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Analysing the Impact of a Learning Video on VFR Student Pilots Mental Model and Flight Performance in a Flight Simulator with the use of Eye Tracking Glasses

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Abstract:

Human error is a leading cause of accident in aviation, especially during the approach phase [1], [2]. Crucial for pilots is to have situation awareness, mental models, and an effective scanning pattern. This work investigates the impact of a learning video for beginner pilots on their mental model and flight performance, that contains gaze visualizations from an expert pilot and theory on manoeuvring an aircraft during the landing. 22 participants performed their first landings in a flight simulator wearing eye tracking glasses. Participants prepared themselves with a written manual. After a familiarization flight, each participant conducted two landings for measurement of training impact on their performance. Questionnaires gathered subjective feedback and personal information. After the first flight, the participants were split into two groups. The experimental group (n=12 participants) received a training video, the control group (n=10 participants) received the same information in textual format. Comparing the group's performance served as attest for superior effectiveness of the video format to teach pilot students optimal visual scanning during landing. Data was analysed using MATLAB and Tobii Pro Lab. Results reveal that the group exposed to the learning video improved scanning pattern to match more closely an expert pilot's scanning. Subjects of the experimental group reported that video teaching positively influenced their attention allocation, situation awareness and mental models. In addition, landing performance was stronger in the experimental than in the control group. These findings underscore the effectiveness and value of incorporating theoretical knowledge and visual demonstrations from an expert in a learning video as a tool for improving student pilots' learning of scanning pattern, mental model and landing performance. Future research in this area could explore additional external influences on the pilots during the landing, such as challenging weather situations as well as enhance the training video, to tailor it to each specific airfield or situations encountered in the different phases of flight, as this video specifically targets the approach.

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1 Introduction

The safety and effectiveness of flights depends on many factors, including pilots' ability to take off and land safely. Landing an aircraft requires not only technical knowledge and skills, but also mental models and situation awareness that enable pilots to make the right decisions and react quickly to unforeseen events. Research shows that 60% to 80% of all accidents are caused by human error [1]. Because humans play a crucial role in the system, it's not yet possible to remove them completely. Not only in complex system pilots need to monitor and interfere in case of emergency, also in less automated cockpits like the one from a Piper 28A pilots need to scan every instrument and surroundings frequently. Crucial to the whole flight process are the holding pattern phase and the approach phase. The majority of worldwide aviation mishaps from 2002 to 2011 took place during the approach phase, according to the Global Fatal Accident Review [2]. However, until student pilots can build a safe and confident scanning pattern it takes multiple flight hours. Enhancing a pilot's monitoring strategies may contribute to flight safety [3] and reduce the number of accidents caused by human errors [4]. Learning videos incorporating eye tracking and visual scanning techniques from expert pilots, enhance airline student pilots' learning and flight performance, and they should be included in the training programs [3]. For this study, similar principles are being used. Instead of airline pilots, Visual Flight Rules (VFR) student pilots are being examined.

As part of a bachelor's thesis at the Zurich University of Applied Sciences (ZHAW) the question arises whether an educational video can have a positive influence on the ability of laymen to land safely. An attempt to answer this question is by creating an educational video from the landing at the airfield of Buochs. Furthermore, the aim of the educational video is to investigate whether people without flight experience can develop a better mental model after watching the learning video including performing a better approach and landing, than pilots who have not seen the video and only received written information. The student pilots should learn from the beginning on how to conduct a safe and efficient scanning, which should support them in recognizing and reading the most important information in the cockpit in a short time.

To prove the effectiveness of the educational video 22 participants are invited to the ZHAW flight simulator using eye-tracking glasses. The participants are divided into two groups, one group (n=12) watching the video and the other group (n=10) will only receive theory in textual form, acting as a baseline, also called control group. In total each person will perform two landings. Using eye-tracking data and recording tools from the flight simulator, the results will provide information on whether the learning video has a positive or negative influence on the landing behaviour. In addition, the eye tracking provides information on how the scanning pattern or dwell time on the instruments has changed between the first and the second landing. The flight experiments in this study take place in VFR condition.

1.1 Starting Point

This bachelor thesis is based on the previous project work (PA) which focused on the "Scanning Behaviour of Private Pilots during the Landing Approach in VFR with the Support of Video- and Eye Tracking Analyses". Using eye-tracking glasses, the results from the PA can be used for this thesis. This includes the conclusion, that experienced pilots with a private pilot license (PPL) look out of the cockpit window and target the aiming point on average 88% of the time, while they only focus on the cockpit instruments about 12% of the time. Furthermore, experienced pilots intuitively fly with a vertical speed of 500 feet/minute.

The simulator and the eye tracking glasses will be the same tools as in the previous project work PA. First, this paper provides a theory part, then looks at the most relevant literature for this project continuing with the presentation of the hypotheses and the research questions. Following, which methods were used are described, proceeding with the results, the discussion of the findings and summing it up with the conclusion.

1.2 Objectives

The aim of the work is to create and test the impact of an educational video that is tailor-made for the landing on a specific airport, which in that case will be Buochs, as mentioned before. The video consists of two main parts. In the first part the most important parameters for performing a landing are presented. In the second part, the landing contains gaze indications of an experienced pilot recorded with eye-tracking glasses. To prove the effectiveness of the learning video, 22 pilots are invited to the simulator and each person performs two landings. One group watches the video, while the control group receives a text, as it is common in a flight theory lesson taken at a flight school. During the landings, subjects wear eye-tracking glasses to identify patterns of the eye movement. In addition, flight data from the simulator at the ZHAW are analysed using MATLAB to assess the accuracy of the landing.

The main part of this work is to see whether it makes a difference to prepare for the landing with a learning video or if only the written theory is sufficient. The student pilots are given the same three tasks during the first and second landing, which will be introduced in 4.3.2. In the case of the training video having a positive impact on the student pilots, it could encourage flight schools to create a learning video, tailored to each airfield. This would help student pilots to better prepare for their flight lessons, develop a solid base of landing skills and intuitively apply them to any potential problems.

1.3 Gaps to Fill

Despite the numerous studies on gaze patterns and flight performance, there are still gaps in the literature that need to be addressed. To begin, while Lefrançois [3] investigated the impact of training videos on the pilot's performance, the video only consisted of eye tracking visualizations in the approach and did not address other parts of flying. This gap should be filled by expanding the training video to include theory on aircraft operation, as well as possible flight scenarios that could be encountered during the landing [3].

Second, Haslbeck and Zhang [5] discovered a link between gaze patterns and landing performance but were unable to pinpoint precise scanning pattern sequences. This study tries to target this gap, by applying a programmed probability tree, to identify scanning pattern sequences of flight students. Third, Huet et al. [6] operated with a video input group and a control group that received no input. However, the control group did not get the same information that was presented on the video in any other form. This study tries to bridge this gap by giving the baseline group the identical set of information in textual form, that the video group received. This enables to measure the impact and effects of the learning video [6].

Finally, all other studies reviewed have worked with student pilots who had more expertise and flight hours. In contrast, this work introduces new student pilots with almost zero flight hours of experience into the flight simulator, to create a good mental model for them. By addressing these gaps in the research, it will provide a better understanding of the impact of training videos. The resulting questions are addressed in the chapter 3.7 Research Questions.

2 Theoretical Foundation

This following part contains the theoretical principles of the flight theory and fundamentals of the eye movements which are explained in more detail. This part is divided into two parts. First, the most relevant parameters are described, which will later be of importance for the evaluation. The second part describes which parameters are used for the eye tracking glasses. The chapter starts with an explanation of aviation related terms such as the visual approach, the glide slope, the aiming point, true airspeed (TAS) and vertical speed. The second part then continues with the topics of eye movements, where the fixation, dwell time and saccade are described.

2.1 Basic Flight Theory

A visual approach is when the pilot proceeds the landing by visual references. In addition, they must have all the time contact to the runway or to the proceeding aircraft. This phase of the flight is characterized by a slower airspeed, flaps down and gear down. Furthermore it is important to maintain the appropriate approach speed of the aircraft in order to conduct a safe landing [7].

2.1.1 Glide Slope

The glide slope is defined as the proper path of descent for an aircraft preparing to land [8]. It is usually three degrees, with exceptions regarding terrain or noise abatement [9]. The glide slope is part of the instrument landing system (ILS) which is a radio beam upward with the previous mentioned 3-degree angle. It starts from the approach end of an instrument runway. Vertical guidance is provided to the aircraft on the final approach for the aircraft to follow when making an ILS approach [10].

2.1.2 Aiming Point

The aiming point is defined by FAA as “The aiming point marking serves as a visual aiming point for a landing aircraft.”. It is the point on the runway that the pilot is aiming at during the landing, to proceed with the touchdown with their aircraft. It is usually set for a VFR flight at the beginning of the runway, but so that the pilot has enough margin in case they get below the glideslope [11].

