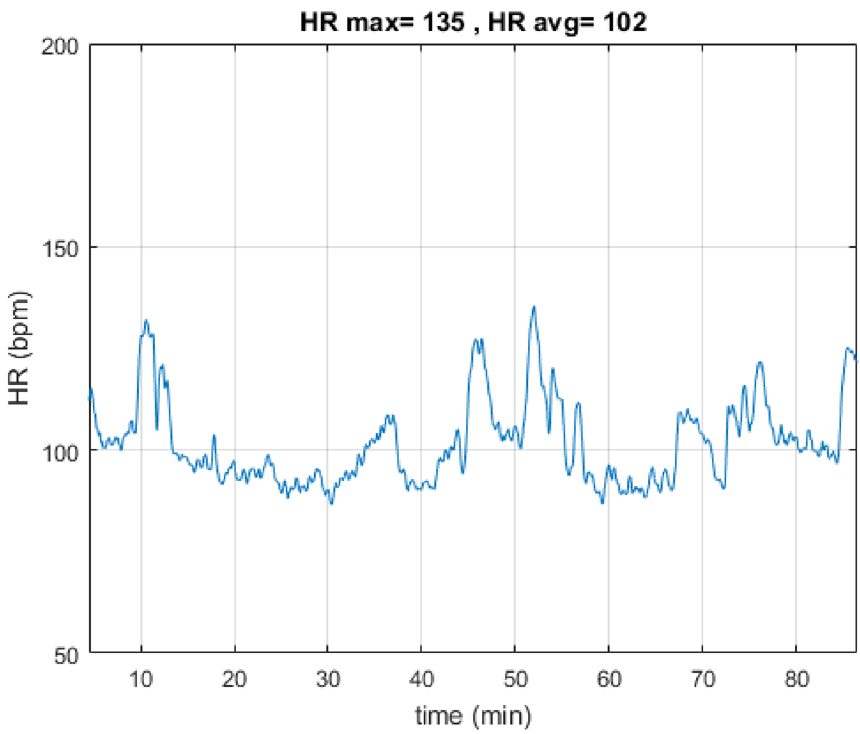


Figure 4.4 S/N 3rd Pilot’s HR Data

The average HR of the pilot was 102 and and maximum HR reached 135. The first section of the flight was normal flight section. Like the previous pilot, electrical system failure is given to him at the 41st minute of the flight. The cause of anxiety observed in the figure where the pilot’s HR changed significantly a value of 135 and average HR was 107 in this section. Test pilot observed thatthe participant lost control for a 5 minute period after the electrical malfunction was given. Normally, the HR of each person can fluctuate if the position of the helicopter (i.e., while pull down, push down, turn left and right) in the simulator changes more than 30 degrees. The flactuation of HR in this section is caused because of this. During the landing section, an unexpected standard twin-engine malfunction was given to him at 65th minutes of the flight. The maximum HR reached 122 and average HR was 104 in the third section. Although he was experienced pilot, he should get more training for electrical malfunction and twin-engine failure as well.

-S/N 4 Pilot's Test:

The fourth pilot was experienced like the third pilot. Normal resting HR was 64 which is shown in Table 3.1. HR data for the fourth pilot during the flight in the simulator is shown in Figure 4.5.

Figure 4.5 S/N 4th Pilot's HR Data

The average HR of the pilot was 68 and and maximum HR reached 86. During the refreshment training program, the test pilot gave him electrical system failure at the 12th minutes of the flight. There was not any significant change in HR of the pilot, even the malfunction was applied in an unexpected time. The rates are very smooth and it reached maximum at 83. The unexpected standard twin-engine malfunction was given to the pilot at the 39th minutes of the flight. During the landing section, the maximum HR reached 86. This test data was an expected result for an experienced pilot and it is one of the good examples.

-S/N 5 Pilot's Test:

The fifth pilot was an experienced pilot who had 300 flight hours on Cougar Helicopter as it can see from Table 3.1. Normal resting HR of the pilot was 77 which is shown in Table 3.1. HR data for the fifth pilot during the flight in the simulator is shown in Figure 4.6.

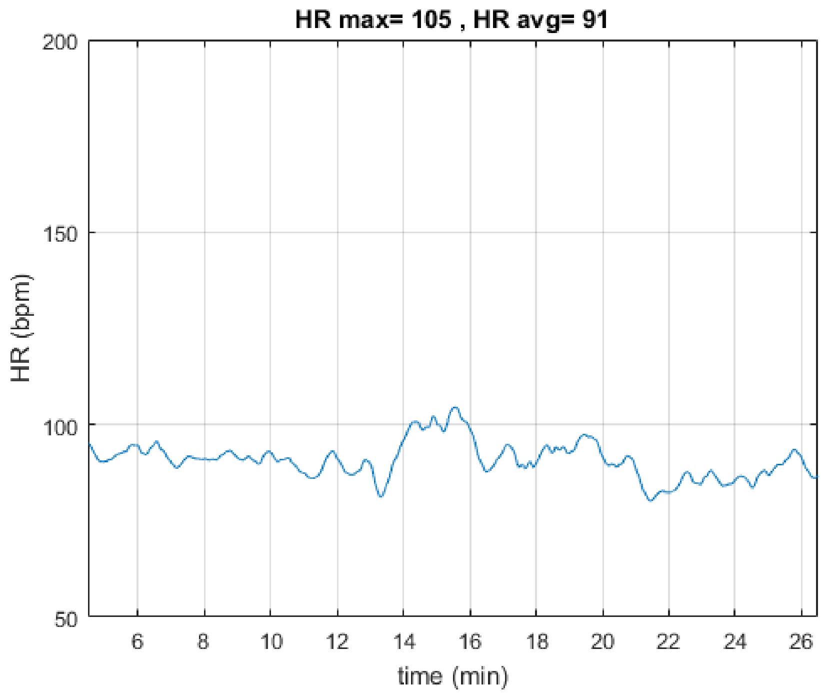


Figure 4.6 S/N 5th Pilot's HR Data

According to the data, it is observed that the average HR was 91 and maximum HR reachda value of 105. The first section was normal flight section. The pilot was first given an electrical system failure at the 12th minutes of the flight. Then, the unexpected common twin-engine malfunction was given 20th minutes after take off. In three sections, maximum HR reached 97, 105, 95 and average HR are 93, 94, 88 respectively. There are not vast differences on maximum and average HR, the rates are very smooth. This test data is an expected result for an experienced pilot.

-S/N 6 Pilot's Test:

The sixth pilot was a very experienced pilot. He had over 2800 total flight hours and 350 flight hours for Cougar as it can see from Table 3.1. Normal resting HR of the pilot was 73 which is shown in Table 3.1. HR data for the sixth pilot during the flight in the simulator is shown in Figure 4.7.

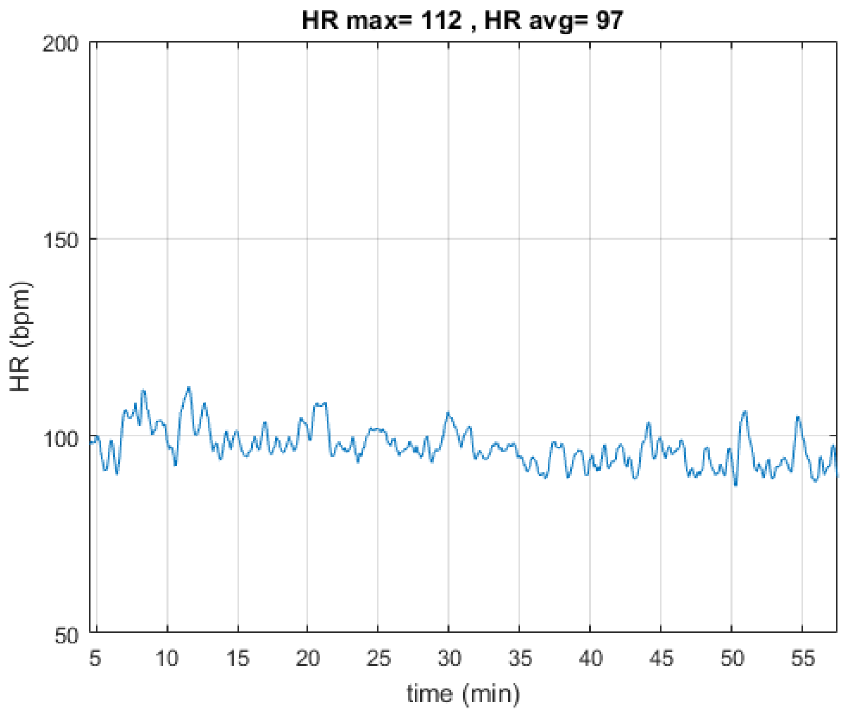


Figure 4.7 S/N 6th Pilot's First HR Data

According to the data, it is observed that the average HR was 97 and maximum HR reached 112. the pilot faced with an electrical system failure at 8th minutes of the flight. Then, standard twin-engine malfunction was given to him during 47th minutes of the flight. There are not vast differences on HR, the rates are nearly smooth. More, there is not any fluctuation of HR during the flight occured. However, the test pilot retested the pilot and one more test was applied. It was helpful to see the changes in the HR after training with the same malfunctions.

According to the data, the average HR was 78 and HR reached maximum at a value of 95. The values were changed significantly i.e., the average HR decreased from 97 to 78 and maximum HR decreased from 112 to 95. The first section of the flight was normal flight section. In this section, the pilot's HR reached maximum at 84 and average HR was 75. Electrical system failure was applied at the 20th minutes of the flight. Although there is not a great difference between maximum ang average HR, the HR still changed because of anxiety. In this section, the pilot's HR reached maximum at 95 and average HR was 81. The third common malfunction section started, after the standard twin-engine malfunction was given to the pilot. This malfunction was given to the pilot at the 48th minutes of the flight. In the third section, the pilot's HR reached maximum at 94 and average HR was 77. The changes in HR of the sixth pilot showed the benefits of simulator training.

Figure 4.8 S/N 6th Pilot's Second HR Data

4.1.2 Tests for the Second Group

In the second group, tests were applied to eight inexperienced Cougar pilots. They only performed standard maneuvers mentioned in section **4.1**, because they were in the initial training program. For disrupted effect; twin-engine malfunction was a common malfunction for the second group. Data was analyzed one by one with the help of a test pilot. For this group, normal flight section and common malfunction sections of the flight are focussed

-S/N 7 Pilot's Test:

The seventh (first in the second group) pilot was an inexperienced for Cougar platform, although he had totally 160 flight hours. Normal resting HR of the pilot was 75 which is shown in Table 3.2. HR data for the seventh pilot during the flight in the simulator is shown in Figure 4.9 below.