2.1.3 True Airspeed

The true airspeed is composed of the calibrated airspeed (CAS) which has been corrected for altitude and non-standard temperature. The TAS shows the aircrafts speed in relation to the airmass it is flying through. Modern aircraft instrumentation conduct the calculation for the TAS in real time and display the TAS reading directly [12].

2.1.4 Vertical Speed

The vertical speed indicates how fast an aircraft climbs or descends. It is indicated on the instrument called the vertical speed indicator (VSI) and are displayed in feet per minute [13].

2.2 Eye Movements

A central appeal to eye movement monitoring in the cockpit is the possibility of a window onto the aircraft operator's cognitive state. The cognitive state of the operator is obviously important for safe and effective aircraft operation. For example, a pilot that is overloaded with concurrent cockpit tasks might be more likely to miss a critical warning indicator in the cockpit display, or perhaps fail to notice the appearance of another aircraft in nearby airspace. Eye movements have the potential to provide additional, and possibly more direct, measures of pilots' information processing in the cockpit. Importantly, this early research identified eye movement measures that have been pursued in subsequent research: fixation duration, fixation frequency, and fixation pattern [14].

2.2.1 The Fixation

As soon as the eye stop scanning the scene and concentrate on a specific AOI it is called fixation. This way the information being looked at can be proceed by the visual system and mental model in more detail. The fixation can last between 50ms to 600ms [15].

2.2.2 The Dwell Time

The dwell time is the cumulation of all fixations during a measurement. This metric gives an indication about search behaviour and whole stimulus [16].

2.2.3 The Saccade

This type of eye movement is referred to when the eyes move from one point to another. The duration of a saccade is about 20ms to 40ms. Because of the rather fast movement, the information intake happens during the fixation [15].

3 Literature Review

This following part contains a literature review divided into thematic categories, where the research questions and hypotheses are additionally presented. The literature review was designed to provide a comprehensive overview of research on situation awareness (SA), a pilot's scan pattern and gaze behaviour and its relationship to the flight performance. Furthermore, literature associated to the topic's memory structure, video-based learning and improving scanning patterns is mentioned. The selected studies include a variety of methods involving simulators, eye tracking, and video visualizations, which align with the planned methods for this paper. A recurring theme in the literature is the comparison of novice and expert pilots flight performance, dwell times and visual scanning patterns.

The aviation industry is known for introducing many new technologies and concepts. Although the innovations are progressing, theory inputs through traditional classroom and teacher centred methods, such as texts and books, are mainly used to teach new skills. Educational videos are not yet widely utilized in aviation, especially for aspiring pilots. A growth in research on video-based learning has been seen in the past years, especially after 2007 [17]. It has been proven by multiple sources that are listed in the next part, that educational video inputs can encourage a better learning ability in students and lead to a better performance. Only few studies have examined how the attention of pilots can be directed towards relevant information in action during a flight.

3.1 Situation Awareness

While the term situation awareness has its roots in the aviation domain, it is now used and researched in a wide range of industries, including education, military operations, driving, weather forecasting, and maintenance. One of the earliest definitions of SA given by Endsley [18] is: "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status on the near future." [18] It has been found that SA can be attributed to be the most important area of single pilot resource management [19]. SA is the process through which a pilot makes an accurate assessment of the environment, both inside and outside the aircraft, to ensure a safe and effective flight [20]. The study by Haslbeck and Zhang [5] mentions that an effective strategy of the instrument scanning can maintain the pilots in a loop by continuously updating their memory about the current state of the aircraft. Sufficient visual scanning furthermore allows pilots to take effective control in time [5]. From Glaholt's [14] study it can be said that the pilot's performance has a strong link to their situational awareness. Being overloaded with information can lead to the pilot missing critical information [14].

It has been found that pilots scanning patterns, SA, performance and workload differ depending on their levels of expertise [21], [22], [14], [23]. Pilots are taught to allocate their visual attention strategically to make sure they are obtaining flight information under various flight restrictions in order to maintain situational awareness in rapidly changing situations [24]. Diaz et al. [25] indicates that “Cognitive skills refer to the understanding of the current state and dynamics of a system involving conscious recognition of all the elements and conditions (operational, technical and human) in the cockpit and outside the aircraft.“ [25] This ability comes from a lot of experience and training. The study by Diaz et al. [25] highlights the importance of SA for a pilot during the landing. This assures a good control for a pilot during visual flight rules (VFR) when landing an aircraft [25].

3.2 Comparison between Experts and Novice Pilots

There have been found noticeable differences in the landing performances between expert pilots with 1’500-2’000 flight hours and cadet pilots with 40-70 flight hours. Experts have a more defined visual scan pattern, shorter dwell times, and different gaze behaviour that can be linked to flight performance [26]. Experts employ structured supervisory visual search, an effective attention allocation mode and frequently cross check instruments, while novices tend to focus more on outside visuals [23], [27], [26], [28].

Experts seem to better narrow down their visual attention to the relevant instruments, where new information was expected to be read, to prevent cognitive overloading, and so avoiding piloting errors [26], [24]. Longer fixations on the runway are associated with better landing performance and thus with a better estimation of the runway size [29]. The information processing of experts is in a way of high efficiency of top-down that can process information with modularization [28]. To conclude this chapter, novice pilots have significant problems in building situation awareness, suffer from poor information management and scan patterns strategies. Their cognitive resources can be overloaded quickly, and they stay behind when developing needed situation awareness [30].

3.3 Scan Pattern and Gaze Behaviour

As mentioned in the chapter before, the expert pilots have a noticeable and more defined visual scanning pattern and more fixation times, which is linked to their experience in landing approaches. Establishing a sufficient balance between visiting the instruments and the outside world is crucial to ensure the best flying performance, especially in fast paced environments [26]. More efficient and determined eye movements lead to a better performance. It must be considered that the scan pattern can be influenced by several factors, such as the phase of flight [28], [23]. An adequate visual scanning strategy enables pilots to take effective control in time, which further requires a sophisticated understanding of the relationship between the flight instruments. Pilots using triangular scanning strategies, displayed the best performance in terms of an ILS performance [5]. Experienced pilots are not greatly affected by external factors, as evidenced by the fact that these factors did not have a major impact on the flight performance and scanning behaviour. However, it did cause pilots to use a slightly adapted scanning technique depending on the situation [31]. The study by Brams et al. found that the gaze behaviour might be able to provide important information regarding underlying processes in pilots, which can provide an explanation of the successful performance of expert pilots during a flight [22].

3.4 Memory Structure

Mental models have been defined by Endsley as “mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observe system states, and predictions of future states”. [30] Another definition found by Rapp [32] is that mental models are the mental representations of facts and experiences from the outside world. Rapp has found difficulties in defining mental models, since they are purely abstract descriptions of memory. They can alter over time since they are dynamic representations [32].

Mental models are used to describe a person’s representation of some physical system, such as how an engine works [30]. Applied to a pilot, they not only develop a mental model of how an aircraft is operated but also a mental model of flight operations, including air traffic control (ATC) procedures and expected behaviours when interacting with the ATC or other pilots [30]. Endsley [30] has found that many errors in understanding information and projecting future dynamics could be linked to insufficiently developed mental models. This is shown when pilots had difficulties with operations in new geographical areas, recognizing landmarks and matching them to maps, understanding new procedures of flight, landing, and departures in unfamiliar places [30]. Verna and Mettler [33] found that people need a memory structure in order to be able to learn new tasks especially in unknown environments. They wrote that: “Humans are capable of learning complex unknown environments in a variety of guidance tasks and use the knowledge to determine near-optimal performance and remain versatile and adaptive to unexpected changes in the environment.” [33] Working memory refers to the restricted quantity of information that people can recall or remember at one time due to their limited cognitive processing capacity. Making decisions is based on the knowledge stored in working memory [33].

3.5 Video Based Instructions and Learning

Chen [34] makes a comparison between textual and visual content. This research has shown that the brain processes visual content differently than textual information [34]. Visual processing can occur simultaneously along with verbal processing since it involves different brain regions [34]. Deshpande [35] elaborates on the fact that the brain also is able to process visuals faster than written text. Videos tend to quickly engage the viewer since they integrate music, text, and movement. Users perceive and retain 90% more information from video than from text, according to Forbes [35]. By providing students with visual-based learning, they receive a condensed amount of information in a short time, that can be repeated as much as necessary. The conclusion by Chen [34] showed an improvement of learning effectiveness and higher cognitive learning. Similar to Chens [34] study, Castleberry et al. [36] wrote about an overall positive impact on exercises through video instructions. The approach of teaching through videos has also shown a positive effect on students in the study by A. Korf and C. Campbell [37]. Jardodzka et al. [38] even used recorded Eye-Tracking movements while executing a task with additional verbal explanations, to later teach a certain task to students. This allowed the students to improve their visual search and enhanced interpretation of relevant information [38]. The study by Huet. et al. [6] takes an extensive look at the learning process on the final approach in a simulator and the effectiveness of different types of feedback for novice pilots. It has been shown that the novice pilots with feedback outperformed the novice pilot control group with no visual feedback [6]. Visualizations have helped construct mental models in students in science education and have led to improvement amongst the students' performances [32].