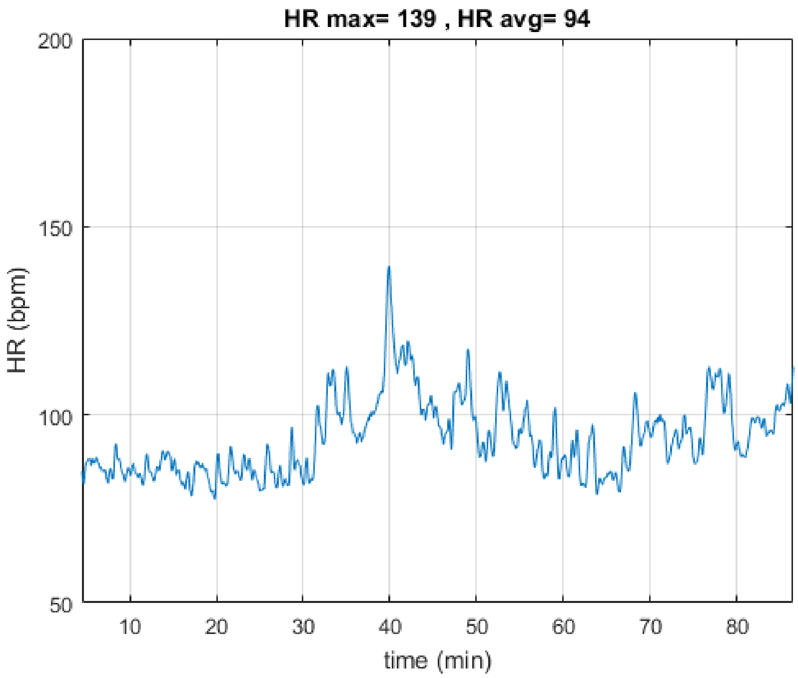


Figure 4.9 S/N 7th Pilot's First HR Data

According to the data, the average HR was 94 and maximum HR reached a value of 139. The first section was normal flight. During the landing section, the unexpected common twin-engine malfunction was given to the pilot at the 31st minutes of the flight. In the second section, the rates were changed and reached maximum at 139 and average at 98. At the beginning, these results were very low which is suitable for an experienced pilot. According to test pilot this situation could have two reasons. First of all, new pilots have not faced such a big malfunction in the real flight. Therefore, they do not have enough awareness and severity of flight training yet. Secondly, they trust their instructor and believe that he/she would rescue the pilot from that situation in order to teach about the malfunction.

To show the pilots how serious are these malfunctions, the second test was applied. HR data of the same pilot during the second flight in the simulator is shown in Figure 4.10. It is observed that the average HR was 132 and maximum HR was

199. The maximum HR value is observed when the twin-engine malfunction was applied 17th minutes after take off.

This increase indicated that this pilot understood the severity of the training. Because of this, the average HR increased from 94 to 132 and maximum HR increased from 139 to 199. After disruptive effect was given, the HR increased significantly as it is illustrated in Figure 4.10. This was another benefit of simulator training which observed during the test.

Figure 4.10 S/N 7th Pilot's Second HR Data

-S/N 8 Pilot's Test:

The eighth pilot was an inexperienced too. Normal resting HR of the pilot was 80 which is shown in Table 3.2. When a twin-engine failure (following the 27th minutes after take-off) was given to the eighth pilot, HR value reached a maximum value of 128. According to the data shown in Figure 4.11, average HR was only 99.

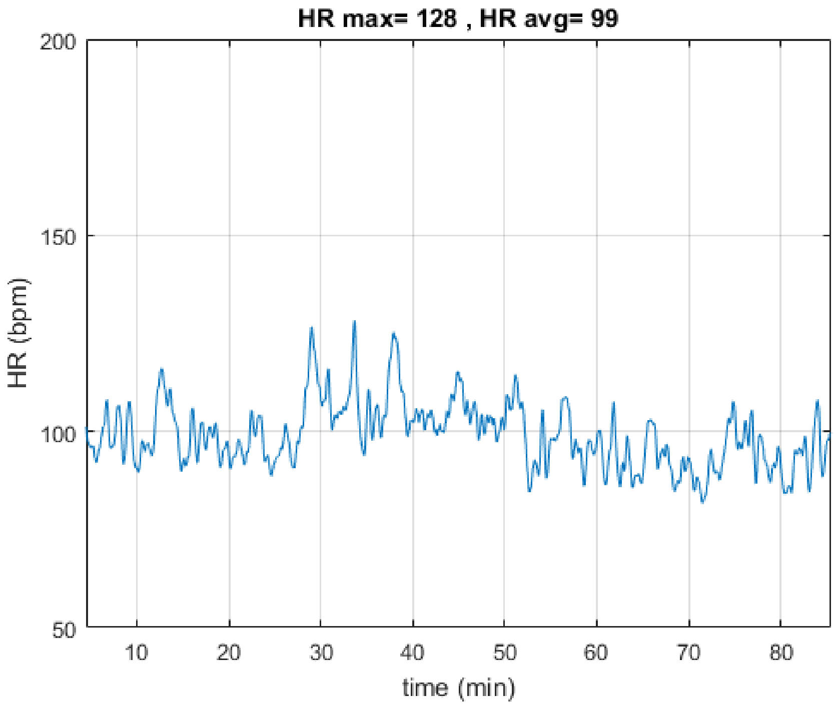


Figure 4.11 S/N 8th Pilot's First HR Data

For training purposes, the second test was applied for the same pilot. HR data for this pilot during the flight in the simulator is shown in Figure 4.12. According to the data; the average HR of the pilot was 112 and HR reached maximum value of 194. The first section of the flight was normal flight section. In this section, the pilot's HR reached maximum 138 and average HR was 106. After 34 minutes of take-off, the twin-engine malfunction was applied. Because of anxiety, the pilot's HR reached a maximum value of 194 and the average HR of the pilot was 122.

. In the second flight, average HR increased from 99 to112 and maximum HR increased from 128 to 194. Significant changes in the HR data of the pilot showed that the pilot understood the severity of the malfunctions. Also in landing section, the HR data increased significantly as it is illustrated in Figure 4.12.

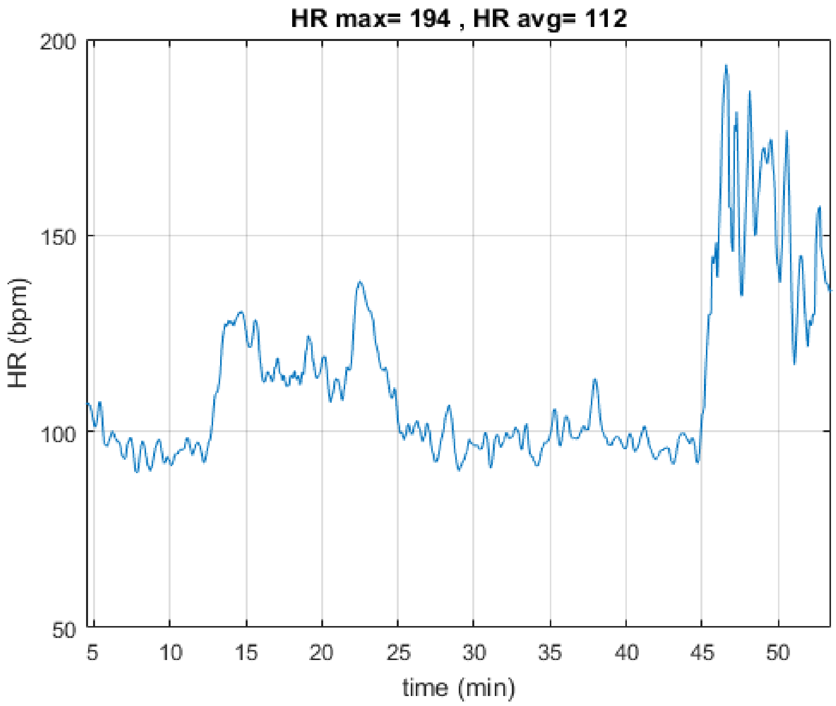


Figure 4.12 S/N 8th Pilot's Second HR Data

-S/N 9 Pilot's Test:

The ninth pilot was an inexperienced Cougar helicopter pilot like S/N 7 and S/N 8. Normal resting HR of the pilot was 76 which is shown in Table 3.2. HR data for the ninth pilot during the flight in the simulator is shown in Figure 4.13. As shown in figure, the average HR of the pilot was 89. After 30 minutes of the take-off, the standart twin-engine failure was given to the ninth pilot and maximum HR of pilot reached around 117.

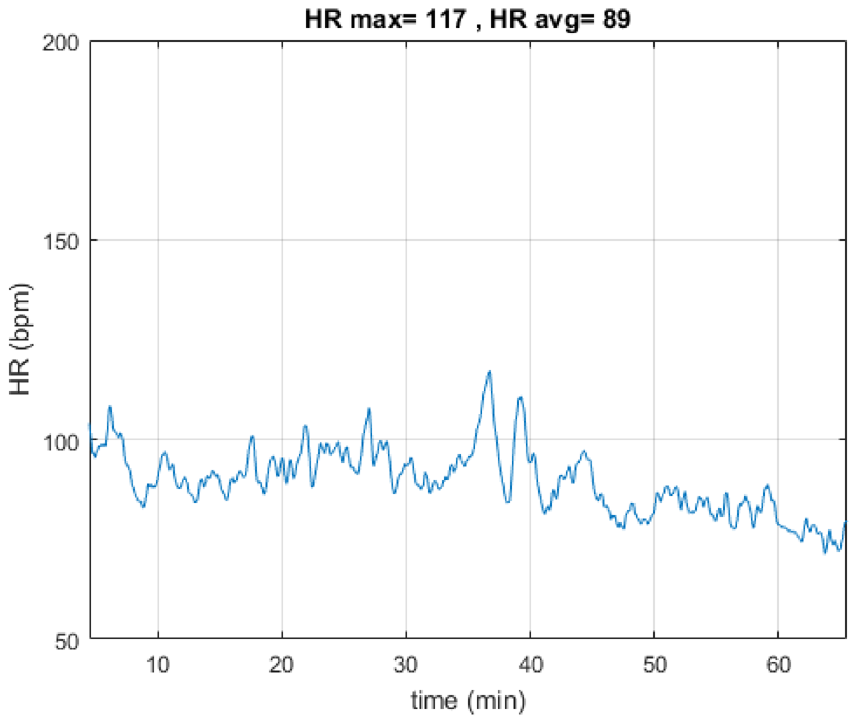


Figure 4.13 S/N 9th Pilot's First HR Data

Since he was an inexperienced pilot, the second test was also applied to him. HR data for the ninth pilot during the flight in the simulator is shown in Figure 4.14. It is observed that the average HR was 99 and maximum HR was 199. The first section was common malfunction section. It lasted 24 minutes. The maximum HR of the pilot reached a value of 199 when the twin-engine malfunction was applied. In this section, the average HR of the pilot was 123. The following section was normal flight section. In the second section, the HR of the pilot reached a maximum at 113. The average HR of the pilot was 79.

. The HR values for this pilot were also changed significantly. The average HR of the pilot increased from 89 to 99 and the maximum HR of the pilot increased from 117 to 199. Following the disruptive effect, the HR data increased as it is illustrated in Figure 4.14. These three tests (7th, 8th, 9th pilots test results) were enough to show the improvement of pilots' awareness.

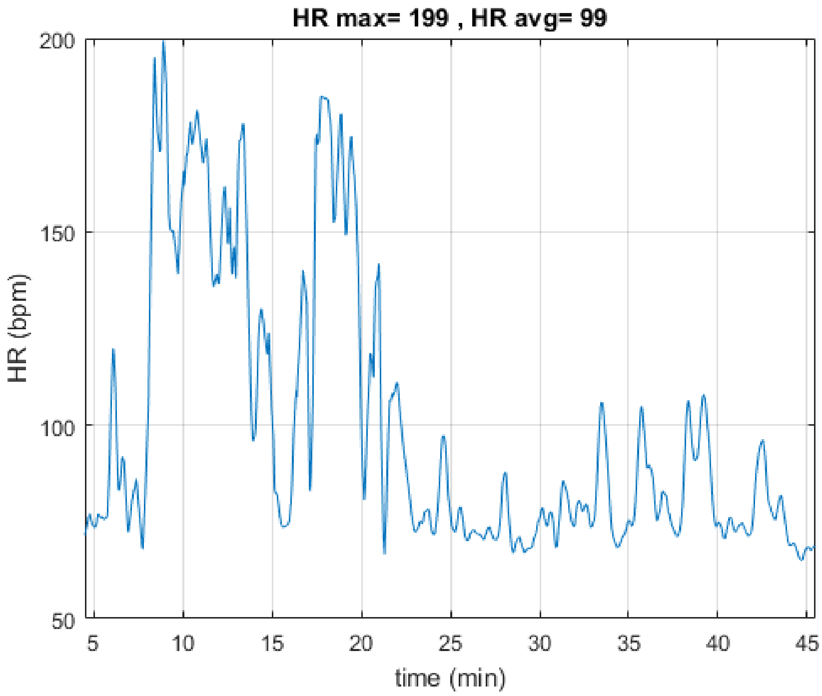


Figure 4.14 S/N 9th Pilot's Second HR Data

-S/N 10 Pilot's Test:

The tenth (fourth in the second group) pilot was an inexperienced pilot.