3.6 Improving Scan Strategies with Eye Tracking

To get to the bottom of human errors, monitoring tools have been implemented in various studies to be able to trace where a pilot is looking at. Many have decided to use eye tracking glasses for this purpose. In the US Air force, F16 instructors have used eye tracking technology in real time to improve the awareness of the pilots of their own visual scanning patterns. Through eye tracking glasses, the expert instructors were able to follow the gaze of their students, give them feedback of their own performance and visual behaviour. The phenomenon of having a joint attention happens, which is characterized as automatically looking at an object someone else is looking at [3]. Glaholt [14], Lounis et al. [4] and Ahmadi et al. [24] focused on saccades and fixation duration of gazes when analysing pilots' eye movements in flight simulators and actual aircraft to identify repetitive and reliable scanning patterns. Xiong et al. [28] highlight that eye movement measuring instruments could be utilized in the training of novice pilots by analysing their unestablished scanning and contrast them to expert pilots. Using eye tracking as support tool, allows to have insight in a student's current state of mind. The use of eye tracking could aid the rapid improvement of a student pilots training process by providing instructors references of the student pilots current status and adjust the training plan and formulations [28]. The study by Niehorster et al. [39] comes to the conclusion that gaining insight through eye tracking glasses it is an advantage for instructors.

Establishing a well elaborated and sophisticated scanning pattern is essential for improving the flying performance [26]. Experts do not need to stare at an instrument to obtain information, which reduces fixation time, according to the study by Xiong et al. [28]. Lefrançois et al. [3] found that following an expert's gaze can guide attention towards important objects and support learners in developing their own structured visual scanning patterns. A training video was used, consisting of eye-tracking visualizations from more experienced pilots to train novices [3].

A common approach to analysing pilot gaze behaviour is to divide the cockpit into relevant areas and compute total viewing time (i.e. dwell time) for each area. Pilots with more experience have shorter dwell times than novices since they are more accustomed to their routine of scanning patterns [22], [40]. Ziv [26] has found that longer dwell times of experts relate to better decision making, such as choosing a necessary corrective action. Shorter dwell time can be backtracked to more flying experience overall [41].

3.7 Research Questions

RQ1: *Can visual scanning and the landing performance of novices be improved by a video instruction including visualizations of the landing and gaze points from expert pilots as guidelines?*

RQ2: *Can inexperienced student pilots learn how to accurately scan and perform a landing by the visualization of an expert model in a video?*

RQ3: *Is there a difference in dwell time between inexperienced pilots during a flight simulator session before and after a video input as a learning tool?*

RQ4: *What are the visual scanning patterns of novice pilots in the cockpit during a landing approach?*

3.8 Hypotheses

H1: *For the landing approach phase, student pilots’ mental models and situation awareness development can be improved more effectively by using video as a support tool, which includes eye movements from expert pilots, compared to standard textual instructions on how to land the aircraft. This results in a better performance.*

H2: *Visualizations such as videos help student pilots learn by giving them a condensed set of information that can be played back repeatedly. This can increase a student’s engagement, improve their learning efficiency, and enhance the information transfer when they see a realistic scheme on how the landing is done by an expert as a role model.*

H3: *Unexperienced pilots have a longer dwell time in a flight simulator training session when landing for the first time, as they may require more time for information processing and decision making. After watching the learning video, the student pilots have a shorter dwell time compared to students with no video input.*

H4: *Since the student pilots are inexperienced with landing, the scanning pattern is not yet as accurate as the experts, but after the learning video, the student pilots' scanning patterns change to match the expert's scanning pattern. Eye tracking data is compared with an expert.*

4 Methods

This section outlines the different methods which were used for this project in five main parts. Beginning with the descriptions of the participants, then the study design, continuing with how the procedure for the experiments evolved and at last what type of data analysis was used. In the following chapters, these laymen are described as student pilots or pilots. In the first chapter the number of participants is shown, and an expert is described. Then it continues with the study design for this thesis, which includes the type of experiment and evaluation method. The materials used for this study are described next, including the video editing program, the flight simulator, the eye tracking glasses, and the various software's used to analyse the data. Finally, the initial flight scenario, the theory input for the participants and the associated questionnaires are shown.

4.1 Participants

As mentioned in the introduction, 22 people were invited in the simulator to perform two landings in total. In the table below (Table 1) it is visible that their mean age is around 31 years, with the minimum age of a participant being 19 years, and the maximum age of a participant 55 years. The standard deviation of the participants age is 11.2. The gender distribution of the participants is composed of 6 female and 16 male participants. The participants have no flying experience, so to speak, and no prior knowledge of how to operate and land an aircraft. Only one participant had 10 hours of flying experience, but which are not up to date.

	Mean value	**Minimum**	**Maximum**	**Standard deviation**	**Gender [PAX]**
Age in [y]	30.7	19	55	11.2	M: 16, F: 6

Table 1: This table displays the mean value of the participants age, the minimum and maximum age of the participant and the distribution of the participants genders.

Also, an expert pilot was invited to the simulator to perform one landing. His landing was recorded with Tobii eye tracking glasses. Based on the expert pilot point of view, the gaze samples were collected, which were later used to produce the learning video.

4.2 Study Design

This study conducted quantitative research that examined experiments, questionnaires, and correlational study in a laboratory environment. The setting was composed of a cockpit and a virtual flight environment. In the first part of this study, as seen in Figure 1, the support tool was created, also referred to as video input or video tutorial. For this purpose, an expert pilot was invited into the flight simulator and asked to make a landing under the same conditions, with the same targets that the student pilots had later. How the video was created will be discussed later, in chapter 4.3.4.

After completing the video tutorial, 22 people, with no or little flight experience, were invited to the Redsim simulator to perform two landings in total. It must also be mentioned that the pilots had three tasks that they had to follow during the approach. These tasks will be presented later, in chapter 4.3.2. The 22 participants were split up into the video group (n=12) for the first flight (F1_Video) and the second flight (F2_Video) and the baseline group (n=10) for the first flight (F1_Theory_Baseline) and the second flight (F2_Theory_Baseline). The video group got to watch the learning video and the other group represented a baseline group, who only received written theory inputs. Because it was intended to have more people watching the learning video, the two groups contained a different size.

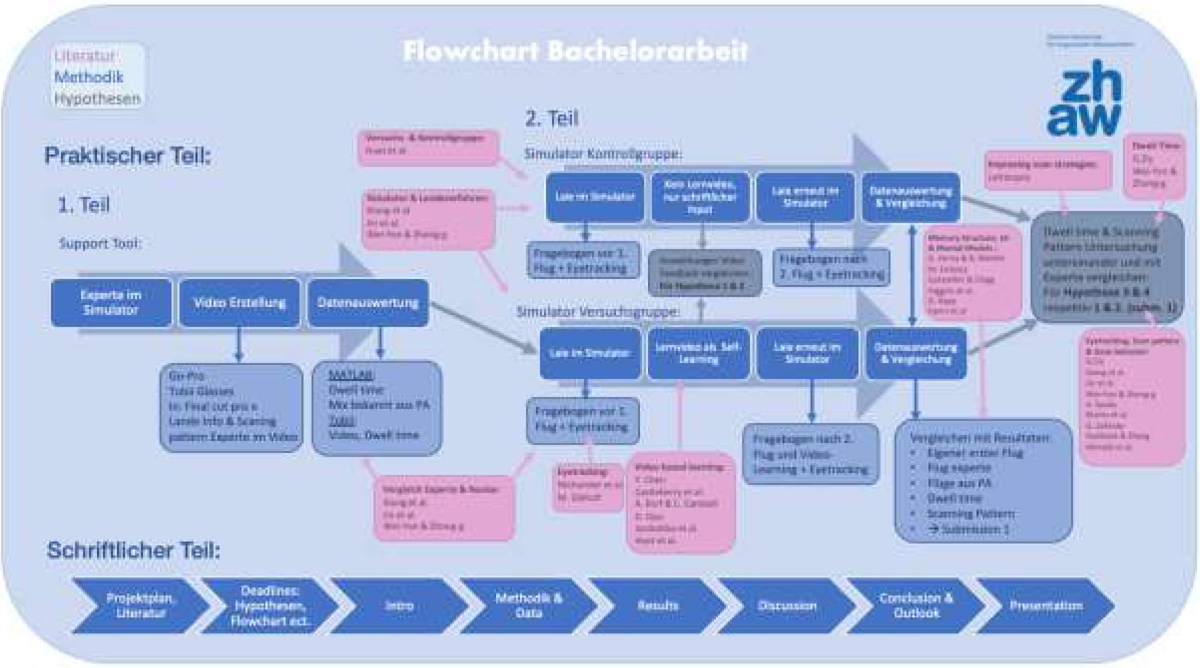


Figure 1: This flow chart shows the approach of this work. It starts on the left side and leads with the arrows to the goal on the right side. The blue colour shows the methodology, the greyish colour the hypotheses and the pink colour the connection to the literature. The flow chart is divided into a practical and a written part, that run simultaneously. The first part concerns the creation of the video tool, while the second part focuses on testing the video tool.