Figure 4.15 S/N 10th Pilot's HR Data

Normal resting HR of the pilot was 78 which is shown in Table 3.2. HR data for the tenth pilot during the flight in the simulator is shown in Figure 4.15. According to the data the average HR was 103 and maximum HR was 121.

-S/N 11 Pilot's Test:

The eleventh pilot was inexperienced Cougar helicopters pilot same as previous new pilots. Normal resting HR of the pilot was 73 which is shown in Table 3.2. HR data for the eleventh pilot during the flight in the simulator is shown in Figure 4.16. According to the data, the average HR was 98. The first section was normal flight section and lasted 50th minutes. In the following section, the twin-engine malfunction was applied. In this section, the maximum HR of the pilot reached around 131 because of the anxiety.

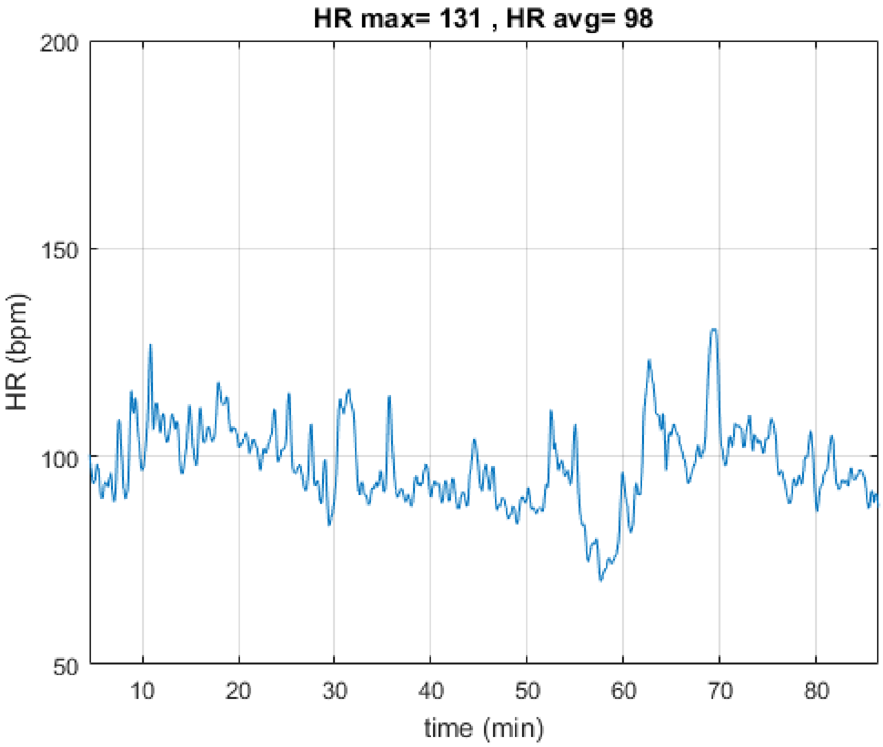


Figure 4.16 S/N 11th Pilot's HR Data

-S/N 12 Pilot's Test:

The twelfth pilot was also a new pilot. Normal resting HR of the pilot was 76 which is shown in Table 3.2. HR data for the twelfth pilot during the flight in the simulator is shown in Figure 4.17. It is observed that the average HR was 90. The first section was normal flight section. In the following section the twin-engine malfunction was applied at the 30th minute of the flight. The maximum HR of the pilot reached around 131 because of the anxiety.

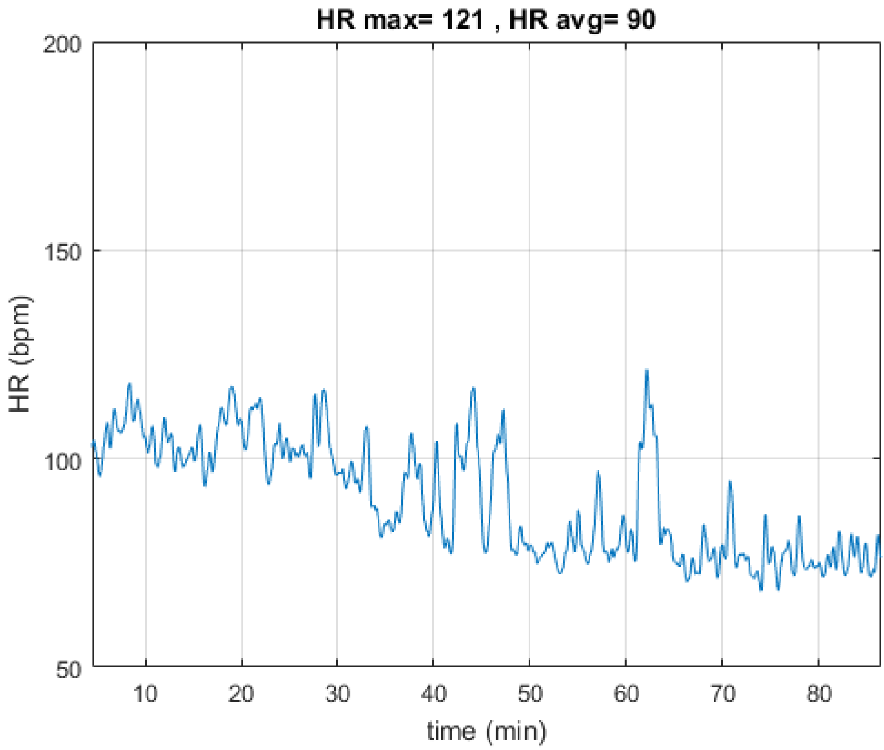


Figure 4.17 S/N 12th Pilot's HR Data

-S/N 13 Pilot's Test:

The thirteenth pilot was an inexperienced Cougar helicopter pilot. Normal resting HR of the pilot was 77 which is shown in Table 3.2. HR data for the thirteenth pilot during the flight training in the simulator is shown in Figure 4.18. According to the data; the average HR of the pilot was 102. When a twin-engine failure (at 25th minutes after take-off) was given to the thirteenth pilot HR reached maximum at 130.

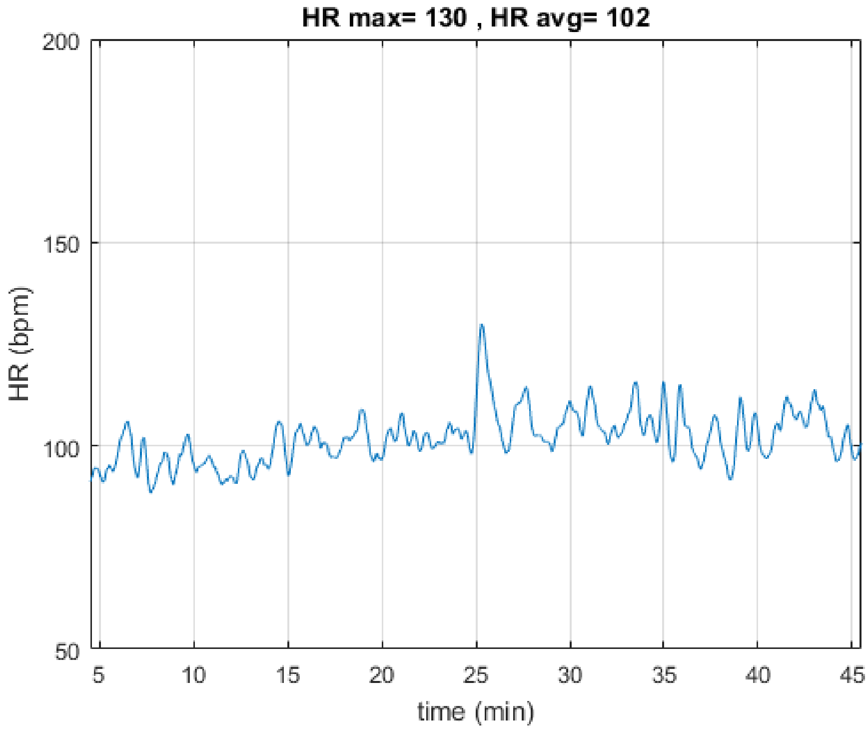


Figure 4.18 S/N 13th Pilot's HR Data

-S/N 14 Pilot's Test:

. Normal resting HR of the fourteenth pilot is 73 which is shown in Table 3.2. HR data for the fourteenth pilot during the flight in the simulator is shown in Figure 4.19. The average HR was 93. The common twin-engine failure (after 25 minutes of flight) was given to the fourteenth pilot.Maximum HR reached at 113.

Figure 4.19 S/N 14th Pilot's HR Data

4.1.3 Tests for the Third Group

In the third group, tests were applied to three candidate pilots. Three pilots' data were enough to analyze the difference between this and the other groups. They all performed standard maneuvers mentioned in section **4.1**. As a disrupted effect; twin-engine malfunction was common malfunction for the third group. Data is analyzed by considering into two sectionsof the flight; normal flight section and common malfunction section.

-S/N 15 Pilot's Test:

The fifteenth (first in the third group) pilot was a candidate pilot and has not flown on a real helicopter yet. Normal resting HR of the pilot was 82 which is shown in Table 3.3. HR data for the fifteenth pilot during the flight in the simulator is shown in Figure 4.20. The average HR was 85. The common malfunction which was a twin-engine failure was given to the fifteenth pilot at the 20th minute of flight. HR reached a value of 114.

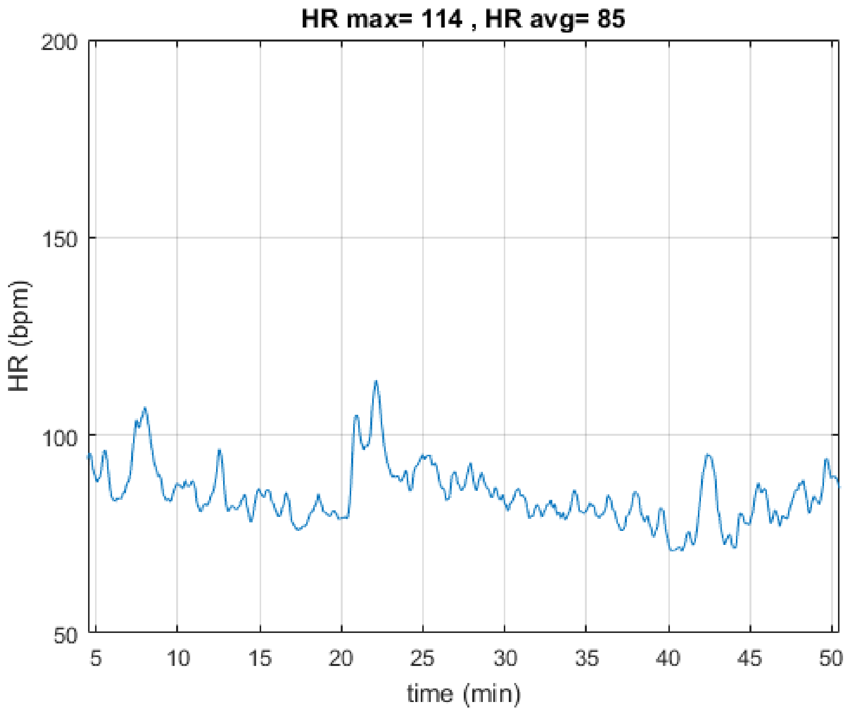


Figure 4.20 S/N 15th Pilot's HR Data

The HR values of this test group were smaller than both experienced and inexperienced pilots. As it is mentioned before, this is an expected outcome since new pilots have not faced such a big malfunction in a real helicopter. Thus, they do not have enough awareness about the severity of the malfunctions.

-S/N 16 Pilot's Test:

The sixteenth (second in the third group) pilot was another candidate pilot and has not flown on a real helicopter yet. Normal resting HR of the pilot was 74 which is shown in Table 3.3. HR data for the sixteenth pilot during the flight in the simulator is shown in Figure 4.21. It is observed that the average HR was 76. The common twin-engine failure (at the 16th minute of flight) was given to the sixteenth pilot. After this malfunction, HR of the pilot reached maximum value of 102. The fluctuations in the HR for this pilot between 7th and 38th minutes are shown in Figure 4.21.

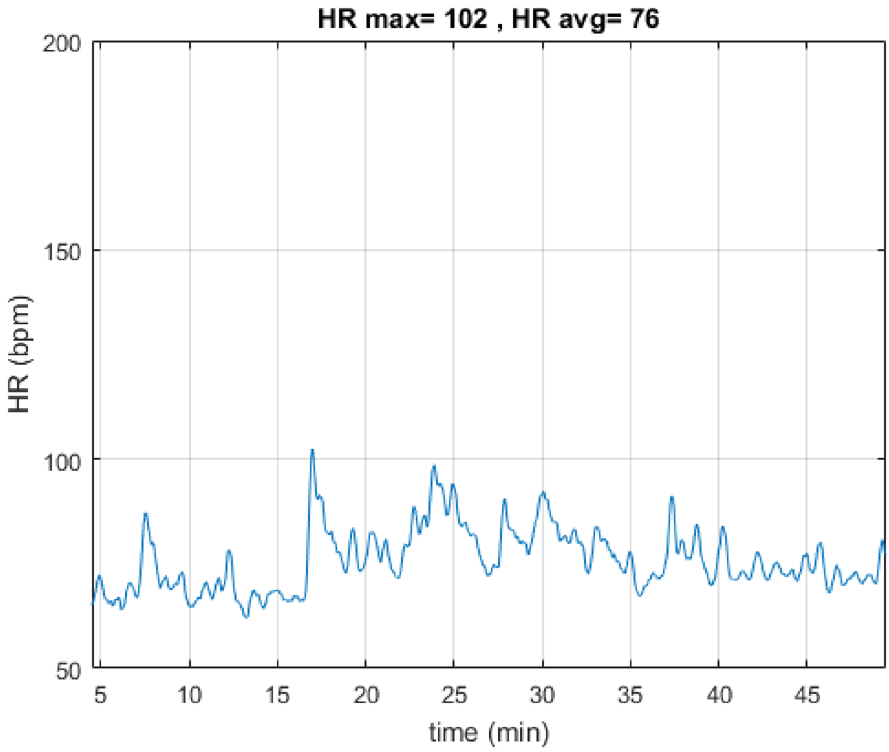


Figure 4.21 S/N 16th Pilot's HR Data

-S/N 17 Pilot's Test:

The seventeenth pilot was also a candidate pilot. Normal resting HR of the pilot was 78 which is shown in Table 3.3. HR data for the seventeenth pilot during the flight in the simulator is shown in Figure 4.22. The average HR was 80. The HR values were smaller than both experienced and inexperienced pilots. At the 27th minute of flight, the common twin-engine failure was given to the seventeenth pilot.Afterwards, HR reached 99 in the second section.

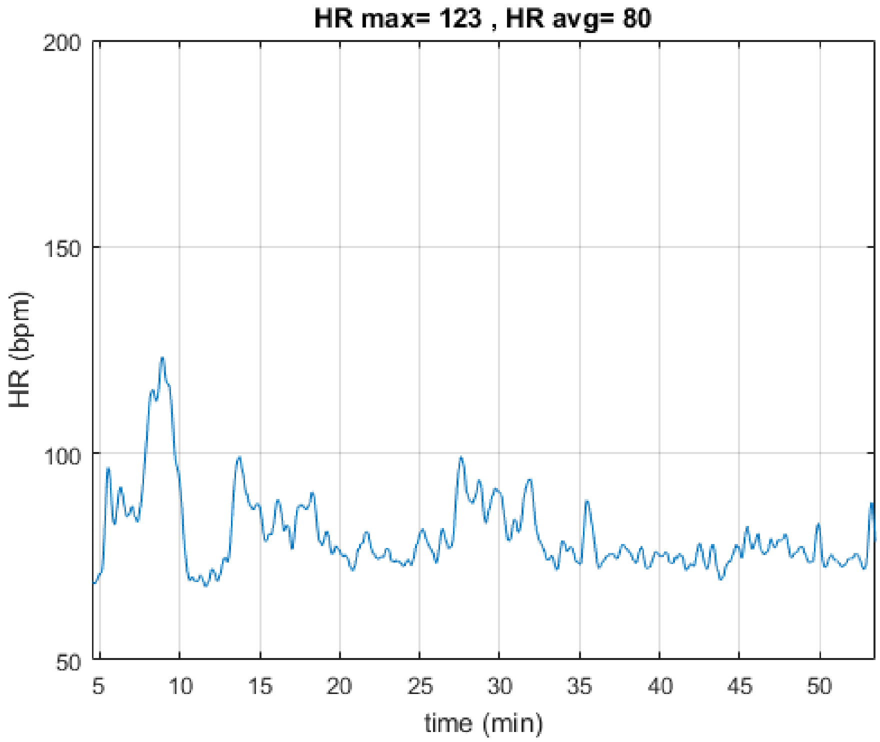


Figure 4.22 S/N 17th Pilot's HR Data

4.2 Test Results

Seventeen pilots were divided into three groups in this study. Pilots' HR data (used for physiological measures) are analyzed in this chapter in accordance to;

- the maximum and average HR of pilots
- the response of pilots to the disruptive effects related with their experience
- the response of pilots to the disruptive effects After retest

First group's test results were expected results. The highest average HR value of the group was 102. This was a good result for experienced pilots. The response of the pilots to the disruptive effects such as twin-engine, hydraulic and electrical malfunctions is explained before.

Table 4.1 Test Results of First Group

S/N	TYPE OF TRAINING	AGE	TOTAL FLIGHT (hr)	AS-532 FLIGHT (hr)	Resting HR	After Sim Average HR	After Sim Normal Flight Section	After Sim Common Malfunction Section	After Sim Second Malfunction Section
1	REFRESHER	26,0	550,0	55,0	73,0	78,0	91,0	78,3	75,3
2	REFRESHER	31,0	1500,0	900,0	78,0	87,0	88,6	86,8	87,2
3	REFRESHER	26,0	600,0	250,0	79,0	102,0	99,4	103,5	106,6
4	REFRESHER	27,0	750,0	250,0	64,0	68,0	66,6	69,7	68,6
5	REFRESHER	31,0	2200,0	300,0	77,0	91,0	92,7	88,0	93,5
6	REFRESHER	33,0	2800,0	350,0	73,0	78,0	75,4	76,8	81,1

The response of the refresher pilots were analyzed by considering HR values before and after simulator training. Hydraulic malfunction (one of the disruptive effect) was given to the first pilot during the second malfunction section. The average HR of the first pilot dropped to 75 whereas it was 110 before simulator training. Following the twin-engine malfunction (common disruptive effect), the average HR of the first pilot was around 78 where it was 134 before simulator training in common malfunction section. The second test was applied to the sixth pilot. Both average HR and maximum HR values were better. The electrical system malfunction (one of the disruptive effects) was given to the sixth pilot in second malfunction section. The average HR of the sixth pilot was around 81 whereas it was 98 before simulator training. After the twin-engine malfunction (common disruptive effect) the average HR value of the sixth pilot dropped to 77 where it was 94 before simulator training. After the application of the second test, an improvement in cognitive status of the pilot is observed, even though he is an experienced pilot. This improvement indicates the benefits of simulator training. To test the following hypothesis, ANOVA (Analysis of Variance) is applied in Excel using Data Analysis Add-in. The inputs are presented in Table 4.2. The results are presented in Table 4.3.

Table 4.2 Average HR values of the First Group

S/N	TYPE OF TRAINING	AVG. RESTING HR	AVG. HR AFTER TEST 1	AVG. HR AFTER TEST 2
1	REFRESHER	73	116	78
2	REFRESHER	78	87	87
3	REFRESHER	79	102	102
4	REFRESHER	64	68	68
5	REFRESHER	77	91	91
6	REFRESHER	73	97	78

H_o: There is no significant difference in means of average HR values of the first group while resting, after test 1 and after test 2 in simulation flight

H_1: There is significant difference between the means

Table 4.3 ANOVA for Average HR values of the First Group

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	444	74	30,4
Column 2	6	561	93,5	257,9
Column 3	6	504	84	142

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1141	2	570,5	3,977458	0,041126	3,68232
Within Groups	2151,5	15	143,4333			
Total	3292,5	17				

Here F > F critical for $p = 0.05$, thus H_0 is rejected. That is, for the first group there is significant difference in average HR before test, after test 1 and after test 2.

To see if there is a significant difference in average HR after normal flight and common malfunction, the following hypothesis is tested.

H_o: There is no significant difference in means of average HR values of the first group after normal flight and after common malfunction in simulation flight

H_1: There is significant difference between the means

Table 4.4 Common Malfunction Section Analysis for First Group

Summary						
Groups	*Count*	*Total*	*Ave*	*Variance*		
Column 1	6	513,7	85,61667	148,8097		
Column 2	6	503,1	83,85	138,555		
ANOVA						
Variance Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9,363333	1	9,363333	0,065167	0,803682	4,964603
Within Groups	1436,823	10	143,6823			
Total	1446,187	11				

Accoding to the ANOVA results, Here $F < F$ critical for $p = 0.05$. Thus, null hypothesis is accepted. For experienced pilots, the mean of average HR values are not significantly different after normal flight and common malfunction.

To see if there is a significant difference in average HR after normal flight and second malfunction, the following hypothesis is tested.

H_o: There is no significant difference in means of average HR values of the first group after normal test and after second malfunction in simulation flight

H_1: There is significant difference between the means

Table 4.5 Second Malfunction Section Analysis for First Group

Anova: Single Factor						
Summary						
Groups	*Count*	*Total*	*Ave*	*Variance*		
Column 1	6	513,7	85,61667	148,8097		
Column 2	6	512,3	85,38333	184,2057		
ANOVA						
Variance Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,163333	1	0,163333	0,000981	0,975631	4,964603
Within Groups	1665,077	10	166,5077			
Total	1665,24	11				

Also for this case, null hypothesis is accepted since F < F critical for p = 0.05. It can be concluded that, for experienced pilots, the mean of average HR values are not significantly different after normal flight, after common malfunction and after second malfunction.

According to test pilot, second group's test results were expected results. The average HR data for the inexperienced pilots are shown in Table 4.6. Changes in the HR of inexperienced pilots are analyzed by considering two sections of the flight; normal flight section and common malfunction section. As can be seen from Table 4.6, resting HR of the pilots are quite diferent compared to the after simulation HR values in the normal flight section and common malfunction section.

Table 4.6 Test Results of Second Group

S/N	TYPE OF TRAINING	AGE	TOTAL FLIGHT (hr)	AS-532 FLIGHT (hr)	Resting HR	After Sim Normal Flight Section	After Sim Common Malfunction Section
7	INITIAL	23,0	160,0	3,5	75,0	100,9	154,1
8	INITIAL	23,0	180,0	6,0	80,0	105,9	121,9
9	INITIAL	23,0	160,0	6,0	77,0	79,0	122,9
10	INITIAL	23,0	150,0	3,5	78,0	102,7	158,6
11	INITIAL	23,0	170,0	6,0	73,0	98,2	130,1
12	INITIAL	23,0	160,0	8,0	76,0	90,6	135,3
13	INITIAL	23,0	150,0	6,0	77,0	102,1	149,9
14	INITIAL	23,0	170,0	13,0	73,0	93,5	128,4

In order to reach the conclusion that simulator training has potential benefits for pilots, ANOVA is applied for the following hypothesis. Obtained results for the second group are illustrated in Table 4.7.