After completing two landings and answering a self-evaluating questionnaire, the data from the flights got collected and evaluated in MATLAB. The questionnaire included both structured (closed question, yes/no) and semi-structured (open questions). Descriptive statistics of the flight simulator data and the eye tracking data was made, which will be further explained in chapter 4.5.

4.3 Materials

This subchapter describes the materials used for this thesis. It starts off with the flight simulator, the scenario input for conducting the flights and the calculation for obtaining the point of descent (POD), the eye tracking glasses, the evaluation software from Tobii and the learning video created for the student pilots. This chapter concludes with the theory input, the type of questionnaire and the procedure for the student pilots.

4.3.1 Flight Simulator

During the flight experiments the RedSim at ZHAW was used. Participants flew with a simulated Piper 28A. Data was recorded in 100 Hz and stored in MATLAB time series by the RedSim. Since for this study only the landing phase mattered, the simulation started immediately with the approach on the airfield and ended at touchdown. Data used in this study were the true airspeed (TAS), vertical speed, height and bank angle. The data was recorded in SI-Units.

4.3.2 Scenario

The airport where the flight experiments took place is in Buochs. The landings were performed on runway 24. The original procedure for landing at Buochs on the visual approach chart (VAC) in Figure 2 was modified to a new flight path which can be seen in Figure 3. From the earlier project work "Scanning Behavior of Private Pilots during the Landing Approach in VFR with the support of Video- and Eye Tracking Analyses" the results of the expert pilots were incorporated, whereby it was evaluated that the experts could descend intuitively at 500 feet/minute, make the approach and land successfully at a speed of 63 knots on average. At the established speed of 63 knots, the POD must be extended, as shown in Figure 3, to ensure accuracy. The calculations for this are displayed in the appendix 10.4.

Figure 2: Shows the original VAC of the airfield Buochs.

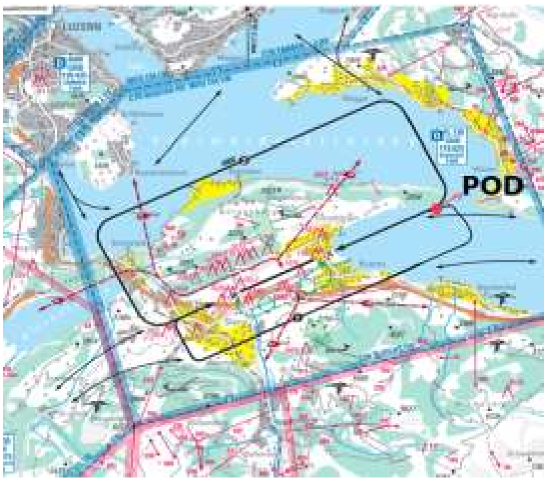


Figure 3: The new VAC shows the extended final for runway 24 and POD

The student pilots for this thesis had the task of starting at this new POD, and land at a speed of 63 knots with a sink rate of 500 feet/minute. With this prerequisite, the student pilots were expected to accomplish a landing, as this was the set goal for the participants. The three requirements are summarized in the Table 2 below.

Task	**Hold a steady velocity**	**Hold a steady sinking rate**	**Focus on**
Value	63 knots	500 feet per minute	Aiming Point

Table 2: This table displays the task requirements for the student pilots and the expert. It consists of three tasks in total.

4.3.3 Tobii Eye Tracking Glasses and Tobii Pro Lab Software

In addition to the simulator, eye tracking glasses and the Tobii Pro Lab software were used, which allowed the ability to categorize AOI in the cockpit. The Tobii eye tracking glasses, as seen in Figure 4, were integrated into the cockpit, and worn by the pilots for the purpose of this study. Through the glasses, an exact gaze vector was identified with the aid of the integrated sensor technology. Eight inwardly pointing infrared light sources were included within the lens of the glasses specifically for this purpose, reflecting in the appropriate places on the cornea of the eye. Both the location of these reflections and the location of the pupil were captured by two cameras, which are also referred to as detectors. Above the nose, in the middle, is a forward-facing camera that recorded an HD video of the scene. The estimated gaze vectors were combined and displayed parallax compensated. A parallax is an apparent displacement of an object with respect to the background when the observer changes the angle of view [42]. The sampling rate of the glasses were recorded with 50Hz. During the utilization of the glasses, various parameters were measured. For the following experiments they were used to track how often the pilot has looked at the aiming point, how often at the velocity and vertical speed on the instruments. The occurrence and duration of fixations made by the pilot during a landing were of interest for this study. A fixation is equivalent to the focusing of the eye on a point. [42]

Figure 4: These are the eye tracking glasses used in this study, called Eyetracking Glasses 3 by the company Tobii Pro.

The glasses needed to be attached to the recording unit, which must have been equipped with a battery and a SD memory card for the recordings. After the pilot had put on the glasses and the recording unit was started, the calibration of the glasses took place with the help of a calibration card with a black circle and point on it. With the help of the Pro Glasses 3 application for a smartphone the calibration was then manually started. Following that, the recording through the eye tracking glasses could then be started. After the landing had been performed by the pilot, the recording was manually stopped through the smartphone application. If all the landing and recording cycles had finished, the data on the SD memory card then was extracted from the recording unit and loaded into Tobi Pro Lab on a Computer.

The Tobii Pro Lab is a software, which helps to analyse the data obtained from the eye tracking glasses after the experiments had been conducted. The data was imported in form of a video into the program. The video then was edited in Tobii. For the purpose of this study, only the recording of the landing was selected. The recording was then visually matched and rendered in the program with a snapshot, a selected image that included the runway and the instrument display. If a calibration was done previously, using the appropriate Tobii software, the relative location of the centre of the pupil to the reflections can be registered and a gaze vector or the gaze direction can then be determined for both eyes. The gaze map gave an overview on where the pilots have looked at for a period. Furthermore, Tobii Pro Lab provides an additional function for adding a heat map in Figure 5 and a gaze plot in Figure 6 to the results. In the heat map the areas which have been looked at the most were marked in red. In the gaze plot, the duration of the fixations and the order in which they occurred are visible. For this study, the gaze plots and heat maps of each flight pilot were collected. This was used to roughly clarify what student pilots looked for and what their scanning pattern was when landing. It allowed to see whether the aiming point was correctly selected by the student pilot.

Figure 5: This is a heat map from the analysis of the eye tracking data in Tobii Pro Lab. The areas which have been looked at the most are marked in red. As it is visible, the main focus is on the runway, indicated by the red colour. The other focus lies on the speed indicator and then the vertical speed indicator.

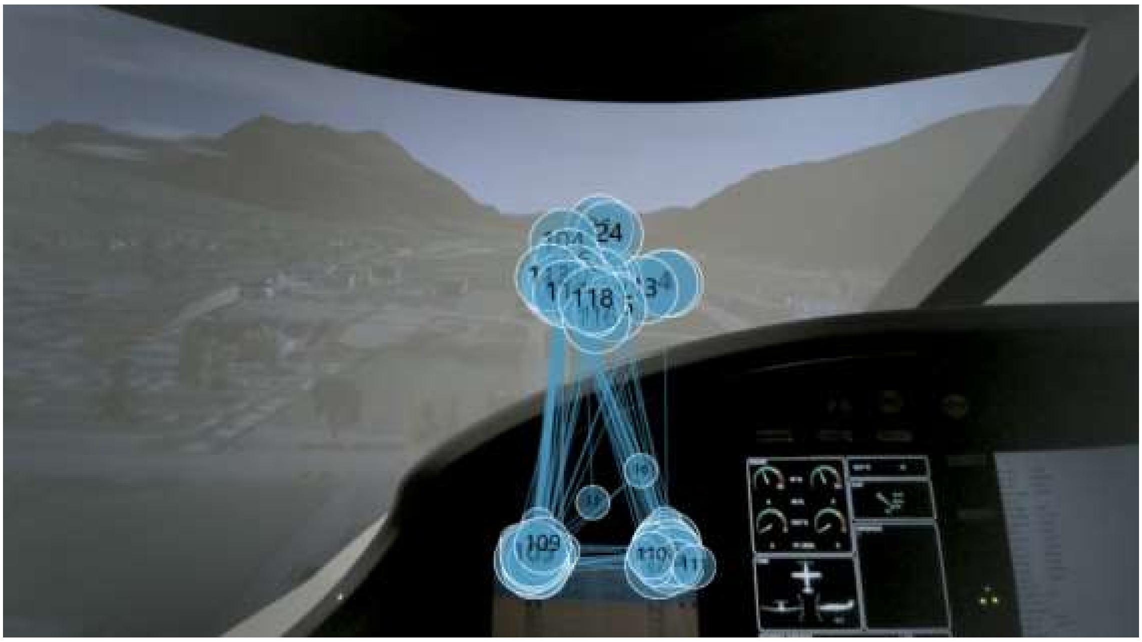


Figure 6: This is a gaze plot from the analysis of the eye tracking data in Tobii Pro Lab. The duration and order in which the fixations took place are marked as circles. As it is visible, the main focus is on the runway. The other focus lies on the speed indicator and then the vertical speed indicator