H_o: There is no significant difference in means of average HR values of the second group while resting, after test 1 and after test 2 in simulation flight

H_1: There is significant difference between the means

Table 4.7 ANOVA for Average HR values of the Second Group

Anova: Single Factor						
Summary						
Groups	*Count*	*Total*	*Ave*	*Variance*		
Column 1	8	609	76,125	5,839286		
Column 2	8	768	96	28		
Column 3	8	946	118,25	155,9286		
ANOVA						
Variance Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7105,583	2	3552,792	56,16533	3,73E-09	3,4668
Within Groups	1328,375	21	63,25595			
Total	8433,958	23				

According to the ANOVA test, with 95% confidence we reject the null hypothesis since F > F criterion. Thus, we can conclude that there is a significant diference between in means of average HR values in resting, after Test 1 and after Test 2. Another F test is conducted to see if there is a significant difference between average HR values after test 1 and after test 2. As can be seen in Table 4.8, there is a significant difference in means of average HR values after test 1 and test 2.

H_o: There is no significant difference in means of average HR values of the second group after test 1 and after test 2 in simulation flight

H_1: There is significant difference between the means

Table 4.8 ANOVA for Average HR values of the Second Group after Test 1 and Test 2

Anova: Single Factor						
Summary						
Groups	*Count*	*Total*	*Ave*	*Variance*		
Column 1	8	768	96	28		
Column 2	8	946	118,25	155,9286		
ANOVA						
Variance Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1980,25	1	1980,25	21,53282	0,000382	4,60011
Within Groups	1287,5	14	91,96429			
Total	3267,75	15				

The results of the ANOVA for the following hypothesis are presented in Table 4.9.

H_o: There is no significant difference in means of average HR values of the second group during resting and after normal flight in simulation flight

H_1: There is significant difference between the means

When the obtained results are evaluated, a significant difference in means of average HR values during resting and after normal flight session is found, because F > F criterion where p = 0.05.

Table 4.9 Normal Flight Section Analysis for Second Group

Anova: Single Factor

Summary

Groups	*Count*	*Total*	*Ave*	*Variance*
Column 1	8	609	76,125	5,839286
Column 2	8	772,9	96,6125	75,76696

ANOVA

Variance Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1678,951	1	1678,951	41,1476	1,61E-05	4,60011
Within Groups	571,2438	14	40,80313			
Total	2250,194	15				

The following hypothesis is also tested and the obtained results are presented in Table 4.10.

H_o: There is no significant difference in means of average HR values of the second group while resting and common malfucntion in simulation flight

H_1: There is significant difference between the means

As can be seen from Table 4.10, there is a significant difference in means of average HR values during resting and after common malfunction, since F > F criterion where p = 0.05. This is an expected result because the pilots in the second group are inexperienced.

Table 4.10 Common Malfunction Section Analysis for Second Group

Anova: Single Factor

SUMMARY

Groups	*Count*	*Total*	*Ave*	*Variance*
Column 1	8	609	76,125	5,839286
Column 2	8	1101,2	137,65	210,4686

ANOVA

Variance Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15141,3	1	15141,3	139,9977	1,12E-08	4,60011
Within Groups	1514,155	14	108,1539			
Total	16655,46	15				

Third group's test results supported the outputs of the other group tests. The average HR data were smaller than the other two groups. Even the responses to the disruptive effect (just twin-engine malfunction for the third group) in terms of maximum HR (for pilots S/N15, S/N 16 and S/N 17) were smaller.

Table 4.11 Test Results of All Pilots in Normal Flight Section

S/N	TYPE OF TRAINING	AGE	TOTAL FLIGHT (hr)	AS-532 FLIGHT (hr)	Resting HR	After Sim Normal Flight Section
1	REFRESHER	26	550	55	73	91,0
2	REFRESHER	31	1500	900	78	88,6
3	REFRESHER	26	600	250	79	99,4
4	REFRESHER	27	750	250	64	66,6
5	REFRESHER	31	2200	300	77	92,7
6	REFRESHER	33	2800	350	73	75,4
7	INITIAL	23	160	4	75	100,9
8	INITIAL	23	180	6	80	105,9
9	INITIAL	23	160	6	77	79,0
10	INITIAL	23	150	4	78	102,7
11	INITIAL	23	170	6	73	98,2
12	INITIAL	23	160	8	76	90,6
13	INITIAL	23	150	6	77	102,1
14	INITIAL	23	170	13	73	93,5
15	CANDIDATE	36	0	0	82	84,9
16	CANDIDATE	32	0	0	74	76,0
17	CANDIDATE	28	0	0	78	80,5

As it is mentioned before, candidate pilots in this group do not have enough awareness related to the simulation training and malfunctions observed during the training. The average HR data for all pilots during the normal flight section are shown in Table 4.11.

The following hypothesis is tested by considering average HR values during resting and after normal flight.

H_0: There is no significant difference in means of average HR values of the the pilots while resting and after normal flight in simulation flight

H_1: There is significant difference between the means

Obtained results supplied in Table 4.12 demonstrated that there is a significant difference in means of average HR values of the pilot during resting and after the normal test. With 95% confidence F > F criterion, which indicates that null hypothesis should be rejected.

Table 4.12 ANOVA for Average HR values of Pilots During Resting and after Normal Test

Anova: Single Factor

SUMMARY

Groups	*Count*	*Total*	*Ave*	*Variance*
Column 1	17	1287	75,70588	16,22059
Column 2	17	1528	89,88235	128,2203

ANOVA

Variance Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1708,265	1	1708,265	23,65348	2,95E-05	4,149097
Within Groups	2311,054	32	72,22044			
Total	4019,319	33				

To determine the factors that affect the average HR value after the normal flight section, regression analysis is applied. Average HR after the normal flight is the dependent variable, whereas age (x1), total flight hour (x2), AS-532 Flight hour (x3) and average HR value during resting (x4) are independent variables. Table 4.13 represents regression analysis for all groups.

Table 4.13 Regression Analysis for All Groups

Regression Statistics	
Multiple R	0,814842
R Square	0,663968
Adjusted R Square	0,551957
Standard Error	7,579456
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	1362,147	340,5367	5,927723	0,00717538
Residual	12	689,3778	57,44815		
Total	16	2051,525			

	Coefficients	*Stand. Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	3,831748	36,86621	0,103937	0,918937	-76,492825	84,1563208
X 1	-1,88059	0,518283	-3,6285	0,00346	-3,0098276	-0,7513464
X 2	0,002761	0,003452	0,799664	0,439448	-0,0047613	0,01028263
X 3	0,000202	0,011364	0,017776	0,98611	-0,024559	0,02496299
X 4	1,778891	0,492964	3,608559	0,003589	0,70481383	2,85296728

As a result of the regression analysis, the following regresion equation (4.1) is obtained. Since R square value is 0,66, it can be concluded that the fitted model is quite predictive. Here, age (X1) and resting HR values (X4) are significant factors that affect the average HR after normal flight since p values of these two factors (0,0035 and 0,0036) are smaller than 0.05. According to the equation, for each unit increase in age, the average HR value after normal flight decreases with 1,88 units. This is inline with our findings which indicates that as experience increase, the pilots' average HR value decreases because their experience related to different malfunctions increases.

$$Y = 3,8317 - 1,8806X_1 + 0,0028X_2 + 0,0002X_3 + 1,7789X4 \qquad \text{(Equation 4.1)}$$

CHAPTER FIVE

5. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study is prepared for monitoring the changes in the cognitive status of pilots during training on a new generation simulators. HR data of the seventeen pilots, which are classified under three groups, are collected. Using this data, anxiety of a pilot when faced with a malfunction is evaluated. The main purpose is to evaluate the benefits of simulator training using quantitative data collected via physiological tests.

First, quantitive data was obtained by HR measurement method which is one of the physiological test methods used in the simulators. Then, the collected raw data is processed by first order high pass filtering with the aid of MATLAB signal processing toolbox. Finally, F test and regression analysis are used to evaluate the data statistically. In addition to these analysis, test pilot explained the pilots' their faults (about using instruments and commanding controls) during the flight according to recorded video.

After analyzing HR measurements, the test pilot evaluated the anxiety level of the pilot and decided whether the trainee needs retest or not.

The learning process proceeds through different levels, namely; beginner, intermediate and advanced levels. Besides, HR changes according to the learning level. At the beginner level neural activity is increasing whereas at the advanced level HR is reduced. On the contrary, for candidate pilots' HR do not change significantly compared to pilots' normal HR. The results showed that this is due to the fact that candidate pilots do not have enough awareness about the severity of flight training.

Same as the third group after having enough awareness and severity of flight training; S/N7, S/N8, and S/N9 pilots' data in the second group give us information to make the correct decision. The data of experienced pilots and new pilots (S/N7, S/N8, and S/N9 pilot's data in the second group) are shown in Figure 5.1.

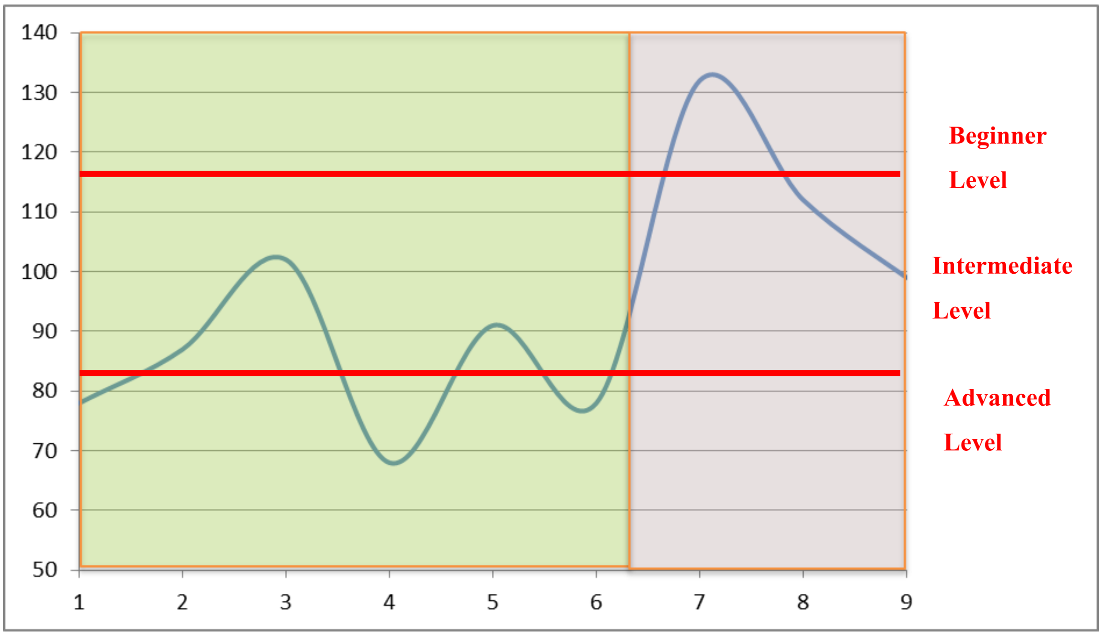


Figure 5.1 HR(avg) Data Analysis According to Level of Pilots

Pilots S/N1, S/N4 and S/N6 could be called as advanced level trained pilots according to Table 4.2. The average HR values of these pilots were greater than the average rate of 84. Others pilots in the experienced group can be called as intermediate level pilots. Pilots S/N7, S/N8 and S/N9 could be called as beginner level trained pilots according to Table 4.6. The average HR values of these pilots were greater than the average rate of 118. As the Figure 5.1 demontrates; the average HR value of advanced level pilots were less than 84 whereas beginner level pilots' were more than 118. The average HR values of intermediate level pilots were between 84 and 118. Thus, it can be concluded that, the number of HR changes according to the learning level.