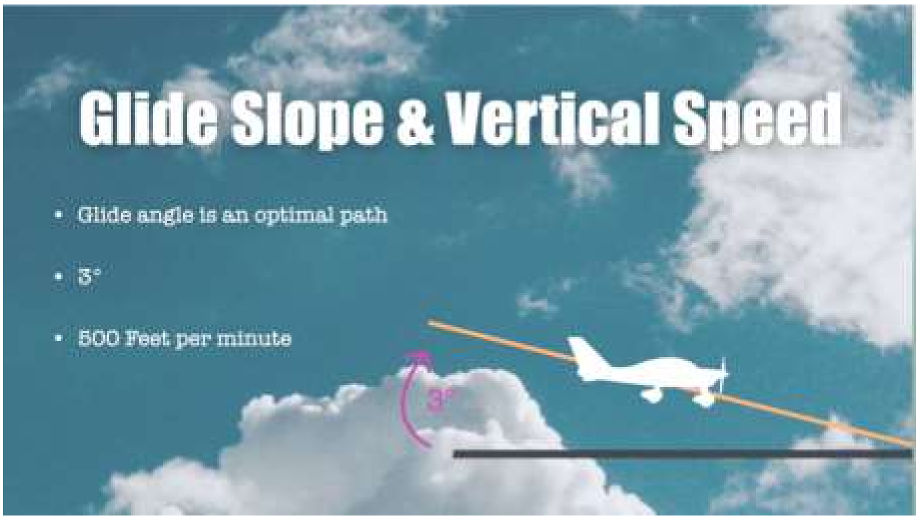
As explained in the previous section the eye tracking glasses were used to check how many times the student pilot looked at three areas. To define the three areas a tool in the program Tobii Pro Lab was used, called the area of interest (AOI). For this study three AOI were selected, one being in the proximity of the runway, the other including the flight instruments velocity [V] and vertical speed [VS]. One area was defined for when the pilot was looking out of the window for scanning the aiming point, the second area is for checking the velocity and the third for the vertical speed, as seen in Figure 7.

Figure 7: This picture displays the point of view of a pilot in the Redsim. The three AOI's are highlighted in green for the cockpit window, magenta for the velocity and brown for the vertical speed

Every time the eye tracking glasses registered that the pilot was looking at an AOI, the time looking at a certain AOI was recorded. With these fixation times, the dwell time could be evaluated. After the data was analysed, the data was exported into an Excel file and imported into MATLAB.

4.3.4 The Learning Video for the experimental group

The video was created and edited with the application Final Cut Pro. For the making of the video, textual inputs were used, a voice over, video images, gaze samples, and audios were added, as well as animations and pictures. The video consists of two main parts. The first part contained an extended theory input, and the second part showed the landing from the expert's point of view with a scanning sequence at the end. The first part summed up the most relevant instruments in the cockpit, which are relevant to land this type of aircraft. The relevant instruments that were considered important for the video are based on the findings from the previous project work "Scanning Behaviour of Private Pilots during the Landing Approach in VFR with the support of Video- and Eye Tracking Analyses" and interviews with flight instructors from the Basel flight school. The interviews revealed that it is very important that the approach speed is always correct during the approach phase. For this reason, different scenarios, which can occur, the correct approach speed is not being maintained and how to encounter unwanted situations. The tasks are also explained once again and signalled in the cockpit where attention should be directed. Other parts, such as the usage of the pedal or the explanation of the glide slope, served only as information for the listener, as seen on an example in Figure 8.



Glide Slope & Vertical Speed

- Glide angle is an optimal path
- 3°
- 500 Feet per minute

Figure 8 This picture shows an outtake from the video tutorial from the first part that contains the theory. This outtake specifically shows an example of the explanation for the glide slope and the vertical speed. It displays the most important values on the left in text and shows an animation of an airplane on the right. In the video this slide is also supported by a spoken explanation.

The second part of the video shows a landing by an experienced pilot, as seen in Figure 9. The first few minutes showed the approach of the pilot's view. The placement of the flight instruments and the aiming point were highlighted again. After a while, the pilot's gaze points, in Figure 9 were also displayed, showing how the active gaze point changed. This allowed the student pilots to follow the expert's gaze points and his point of view. The student pilots had the opportunity to watch the video as many times and for as long as they wanted.

Figure 9 This picture shows an outtake from the second part of the theory video. It shows a gaze point of the expert pilot in red, which is located on the aiming point in this case. The thin red line shows that the pilot was looking at the displays beforehand.

4.3.5 Theory-Input for the Control Group

The control group received a theory input as well, but in a written format as it would happen in a regular flight lesson. The theory input consisted of the same explanations and possible scenarios as discussed in the videos, but with no visual input in the form of pictures or animations (see appendix 10.2).

4.3.6 Type of questions in the Questionnaires

The type of questions used are open and closed questions, which were dichotomous and answered with yes or no. The detailed questionnaires can be found in appendix 10.3. Some questions were also aimed at getting possible constructive feedback. In particular, the questions were interested in the confidence level of the participants and how they would rate their landing on a scale of 1 to 5 before and after watching the video or reading the theory. In total, there were three questionnaires. The first set of questionnaires is conducted before the student pilots sit in the simulator and the other two are answered after each of the two landings.

4.4 Procedure for Conducting Experiments with Student Pilots

Before entering the simulator, every student pilot received a manual (see appendix 10.1) beforehand in which the most important parameters and instruments are presented in the cockpit and explained shortly. Moreover, the manual gave insight not only about the cockpit itself, but also about its surroundings for instance in what airfield the simulation took place, including the VAC chart with the aerodrome charts and what the goal of the simulation was. The manual described additionally the three parameters, which at the same time formed the tasks, as mentioned in Table 2, that had to be observed and held during the approach to perform a successful landing. These three tasks also formed the AOI's, as seen in Figure 7.

Prior to beginning with the simulation, the student pilots were asked five questions regarding the manual, concerning their reliance to fly in the simulator with the knowledge given so far. Preliminary to start the recordings, the novices had the chance to get used to the steering of the simulator and fly full circuit. In this training they had the opportunity to recall what was written in the manual and memorize where the important parameters were installed.

After successfully finishing the circuit, the recordings begun. The student pilots were prior introduced that the simulation started immediately within the extended approach of runway 24 in Buochs and the eye tracking glasses were worn. Regardless of which group they belonged to; all 22 pilots completed a first flight with the input from the manual.

Subsequently, after the first landing the student pilots were to split into two groups as mentioned in the previous paragraphs. The allocation of participants to the groups was randomized. The video group, tried to build their mental model with the created educational video, while the baseline group, studied the extended theory.

Since the student pilots have prepared themselves individually, whether with video material or theory, additional question (appendix 10.3.2 / 10.3.3) were asked, regarding their confidence about the upcoming landing. Once the questions have been answered, the second landing could be performed and recorded with the same measurement and conditions as in the first landing. The same procedures were repeated, ending with questions (appendix 10.3.2 / 10.3.3) about their landing and whether they feel an improvement has been made reflecting the first and the second landing

4.5 Data Analysis

This chapter contains the statistical methods used for analysing the data output from the simulator and the eye tracking glasses recordings.

4.5.1 MATLAB

The evaluation, coding and graphing was conducted in MATLAB. The relevant parameters were extracted from the time series, which, as already mentioned, were stored by the Redsim in this format, and imported into the same MATLAB file. The extracted parameters, which were needed from the Simulator were:

- Velocity
- Vertical Speed
- Height
- Bank Angle

The data from Tobii Lab Pro of the AOI’s, as well as the dwell time was exported in Excel files and in a later step imported in MATLAB.

4.5.2 Boxplot

The Boxplot method is used to present the received data in a structured way and to give an overall view. The main characteristics can be found in a boxplot are the lower quartile, median and upper quartile [43]. In the result part, they shall represent if the participants could manage to remain in the wanted section. With this method it gives more insight on whether it has been adhered to.

4.5.3 Mean Dwell Time

The Dwell time is a representation of the total fixation, it reveals which of the three AOI have been viewed the longest. For the sake of clarity, these were displayed in bar plots. The dwell time was calculated, by summing up all the data and divide the sum by the number of participants.

4.5.4 Probability Tree

The probability tree is used to identify how the student pilots shifted their attention between the three AOI and reveal possible pattern. For this method, an algorithm was created in MATLAB that counts the number of times the eye movements switched between the three AOI’s. To be more specific, the saccades were counted. The possible patterns that the algorithm searched for have been built into the code. The code was designed to scan for 24 possible combinations of where the student's attention might be directed to. An introductory example is shown in Figure 10. For instance, the algorithm counts the saccades between aiming point, velocity, vertical speed and finally aiming point again. Those are the four possible eye movements a student pilot can conduct between the three AOI’s, which create a pattern.