Generally, simulator improves the training level of the pilots. It helps intermediate and advanced level pilots to improve their technical skills, wheras it helps beginner level pilots to increase awareness related to flight training. Trainees learn how to control negative emotions in the safety critical fraught situations and how to give a quick response and complicated decisions under these situations. The analysis of HR waveforms, and their decomposition in different frequency bands have assessed the variation of the cognitive processes.

5.2 Recommendations

It is hoped that this research would assist aviation authorities and pilot training schools to develop pilot-based and neurophysiology targeted intelligent simulators (see Figure 5.2).

Figure 5.2 Intelligent Simulator

In intelligent simulators, behaviours of the pilot could be tracked. With the aid of neurophysiological test methods, data (cause of cognitive status) of an individual could be obtained easily. Even the data related to the normal situation and the situation under disruptive effects could be analyzed using automatic data clustering methods. Feedbacks related to the preious trainings could be suplied to the intelligent simulator to obtain individual training programs. According to these feedbacks, special training syllabus could be prepared for the pilots.

In addition to this, training processes could be further improved with the aid of physiological test methods. Using the information obtained from test records and the simulation flight records; trainees proficiency and the need for the development of new training methods and training syllabus could be evaluated.

REFERENCES

1.Borghini, G., Astolfi, L., Vecchiato, G., Mattia, D., & Babiloni, F. (2012). Measuring neurophysiological signals in aircraft pilots and car drivers for the assessment of mental workload, fatigue and drowsiness. Neuroscience & Biobehavioral Reviews.

2.Bunce, S., Izzetoglu, K., Ayaz, H., Shewokis, P., Izzetoglu, M., Pourrezaei, K., & Onaral, B. (2011). Implementation of fNIRS for Monitoring Levels of Expertise and Mental Workload. In D. Schmorrow & C. Fidopiastis (Eds.), Foundations of Augmented Cognition. Directing the Future of Adaptive Systems (Vol. 6780, pp. 13-22): Springer Berlin / Heidelberg.

3. Air-Traffic Controllers, The Times Of India, http://articles.timesofindia.indiatimes.com/2009-12-23/india/28090514 1 air-traffic controllers-dgca-pilots/ Access Date:21.07.2013

4.ICAO (2014). Safety Report. International Civil Aviation Organization. http://www.icao.int/safety/Documents/ICAO_2014%20Safety%20Report_final_02042014_web.pdf Access Date:30.07.2015

5.Dahlstrom, N., Dekker, S., Van Winsen, R., & Nyce, J. (2009). Fidelity and validity of simulator training. *Theoretical Issues in Ergonomics Science*, 10(4), 305-314.

6.Simülatör Eğitim Merkezi Kazandırdı, MSI, http://www.milscint.com/tr/simulator-egitim-merkezi-kazandirdi/ Access Date:25.07.2015

7.Borghini, G., Vecchiato, G., Ponzo, V., Koch, G. & Isabella, R. (2012). Improving flight simulation performance by using tDCS stimulation. International Journal of Bioelectromagnetism (Vol. 14 (2), pp. 108-114)

8.Havelsan Simulator Orientation Document (2007)

9.Flight Simulator, https://en.wikipedia.org/wiki/Flight_simulator Access Date:05.09.2015

10.Full Flight Simulator, https://en.wikipedia.org/wiki/Full_flight_simulator Access Date:05.09.2015

11.Hays, R. T., Jacobs, J. W., Prince, C., & Salas, E. (1992). Requirements for future research in flight simulation training: Guidance based on a meta-analytic review. The International Journal of Aviation Psychology, 2(2), 143-158.

12.Salas, E., Bowers, C. A., & Rhodenizer, L. (1998). It is not how much you have but how you use it: Toward a rational use of simulation to support aviation training. The international journal of aviation psychology, 8(3), 197-208.

13.Tichon, J.G., Wallis, G., Riek, S. & Mavin, T. (2014). Physiological measurement of anxiety to evaluate performance in simulation training. Cogn Tech Work.

14.Etkin, B. & Reid, L.D. (1996), *Dynamics of Flight - Stability and Control*, Third Edition, John Wiley & Sons, Inc.

15.McCormick, B. W. (1995), *Aerodynamics, Aeronautics and Flight Mechanics*, Second Edition, John Wiley & Sons, Inc.

16.Kasar, S., Mishra, A., Joshi, M. (2014). Performance of Digital filters for noise removal from ECG signals in Time domain, Internatıonal Journal Of Innovatıve Research In Electrıcal, Electronıcs, Instrumentatıon And Control Engıneerıng (Vol. 2, Issue 4)

17.The Axon Guide for Electrophysiology & Biophysics Laboratory Techniques, Axon Instruments, Inc., June 1993,Chapter 6, pp-133-153

18. Parak, J., Havlik, J., (2011) Ecg Sıgnal Processıng And Heart Rate Frequency Detectıon Methods, University Development Foundation

19. Upganlawar, I. V., Chowhan, H., (2014) Pre-processing of ECG Signals Using Filters, International Journal of Computer Trends and Technology (IJCTT) – (Vol. 11, number 4)

20. Moving window filters and the pracma package, http://exploringdatablog.blogspot.com.tr/2012/01/moving-window-filters-and-pracma.html
Access Date:07.02.2016

21. Chakraborty, M., Das, S., (2012), Determination of Signal to Noise Ratio of Electrocardiograms Filtered by Band Pass and Savitzky-Golay Filters", Elsevier Procedia Technology, (Vol. 4, pp- 830 – 833)

22. Sankhari, S., Chakraborty, M., (2012), Optimisation of Filter Order and Frame Length of Savitzky-Golay Filter in Eliminating Noise From Electrocardiograms, CSIR Sponsored National Conference on Modern Trends in Electronic Communication and Signal Processing, (August, 3-4, pp-10-12)

APPENDICES

Appendix-A: AS-532 Cougar Helicopter Simulator Training Tasks

NORMAL PROCEDURES

1. ENGINE STARTING- SHUTDOWN PROCEDURES AND INTERFERENCE WITH RELATED SYSTEMS
2. ENGINE STARTING- SHUTDOWN IN HIGH WINDS PROCEDURES AND INTERFERENCE WITH RELATED SYSTEMS
3. MANUEL ENGINE STARTING- SHUTDOWN PROCEDURES AND INTERFERENCE WITH RELATED SYSTEMS
4. ENGINE STARTING- SHUTDOWN IN HOT WEATHER AND INTERFERENCE WITH RELATED SYSTEMS
5. CRANKING PROCEDURES
6. WINDSHIELD DE-ICE TEST AND OPERATING PROCEDURES
7. AUTOPILOT ELECTRICAL HEATING SYSTEM TEST AND OPERATING PROCEDURES
8. MGB FIRE, ENGINE FIRE ve FIRE DETECTION TEST PROCEDURES
9. FLIGHT CONTROLS CHECK PROCEDURES
10. ENGINE OVERSPEED TEST PROCEDURES
11. P2 VALVE AND BLEED AIR TEST PROCEDURES
12. FREE WHEEL TEST PROCEDURES
13. MPAI TEST PROCEDURES
14. POWER LOSS INDICATING SYSTEM TEST PROCEDURES
15. BLEED VALVE OFFSET TEST PROCEDURES
16. ICE DETECTOR TEST PROCEDURES
17. HORIZONTAL STABILIZER DE-ICING SYSTEM TEST PROCEDURES
18. AUTOPILOT, BEEP TRIM, TRIM RELEASE TEST PROCEDURES
19. FUEL CONTROL PANEL TEST PROCEDURES
20. COMMUNICATION AND NAVIGATION EQUIPMENTS TEST PROCEDURES
21. ENGINE TRAINING KIT TEST PROCEDURES
22. ENGINE THERMAL LOAD CHECK AND ENGINE POWER CHECK TEST PROCEDURES
23. TOUCH OF DROOP RESTRAINER AND MAIN ROTOR
24. RUNNING AND HOVER TAXI PROCEDURES
25. TURNING IN RUNNING TAXI PROCEDURES, WHEEL BRAKES (DYNAMIC BRAKES) OPERATING PROCEDURES, USAGE OF CYCLIC, COLLECTIVE, PEDALS AND WHEEL BRAKES IN TAXI, INTERFERENCE WITH DROOP RESTRAINER
26. USE OF WHEEL BRAKES AND PARKING BRAKES IN RUNNING LANDING AND TAXI, INTERFERENCE OF NOSE WHEEL LOCK AND UNLOCKED POSITIONS
27. RUNNING LANDING PROCEDURESHOVER, TAKE OFF, TRAFFIC PATTERN AND LANDING PROCEDURES

28. SHARP TURNS, TURNS WITH BIG BANK ANGLE, EFFECTS OF HIGH TAKE-OFF GROSS WEIGHT AND HIGH ALTITUDE
29. TAKE OFF AND LANDING PROCEDURES IN DUSTY AND SNOWY AREAS
30. AUTOPILOT MODES PROCEDURES (NORMAL, EMERGENCY AND IN IFR FLIGHT ENVELOPE)
31. USAGE OF SWITCHES, PUSH BUTTONS AND MODES ON AUTOPILOT CONTROL BOX
32. HDG, ALT AND A/S HOLD AND BARAN ALT PROCEDURES
33. FUEL MANAGEMENT (INCLUDING REFUELING AND DEFUELING) PROCEDURES AND INTERFERENCE WITH RELATED SYSTEMS
34. ENGINE STARTING WITH AC, DC GPU PROCEDURES AND INTERFERENCE WITH OTHER SYSTEMS
35. UTILITY ACCUMULATOR OPERATING PROCEDURES
36. NORMAL, SHORT, VERTICAL AND PLATFORM (SHIP, PETROL PLATFORM, HIGH PLATFORM, HOSPITAL) TAKE-OFF PROCEDURES
37. NORMAL, STEEP, PLATFORM LANDING PROCEDURES
38. AUTOPILOT ELECTRICAL AND/OR HYDRAULIC OFF LANDING PROCEDURES
39. RUNNING LANDING PROCEDURES
40. TRIM RELEASE AND BEEP TRIM OPERATING PROCEDURES
41. ON GROUND AND IN FLIGHT RECONNAISSANCE PROCEDURES
42. FORCED LANDING (SIMULATED ENGINE FAILURE) PROCEDURES
43. AUTOROTATIVE LANDING, MISSED APPROACH, POWER RECOVERY AND NO- HOVER LANDING PROCEDURES
44. ACCELERATION AND DECELERATION
45. VFR NAVIGATION PROCEDURES
46. ALL FUNCTIONS AND USE OF FMS PROCEDURES (INCLUDING SEARCH AND RESCUE PATTERNS)
47. HAVE QUICK, UHF HOMING, IFF OPERATING PROCEDURES
48. ARS-700 OPERATING PROCEDURES
49. EMERGENCY LOCATOR TRANSMITTER OPERATING PROCEDURES

TACTICAL FLIGHT TRAINING TASKS

1. RECONNAISSANCE OPERATION
2. CONFINED AREA OPERATION, MASKING AND UNMASKING OPERATION
3. SLOPE, RIDGE VE HILL OPERATIONS
4. PASSING WIRE OBSTACLES PROCEDURES
5. TERRAIN FLIGHT PROCEDURES
6. FORMATION FLIGHT, PERFORMING EVASIVE MANEUVERS
7. PERFORMING AIR ASSULT OPERATION
8. PERFORMING FARP OPERATION
9. FLIGHT PROCEDURES IN THREAT ENVIRONMENT
10. USE OF ELECTRONICAL WARFARE SURVIVABILITY EQUIPMENTS IN THREAT ENVIRONMENT