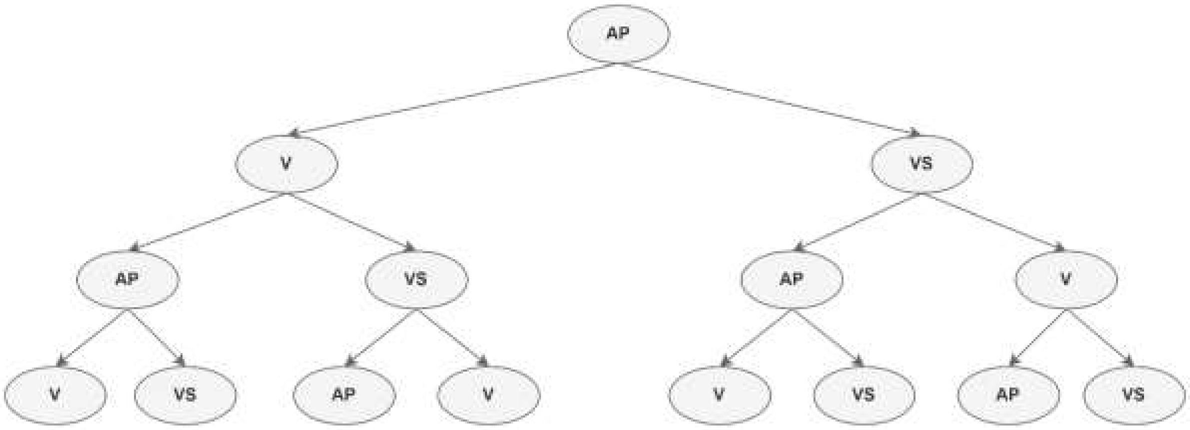


Figure 10 This figure shows a probability tree of a scanning pattern starting with the aiming point. AP: Aiming point; V: Velocity; VS: Vertical Speed.

Each labelled node of this probability tree in Figure 10 represents a possible event. Every connected branch represents a chain of possible successive events. The possibility of such an event occurring is given as a percentage. The node at the end of each branch symbolizes an event, and the probability of its occurrence is given in percent. The probabilities were multiplied along the branches of each path and the sum of the probabilities resulted in the desired values.

5 Results

This chapter presents the landing results, featuring the simulator parameters represented by boxplots of velocity and vertical speed. The subsequent section examines the eye tracking results, including mean dwell time and mean values of the cockpit mix. Lastly, the chapter presents the probability tree analysis and reports the findings of the questionnaires.

This section introduces the two primary groups. As stated before, the video group includes those who watched the video, while the baseline group consists of individuals who read the theory. Within each group, the results before and after watching the video or reading the theory are illustrated. These are represented with the names F1_Video (F1=Flight one), F2_Video (F2=Flight two), F1_Theory_Baseline and F2_Theory_Baseline.

5.1 Boxplot of the True Airspeed

These four boxplots in Figure 11 show the TAS of the conducted flights in the simulator, measured in knots, which are marked on the y-axis. On the x- axis the corresponding groups are listed. The two groups are separated by the blue rectangle. The left side in Figure 11 represents the video group and the right the baseline group, who read the theory. Simultaneously, within the rectangle, the first and second flight of each group is shown.

Regarding the velocity, the objective for the pilots was to maintain a consistent speed of 63 knots during the approach, as indicated by the orange arrow. Analysing the boxplots for the video group, it is evident that prior to watching the video for F1_Video, the pilots exhibited a wider range of velocities compared to after the video input for F2_Video. Additionally, the whiskers length reduced for F2_Video. The median velocity remained higher at first for F1_Video, reaching approximately 66.5 knots and after the input decreasing to 64 knots for F2_Video.

Moving on to the second group in Figure 11, represented by the rectangle on the right, it is notable that their velocity spread before reading the theory for F1_Theory_Baseline was approximately the same as for the video group F1_Video. Surprisingly, even after reading the theory, the pilots' velocity spread during the second landing remained large for F2_Theory_Baseline. The velocity remained the same as can be seen in the median for F1_Theory_Baseline and F2_Theory_Baseline, which was at 65 knots. However, the whiskers were higher for F2_Theory_Baseline.

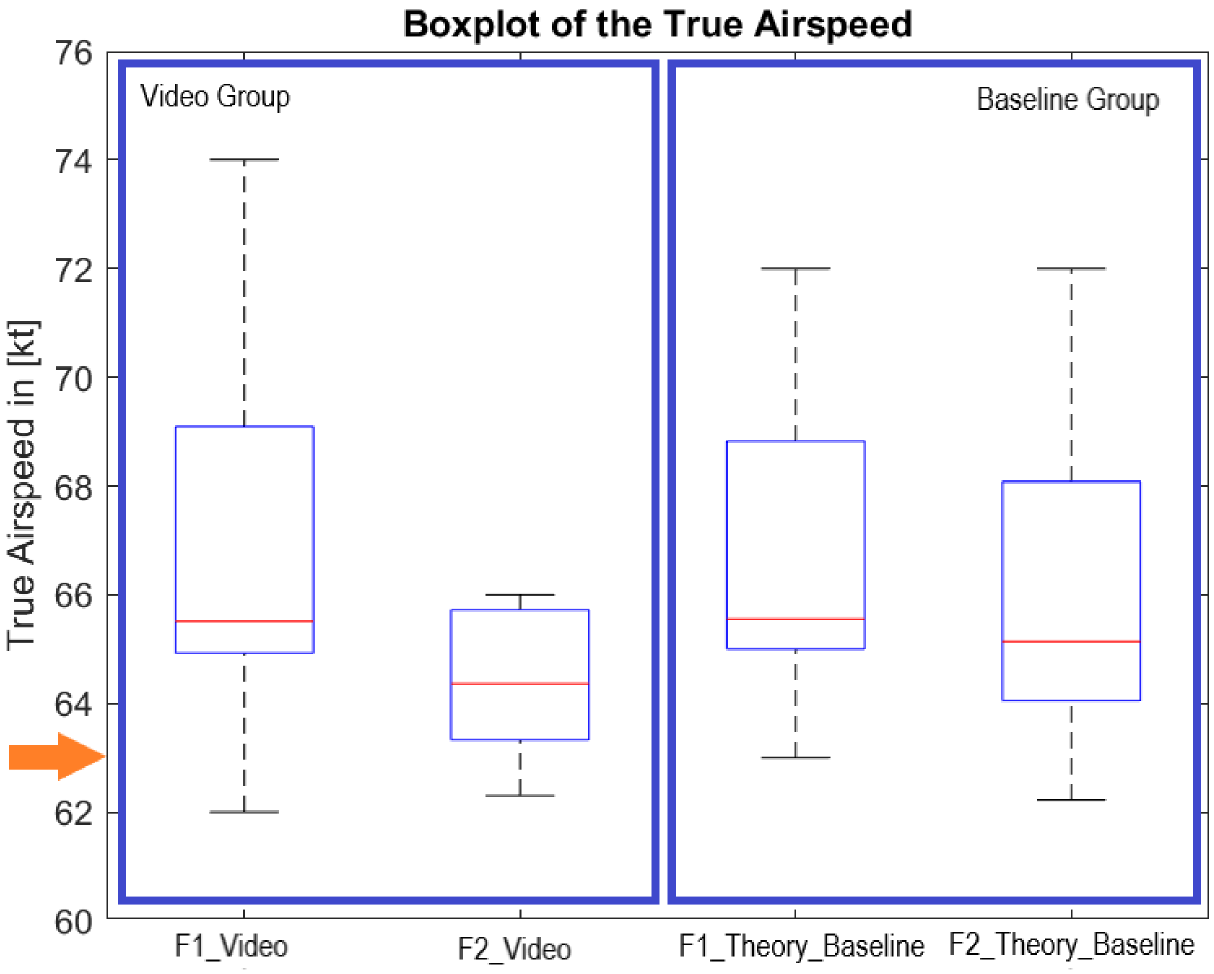


Figure 11 This figure shows the Boxplots of the Vertical Speed of the two groups. The boxplot on the left rectangle refers to the video group with 12 student pilots. The right rectangle represents 10 participants. The medians are seen in red, and the orange arrow shows the desired value.

5.2 Boxplot of the Vertical Speed

Figure 12 displays the boxplots of the vertical speed. On the x-axis the corresponding group is being depicted and, on the y-axis, the vertical speed is represented in feet/minute. The constellation is similar to the boxplots of the velocity in Figure 11. The two groups are separated once again by the two blue rectangles. The orange rectangle shows which value had to be maintained during the approach.

Focusing again on the video group, one can see that for F1_Video the spread was a slightly denser than for F2_Video. Interestingly, the median was 590 feet/minute for F1_Video and increased after conducting the second flight in F2_Video to 610 feet/minute.

When looking at the baseline group in Figure 12, the F1_Theory_Baseline group had a denser spread, but a higher median at 650 feet/minute. After the second flight, it is visible that the spread and the median increased, to 670 feet/minute for F2_Theory_Baseline. The whiskers of both baseline groups remained almost similar.

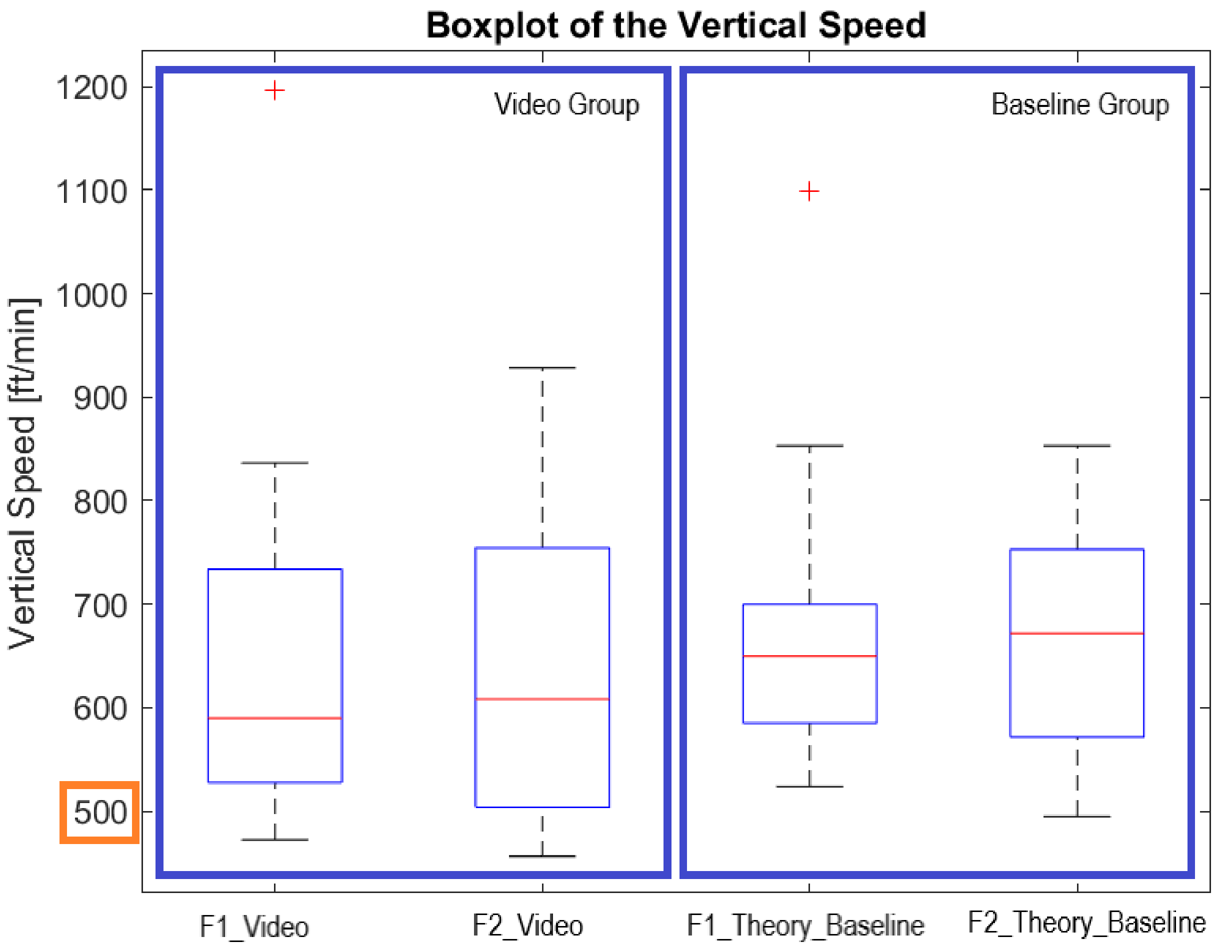


Figure 12 This figure shows the Boxplots of the vertical speed of the two groups. The boxplot in the left rectangle refers to the video group. The right rectangle represents the baseline group. The medians are seen in red, and the orange rectangle shows the desired value.

5.3 Scatter of the Touchdown Point

In the Figure 13 below, the scattered plots of all groups are visible. Instead of having the labelling of the groups on the x-axis as in the previous figures, this time it is depicted on the y-axis. On the x-axis the length of the runway is shown in meters. It is important to note that the x-axis only covers the touch down zone of the runway. The blue point in Figure 13 represents the optimal touch down point and has the ideal length situated at approximately 230 meters. The coloured circles are the touchdown points of the pilots. The same principle is followed here again, the blue rectangles separate the two groups. The video group is placed at the top and at the bottom the baseline group.

For the first flight, the F1_Video group exhibited a standard deviation of 53 meters, with a mean value of 250 meters. Upon viewing the video, the F2_Video group's standard deviation remained at 53 meters, but the mean value decreased to 231 meters.

Conversely, the F1_Theory_Baseline initially displayed a comparable standard deviation of approximately 53 meters before delving into the theory, but their mean value was higher at 280 meters. After reading the theory and conducting the second flight, the F2_Theory_Baseline's standard deviation decreased to 50 meters, while the mean value shifted to 272 meters.

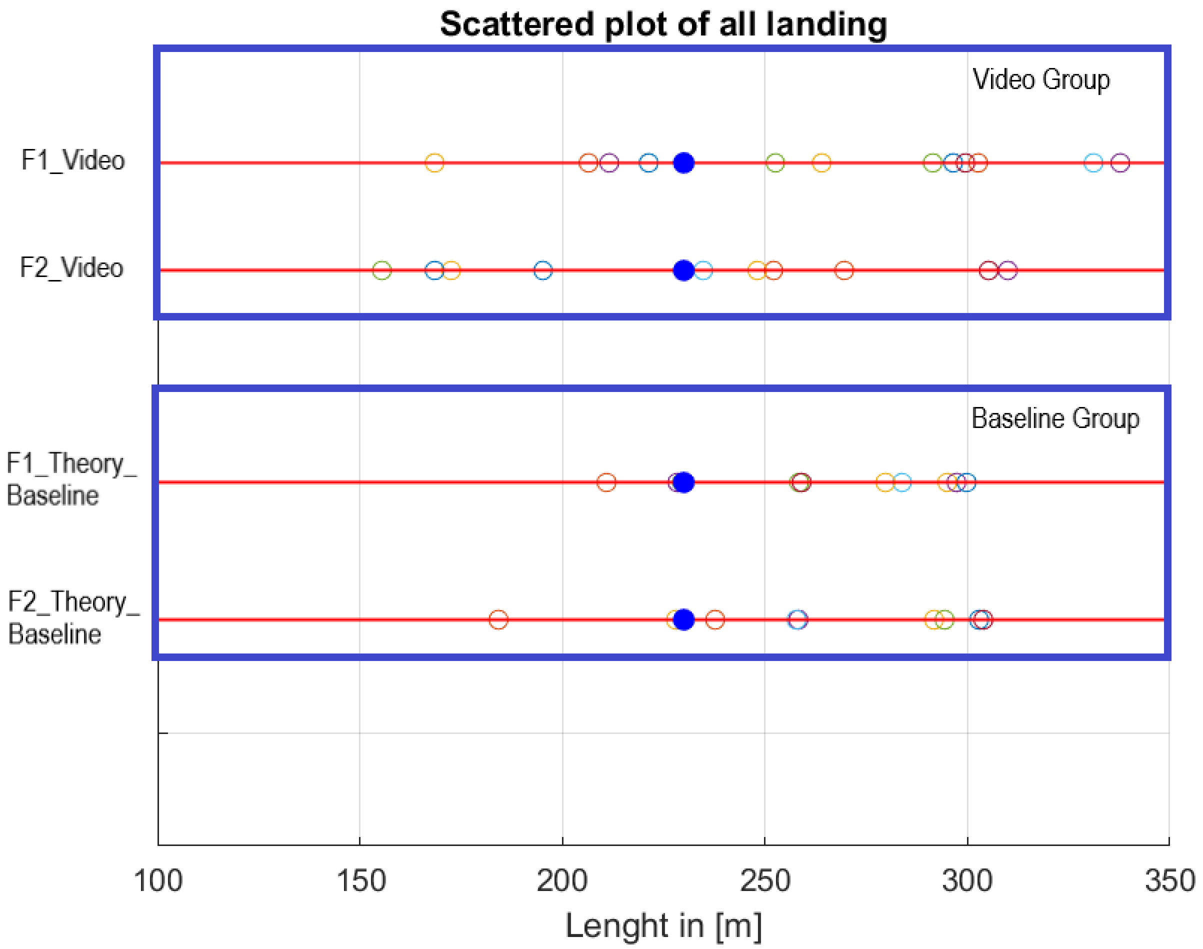


Figure 13 This figure shows the scattered plot of all the landings. It is divided into the two groups, the video group and the baseline group. The x-axis shows the length of the runway in meters. The blue dot represents the optimal touchdown point, at approximately 230 meters. The coloured circles represent each pilot touchdown point on the runway.