11. USING SUB-SYSTEMS OF FMS IN TACTICAL FLIGHT

12. USE OF HAVE QUICK, UHF HOMING, IFF IN THREAT ENVIRONMENT
13. TACTICAL NAVIGATION PROCEDURES
14. AIR ROLE (RETRAN) PROCEDURES
15. HOIST OPERATION AND USE OF RELATED SYSYTEMS
16. EXTERNAL LOAD (SLING) OPERATION AND USE OF RELATED SYSTEMS

OVER WATER FLIGHT TRAINING TASKS

1. SINGLE AND MULTIPLE HELICOPTER OVER WATER FLIGHT PROCEDURES IN DIFFERENT ENVIRONMENTAL CONDITIONS AND IN DIFFERENT GROSS WEIGHT
2. OVER WATER SEARCH AND RESCUE OPERATION
3. SINGLE AND MULTIPLE HELICOPTER APPROACH AND LANDING ON OVER WATER PLATFORMS, ISLAND AND SHIPS IN DIFFERENT ENVIRONMENTAL CONDITIONS AND IN DIFFERENT GROSS WEIGHT
4. PERFORM SINGLE AND MULTIPLE HELICOPTER SLING LOAD AND HOIST OPERATIONS ON SHIP, ISLAND AND OVER WATER PLATFORMS DURING DIFFERENT OVER WATER ENVIRONMENTAL CONDITIONS AND GROSS WEIGHTS
5. SINGLE AND MULTIPLE HELICOPTER OVER WATER FLIGHT PROCEDURES IN THREAT ENVIRONMENT, USING PROCEDURES OF ELECTRONIC WARFARE SURVIVABILITY EQUIPMENT AND INTERFERENCES CAUSED BY THE THREATS

INSTRUMENT FLIGHT TRAINING TASKS

1. PERFORM BASIC INSTRUMENT FLIGHT AND/OR STRAIGHT-AND-LEVEL FLIGHT, STRAIGHT-AND-LEVEL FLIGHT TURNS, CLIMBS, DESCENTS, CLIMBING AND DESCENDING TURNS WITH INSTRUMENT MALFUNCTIONS,UNUSUAL ATTITUDE RECOVERY PROCEDURES
2. PROCEDURES FOR FMS AND SUB-SYSTEMS IN INSTRUMENT FLIGHT
3. PERFORM INSTRUMENT TAKEOFF, CLIMB, COURSE INTERCEPT, HOLDING, DESCENT, APPROACH AND MISSED APPROACH PROCEDURES
4. PERFORM ADF, VOR, TACAN, ILS, GCA PROCEDURES
5. PERFORM SID, STAR AND TERMINAL AREA FLIGHT PROCEDURES
6. PERFORM RADIO NAVIGATION PROCEDURES
7. PERFORM INSTRUMENT FLIGHT PROCEDURES DURING NAVIGATION SYSTEMS, FLIGHT INSTRUMENT MALFUNCTIONS
8. PERFORM LOSS OF RADIO COMMUNICATION PROCEDURES
9. EMERGENCY PROCEDURES DURING INSTRUMENT FLIGHT
10. USING PROCEDURES AUTOPILOT DURING NORMAL AND EMERGENCY SITUATIONS IN INSTRUMENT FLIGHT

11. FLIGHT PROCEDURES IN ICING CONDITIONS
12. PROCEDURES DURING INADVERTENT INSTRUMENT METEOROLOGICAL CONDITIONS

SEARCH AND RESCUE FLIGHT TRAINING TASKS

1. SEARCH AND RESCUE OPERATIONS
2. SEARCH AND RESCUE OPERATIONS WITH GROUND AND AIR TROOPS IN THREAT ENVIRONMENT, USING PROCEDURES OF ELECTRONIC WARFARE SURVIVABILITY EQUIPMENT AND INTERFERENCES CAUSED BY THE THREATS
3. USING PROCEDURES OF ARS-700 AND INTERFERENCES WITH RELATED SYSTEMS

FLIGHT TRAINING TASKS WITH NVG

1. UNAIDED NIGHT FLIGHT PROCEDURES, PERFORMING ALL PROCEDURES FOR NORMAL OPERATIONS DURING UNAIDED NIGHT FLIGHT
2. NORMAL PROCEDURES WITH NVG, TACTICAL FLIGHT TRAINING, PERFORMING THE TASKS FOR OVER WATER AND SHORE-BASED SEARCH AND RESCUE OPERATIONS
3. SINGLE AND MULTIPLE HELICOPTER FLIGHT PROCEDURES WITH NVG IN THREAT ENVIRONMENT, USING PROCEDURES OF ELECTRONIC WARFARE SURVIVABILITY EQUIPMENT AND OBSERVATION OF INTERFERENCES CAUSED BY THE THREATS
4. ENGINE START AND SHUTDOWN PROCEDURES WITH NVG
5. GOGGLING AND DE-GOGGLING PROCEDURES
6. AIR TAXI PROCEDURES WITH NVG
7. HOVER, TAKEOFF, TRAFFIC PATTERN, APPROACH PROCEDURES WITH NVG
8. RUNNING LANDING PROCEDURES WITH NVG
9. THE PRACTICE OF THE LESSONS THAT ARE IN THE SECTION OF “NVG AND NIGHT VISUAL FLIGHT MISSIONS EMERGENCY PROCEDURES”
10. THE PRACTICE OF THE LESSONS THAT ARE IN THE SECTION OF “NVG AND NIGHT VISUAL FLIGHT MISSIONS EMERGENCY PROCEDURES”
11. THE PRACTICE OF THE LESSONS THAT ARE IN THE SECTION OF “NVG AND NIGHT VISUAL FLIGHT MISSIONS EMERGENCY PROCEDURES”
12. THE PROCEDURES OF UNEXPECTEDLY FLYING IN IMC WITH NVG
13. IN DIFFERENT ENVIRONMENTAL CONDITIONS AND GROSS WEIGHTS, WITH ONLY ONE OR MORE HELICOPTERS LANDING ON OR TAKING OFF TO/FROM AN ISLAND OR A PLATFORM ON THE SEA WITH NVG
14. OPERATION IN THE WHITE OUT OR BROWN OUT CONDITIONS WITH NVG

15. THE PROCEDURES OF FLYING IN A VERY MUCH LIGHT CONDITIONS WITH NVG
16. LANDING/TAKING OFF TO A SHIP, CARGO HOOK AND RESCUE HOIST OPERATIONS WITH NVG
17. AIR ASSAULT AND FARP OPERATIONS WITH NVG

EMERGENCY PROCEDURES

1. THE IMPROVING AND FLIGHT PROCEDURES OF AUTOPILOT MALFUNCTIONS
2. THE IMPROVING AND PROCEDURES OF FUEL SYSTEM MALFUNCTIONS WHILE ENGINE START AND SHUT DOWN
3. THE IMPROVING AND PROCEDURES OF POWER TRANSMISSION SYSTEM MALFUNCTIONS WHILE ENGINE START AND SHUT DOWN
4. THE IMPROVING AND PROCEDURES OF THE SIDES OF NEGATIVE ENVIRONMENTAL CONDITIONS WHILE ENGINE START AND SHUT DOWN
5. THE IMPROVING AND PROCEDURES OF ELECTRIC SYSTEM MALFUNCTIONS (INCLUDING GPU MALFUNCTIONS) WHILE ENGINE START AND SHUT DOWN
6. TO SHOW OFF THE EFFECTS OF RUNNING LANDING WITH PARKING BRAKE APPLIED, NOSE WHEEL UNLOCKED AND LANDING WITH HIGH SPEEDS OVER THE LIMITS
7. TO SHOW OFF THE EFFECTS OF DYNAMIC ROLLOVER WHILE ROLL ON LANDING, TAXI OR HOVER

8. ELECTRIC SYSTEM MALFUNCTIONS AND EFFECTS ON ALL OTHER SYSTEMS
9. FUEL SYSTEM MALFUNCTIONS AND EFFECTS ON ALL OTHER SYSTEMS
10. MGB AND ENGINE FIRES AND EFFECTS ON ALL OTHER SYSTEMS
11. FIRES ORIGINATING FROM ELECTRICAL SYSTEM AND EFFECTS ON ALL OTHER SYSTEMS
12. FIRE EXTINGUISHING SYSTEM MALFUNCTIONS
13. ONE OR TWO ENGINE MALFUNCTIONS AND EFFECTS ON ALL OTHER SYSTEMS
14. INTENTIONALLY ENGINE STOPPING AND RELIGHTENING PROCEDURES IN ALL FLIGHT ENVELOPE
15. FORCED LANDING TO A LAND OR SEA WITH POWER OR POWER OFF
16. IN DIFFERENT ENVIRONMENTAL CONDITIONS AND GROSS WEIGHTS SETTLING WITH POWER OR RETRIEVING BLADE STALL NEGATIVE EFFECTS AND RECOVERY
17. IN ALL FLIGHT ENVELOPE POWER SYSTEM AND RELATED SYSTEMS MALFUNCTIONS AND PROCEDURES (WITH TU-219 AND OTHER MODIFICATION
18. TRAINING KIT MALFUNCTIONS AND EFFECTS ON ALL OTHER SYSTEMS

19. LIGHTENING STRIKE AND THE OTHER EFFECTS
20. THE FAILURES OF MAIN/TAIL ROTOR AND EFFECTS
21. GENERAL CUT HANDLE USAGE AND EFFECTS ON ALL OTHER SYSTEMS
22. THE USAGE OF ZEROIZE BUTON AND EFFECTS
23. HYDRAULIC SYSTEM FAILURES(LEAKAGE, ELECTRICAL, MECHANICAL REASONS) AND EFFECTS ON ALL OTHER SUB-SYSTEMS
24. LANDING GEAR FAILURES AND LANDING PROCEDURES
25. FUEL COMPUTING AND FUEL SYSTEM FAILURES
26. ENGINE SYSTEM FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
27. PROCEDURES OF TORQUEMETER SYSTEM FAILURE
28. TRANSMISSION SYSTEM FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
29. TRANSMISSION LUBRICATING SYSTEM FAILURES(LEAKAGE, ELECTRICAL, MECHANICAL REASONS) AND EFFECTS ON ALL OTHER SUB-SYSTEMS
30. IGB AND TGB FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
31. ELECTRIC SYSTEM FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
32. GYRO, INS/GPS FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
33. PITOT STATIC SYSTEM FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
34. NAVIGATION SYSTEM FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
35. ELECTRONICAL WARFARE SURVAVIBILITY EQUIPMENTS FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
36. FMS AND SUB SYSTEM FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
37. GROUND/FLIGHT LOGIC BOARD FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
38. ICE DETECTOR, ANTI-ICE AND DE-ICE FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
39. THE EFFECTS OF ICE ON STRUCTURE AND ON AERODYNAMICAL STRUCTURES AND SHOWING THE EFFECTS OF UNBALANCED ICING
40. MPAI SYSTEM FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
41. SUPPLEMENTARY EQUIPMENTS FAILURES AND EFFECTS ON ALL OTHER SYSTEMS
42. AURAL AND VISUAL WARNING SYSTEM FAILURES
43. RELATIONSHIP BETWEEN ALL SYSTEMS AND CIRCUIT BREAKERS(CB), TRIPPING OF CB AND RESETTING PROCEDURES
44. COMMUNICATION, IFF, UHF HOMING FAILURES
45. ALL SYSTEM MALFUNCTIONS RELATED WITH AYS AND INTERFERENCE WITH OTHER SYSTEMS
46. MISUSING OF ELT AND MONITORING OF RESULTS

MAINTENANCE TEST FLIGHT TRAINING TASKS

1. COCKPIT SYSTEMS TEST ON GROUND
2. CHECKS BEFORE STARTING ENGINES
3. ON GROUND STARTING CHECKS
4. PRE-TAKE OFF CHECKS
5. HOVER CHECKS
6. AFTER TAKE OFF CHECKS
7. LEVEL FLIGHT CHECKS
8. ENGINE SHUT DOWN CHECKS

MAINTENANCE TEST FLIGHT MALFUNCTION TRAINING TASKS:

1. BATTERY CONTACTOR ROLE MALFUNCTION
2. LOW BATTERY VOLTAGE
3. OVERHEAD ELECTRICAL PANNEL WARNING LIGHTS MALFUNCTIONS
4. WARNING LIGHTS MALFUNCTIONS(OVERSPEED, GOVERNOR, BLEED VALVE VS.)
5. LOW ACCUMULATOR PRESSURE
6. AUXILIARY ACCUMULATOR VALF'S ELECTRICAL FAILURE
7. AUXILIARY HYDRAULIC PUMP FAILURE
8. GPU MALFUNCTIONS (OVER VOLTAGE, REMAINING GPU WARNING LIGHT, OR WHEN GPU COUPLED DECOUPLING OF ALTERNATORS)
9. ENGINE FIRE DETECTION SYSTEM FAILURE
10. MGB FIRE DETECTION SYSTEM FAILURE
11. ROTOR BRAKE FAILURE (ON-GROUND)
12. FUEL FLOW CONTROL LEVER MECHANICAL AND ELECTRICAL FAILURE (ON-GROUND)
13. FLIGHT CONTROLS MECHANICAL FAILURE (ON-GROUND)
14. MECHANICAL PITCH INDICATOR FAILURE (ON-GROUND)
15. ENGINE OVERSPEED SYSTEM TEST FAILURE
16. FUEL QUANTITY INDICATOR FAILURE
17. BOOSTER PUMP FAILURE
18. CRANK SYSTEM FAILURE
19. OVERSPEED AT START UP
20. ON START UP OVER T4 TEMPERATURE (OVER LIMITATIONS)
21. ON START UP "NF" ABOVE "NR"
22. ON START UP "POWER" WARNING REMAINS
23. ON START UP NONROTATING ROTOR
24. PITO HEATER SYSTEM FAILURE
25. NAVIGATION AND AVIONIC SYSTEM MALFUNCTIONS ON BIT TESTS
26. FREEWHEELING MALFUNCTIONS
27. P2 VALF AND WARM AIR SYSTEM FAILURE
28. AP ELECTRICAL HEATING SYSTEM FAILURE
29. MPAI SYSTEM FAILURE

30.BLEED VALF SYSTEM FAILURE
31.ICE DETECTOR FAILURE
32.HORIZONTAL STABILIZER DEICING SYSTEM FAILURE
33.AP SYSTEM MALFUNCTIONS AFTER TEST(ON-GROUND)
34.AP BEEP TRIM FAILURE
35.BRAKES FAILURES
36.NOSEWHEEL LUCK FAILURE
37.GROUND REZONANS CONTROL
38.BLEED VALF NORMAL VE OFFSET ADJUSTMENTS OUT OF LIMITS
39.LANDING GEAR EXTENSION / RETRACTION FAILURE
40.LANDING GEAR LOW SPEED / LOW LEVEL WARNING SYSTEM FAILURE

41.AUTO PILOT FAILURES IN FLIGHT (YAW, STATIC STABILIZATION, DYNAMIC STABILIZATION, BEEP TRIM, SAS, TURBULENCE, COLL LINK, HEADING HOLD, ALTITUDE HOLD, AIRSPEED HOLD, HOVER MODES, SAR PATTERNS, AUTO ILS, NAVIGATION HOLD, AUTO LANDING / TAKE-OFF)
42.IN FLIGHT PITOT STATIC SYSTEM FAILURES
43.ENGINE MAX. NG VALUE OUT OF LIMITATIONS
44.AUTOROTATION RPM (LOW / HIGH)
45.NOSEWHEEL FAILURE ON RUNNING LANDING

Appendix-B: Matlab Code Of Comparison Algorithms

```
clear all,clc
close all
%%
load HakanAkkusluData
%% filter
windowSize = 20;
b = (1/windowSize)*ones(1,windowSize);
a = 1;
%%
HakanAkkuslu.SportFil = filter(b,a,HakanAkkuslu.Sport);
%%

%%
cutOff_min=5;
cutOff_max=round(max(HakanAkkuslu.Time1)-5);

%%
HakanAkkuslu.Time=HakanAkkuslu.Time1(min(find(round(Hakan
Akkuslu.Time1)==cutOff_min)):max(find(round(HakanAkkuslu.
Time1)==cutOff_max)),1);
HakanAkkuslu.SportFil1=HakanAkkuslu.SportFil(min(find(rou
nd(HakanAkkuslu.Time1)==cutOff_min)):max(find(round(Hakan
Akkuslu.Time1)==cutOff_max)),1);
%%
max1=round(max(HakanAkkuslu.SportFil1));
mean1=round(mean(HakanAkkuslu.SportFil1));
%%
figure
 subplot(511);
plot(HakanAkkuslu.Time,HakanAkkuslu.SportFil1)
xlim([min(HakanAkkuslu.Time) max(HakanAkkuslu.Time)])
ylim([50 200])
grid on
legend('1st order filter','Location','NorthWest')
title(['HR    max=    ',num2str(max1),'    ,    HR    avg=
',num2str(mean1)])
xlabel('time (min)')
ylabel('HR (bpm)')
%%
```

```
hold on
plot(HakanAkkuslu.Time1,HakanAkkuslu.SportUnFil)
%%

%%
%%%%%%%%%%%%%%%%%%%%%%%%
%%

%% LOW PASS FILTERED

HakanAkkuslu.SportMF        =        filter(0.01,[1        -
0.99],HakanAkkuslu.SportUnFil);
HakanAkkuslu.Time=HakanAkkuslu.Time1(min(find(round(Hakan
Akkuslu.Time1)==cutOff_min)):max(find(round(HakanAkkuslu.
Time1)==cutOff_max)),1);
HakanAkkuslu.SportSGF=HakanAkkuslu.SportMF
(min(find(round(HakanAkkuslu.Time1)==cutOff_min)):max(fin
d(round(HakanAkkuslu.Time1)==cutOff_max)),1);
%%
max1=round(max(HakanAkkuslu.SportSGF));
mean1=round(mean(HakanAkkuslu.SportSGF));
%%
subplot(512);
plot(HakanAkkuslu.Time,HakanAkkuslu.SportSGF)
xlim([min(HakanAkkuslu.Time) max(HakanAkkuslu.Time)])
ylim([50 200])
grid on
legend('LOW PASS FILTERED','Location','NorthWest')
title(['HR    max=    ',num2str(max1),'    ,    HR    avg=
',num2str(mean1)])
xlabel('time (min)')
ylabel('HR (bpm)')
%%
hold on
plot(HakanAkkuslu.Time1,HakanAkkuslu.SportUnFil)
%%



%% MEDIAN FILTERED

HakanAkkuslu.SportMF=medfilt1(HakanAkkuslu.SportUnFil,10)
;

HakanAkkuslu.Time=HakanAkkuslu.Time1(min(find(round(Hakan
Akkuslu.Time1)==cutOff_min)):max(find(round(HakanAkkuslu.
Time1)==cutOff_max)),1);
HakanAkkuslu.SportSGF=HakanAkkuslu.SportMF
(min(find(round(HakanAkkuslu.Time1)==cutOff_min)):max(fin
d(round(HakanAkkuslu.Time1)==cutOff_max)),1);
```

```
%%
max1=round(max(HakanAkkuslu.SportSGF));
mean1=round(mean(HakanAkkuslu.SportSGF));
%%
subplot(513);
plot(HakanAkkuslu.Time,HakanAkkuslu.SportSGF)
xlim([min(HakanAkkuslu.Time) max(HakanAkkuslu.Time)])
ylim([50 200])
grid on
legend('MEDIAN FILTERED','Location','NorthWest')
title(['HR    max=    ',num2str(max1),'    ,    HR    avg=
',num2str(mean1)])
xlabel('time (min)')
ylabel('HR (bpm)')
%%
hold on
plot(HakanAkkuslu.Time1,HakanAkkuslu.SportUnFil)
%%


%% Hampel identifier

HakanAkkuslu.SportSGF                                          =
hampel(HakanAkkuslu.SportUnFil,10);

HakanAkkuslu.Time=HakanAkkuslu.Time1(min(find(round(Hakan
Akkuslu.Time1)==cutOff_min)):max(find(round(HakanAkkuslu.
Time1)==cutOff_max)),1);
HakanAkkuslu.SportSGF=HakanAkkuslu.SportMF
(min(find(round(HakanAkkuslu.Time1)==cutOff_min)):max(fin
d(round(HakanAkkuslu.Time1)==cutOff_max)),1);
%%
max1=round(max(HakanAkkuslu.SportSGF));
mean1=round(mean(HakanAkkuslu.SportSGF));
%%
subplot(514);
plot(HakanAkkuslu.Time,HakanAkkuslu.SportSGF)
xlim([min(HakanAkkuslu.Time) max(HakanAkkuslu.Time)])
ylim([50 200])
grid on
legend('Hampel identifier','Location','NorthWest')
title(['HR    max=    ',num2str(max1),'    ,    HR    avg=
',num2str(mean1)])
xlabel('time (min)')
ylabel('HR (bpm)')
%%
hold on
plot(HakanAkkuslu.Time1,HakanAkkuslu.SportUnFil)
%%
```

```
%% Savitzky-Golay filtering

HakanAkkuslu.SportSGF=sgolayfilt(HakanAkkuslu.SportUnFil,
3,41);

HakanAkkuslu.Time=HakanAkkuslu.Time1(min(find(round(Hakan
Akkuslu.Time1)==cutOff_min)):max(find(round(HakanAkkuslu.
Time1)==cutOff_max)),1);
HakanAkkuslu.SportSGF=HakanAkkuslu.SportMF
(min(find(round(HakanAkkuslu.Time1)==cutOff_min)):max(fin
d(round(HakanAkkuslu.Time1)==cutOff_max)),1);
%%
max1=round(max(HakanAkkuslu.SportSGF));
mean1=round(mean(HakanAkkuslu.SportSGF));
%%
subplot(515);
plot(HakanAkkuslu.Time,HakanAkkuslu.SportSGF)
xlim([min(HakanAkkuslu.Time) max(HakanAkkuslu.Time)])
ylim([50 200])
grid on
legend('Savitzky-Golay filtering','Location','NorthWest')
title(['HR    max=    ',num2str(max1),'    ,    HR    avg=
',num2str(mean1)])
xlabel('time (min)')
ylabel('HR (bpm)')
%%
hold on
plot(HakanAkkuslu.Time1,HakanAkkuslu.SportUnFil)
%%

%%
% set(gcf,'PaperPositionMode','auto')
% print('HakanAkkusluFilterAll','-dpng','-r0')
```

CURRICULUM VITAE

PERSONAL INFORMATION

Name Surname	: İsmail KUMPAS
Nationality	: TC
Date/Place of Birth	:1978 Denizli
Marital Status	: Married
E-mail	: ismailkumpas@gmail.com
GSM	: 0 533 1397447

EDUCATION

1992-1994	: Ankara Science High School
1994-1995	: Denizli High School
1995-2001	: Middle East Technical University
2013-2016	: The University Of Turkish Aeronautical Association

PROFESSIONAL EXPERIENCE

2001-2001	: Production Engineer (GİPSAN)
2001-2003	: Military Service
2003-2006	: Mechanical Design Team Leader (VESTEL ELEKTRONİK)
2006-2009	: Mechanical Design Chief (VESTEL DİJİTAL)
2009-2012	: Mechanical and Thermal Design Team Leader (TAI-TUSAŞ)
2012-2012	: Mechatronics Group Leader (HAVELSAN)
2012-2015	: Production and ILS Group Manager (HAVELSAN)

LANGUAGE

English, German