5.4 Dwell Time

Figure 14 displays the average dwell times on the AOIs as bar plots, with the fixation time measured in minutes on the y-axis. On the x-axis the groups are depicted again, including the expert. This allows a comparison of the novice's scanning with the expert's which is relevant for the hypothesis H4. As of this reason, the expert is only included in this section. This time the two groups are being separated by the two green rectangle. On the left again the video groups are depicted and on the left the baseline group is visible.

It is evident that each group devoted a considerable amount of time to observing the aiming point. The instrument that received the second longest attention duration was the velocity indication, while the least amount of time was spent observing the vertical speed.

Considering the video group, F1_Video had a dwell time on the AP of 1.19 minutes, a dwell time on the velocity of 0.27 minutes and on the vertical speed 0.12 minutes. F2_Video spent 1.2 minutes looking at the AP, 0.22 minutes on the velocity and 0.12 minutes on the vertical speed.

The baseline group had similar values namely, F1_Theory_Baseline spent 1.17 minutes looking at the AP. The velocity and the vertical speed had the same dwell time of 0.15 minutes. The F2_Theory_Baseline had a dwell time on the AP of 1.2 minutes, a dwell time on the velocity of 0.15 minutes and 0.16 minutes for the vertical speed.

Regarding the expert pilot in Figure 14, is it evident, that he had spent less dwell time on every AOI. Most time spent on average was 80 seconds for the AP. Second most time spend dwelling was on the velocity with 8 seconds and at last the vertical speed with less than 4 seconds on average.

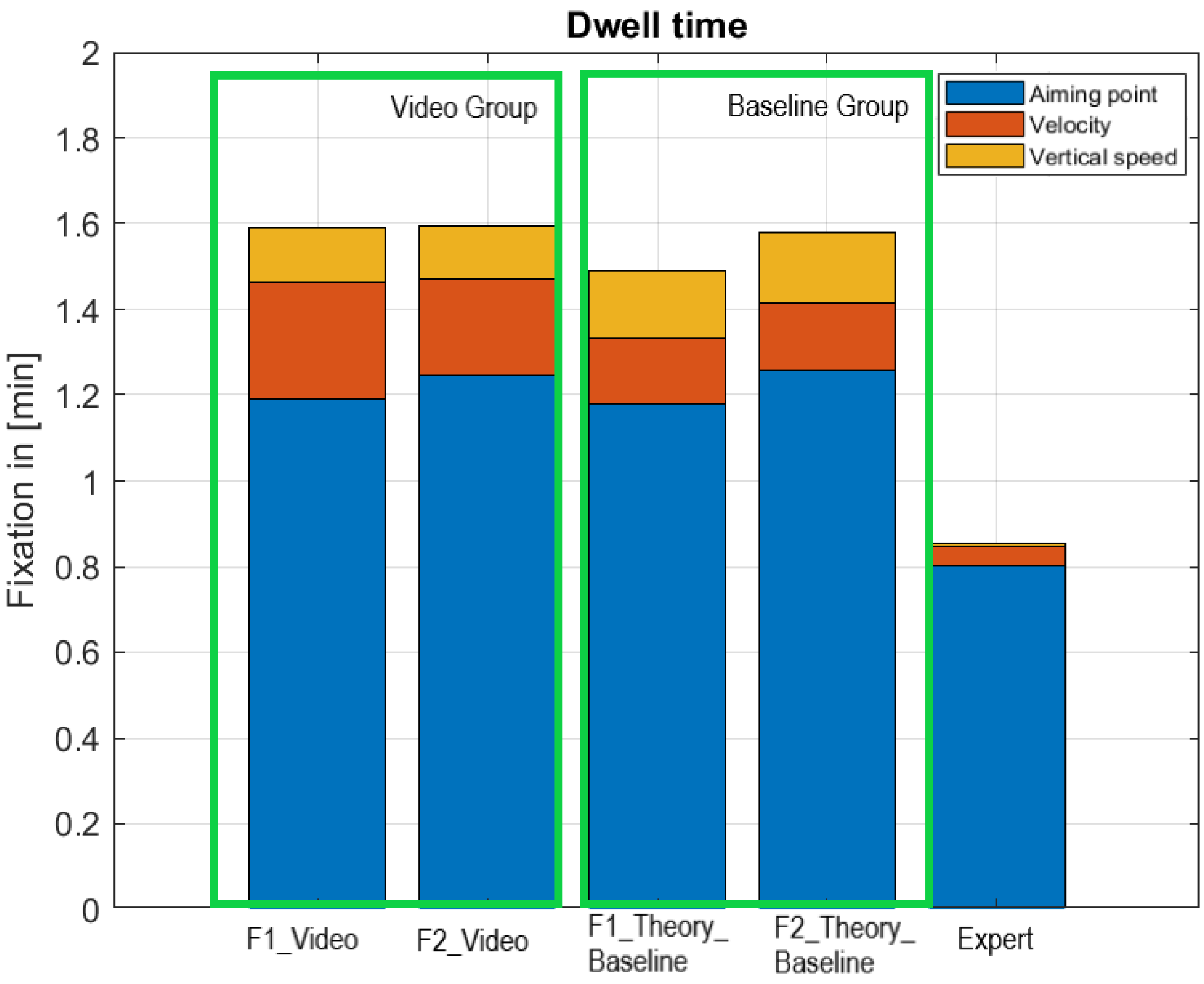


Figure 14 This figure shows five bar plots of the average dwell time of the participants. The fixation time on the y-axis is measured in minutes and the x-axis represents the groups. The bar plots are divided into four categories which are the aiming point, the velocity, and the vertical speed. As it is visible, the largest part of each bar plot is the fixation time on the aiming point. On the right-hand side, the bar plot from the expert is visible.

5.5 Probability Tree

The probability tree in appendix 10.5 shows which scanning pattern was the most frequent. The thicker arrows represent which scanning pattern was the most prominent. At the end of each branch, the agreement in % is indicated. The agreement represents the pattern that was found the most often by the algorithm. The higher the value in %, the higher the agreement. This was then marked in green.

When looking at appendix 10.5.1 the first tree of the F1_Video, it is quite clear that the most frequent eye movement took place between the aiming point and velocity. Here the outcome was 32%. The second tree also shows the same results, but in a different order, where the value was 37%.

Despite the algorithm's search for a pattern starting with the vertical speed, the branch that then continued with the eye movement between velocity and aiming point showed the highest strength, with a percentage of 32%, represented by the last tree.

After watching the video, F2_Video from section 10.5.3 in the appendix had almost similar results compared to F1_Video, except from the last tree. The first tree had a higher percentage of 38% on the left branch, and the second tree had a higher percentage of the leftmost branch, which also had a higher value of 40%. The third tree, interestingly, has two dominant branches with an agreement of 30%. Nevertheless, the interaction was highest where there was an exchange between aiming point and velocity, although the pattern started with vertical speed.

Before reading the theory, the probability tree presented in Appendix 10.5.2 exhibited similar outcomes to those observed in group F1_Video. In particular, the left branches of each tree consistently demonstrated the highest percentages, indicating a recurring eye movement between velocity and vertical speed.

F2_Theory even has two branches on the first tree which were both on the right side. The vertical speed was observed more often in this case. Both branches had a 21% agreement, which can be seen in appendix 10.5.4. In the second tree, which started with the velocity, had a higher eye movement as well on the right side, namely where the vertical speed has again a higher percent. Here, the agreement was 30%. Interestingly, the agreement of 31% was again on the left side of the tree. The values for the experienced pilot were similar to those for group 0 and 1. Here as well in appendix 10.5.5, both eye movements took place between the aiming point and velocity.

Upon comparing the results presented in Appendix 10.5.5, pertaining to the expert analysis, it becomes evident that they closely resemble the outcomes observed in Group F2_Video. In the first tree, a notable branch on the left side exhibited a 47% agreement. Similarly, the second tree displayed a prominent left branch with a 49% agreement. Lastly, the third tree showcased two significant branches, both with a 31% agreement.

5.6 Results Questionnaire

In this section the results of the questionnaire are presented as seen in appendix 10.3. The answers to the decision questions are presented in bar plot format, visible in appendix 10.3.1. The evaluations from the questionnaire are explained again in this section. It is important to note that depending on the question, some questions had a dichotomous answer format (yes/no), others had to give a rating between 1-5, with 5 always being the highest. Not all questions are dealt with individually, but only those that are relevant to the hypotheses.

After the student pilots had familiarized themselves with the manual, only four pilots out of F1_Video and three out of F1_Theory_Baseline answered that they felt prepared for the simulator before their first flight, which is less than a third for each group. Only four pilots of F1_Video and F1_Theory_Baseline group answered that they felt confident enough to perform a good landing for their first flight. After getting the informational input and before their second flight, all of the student pilots had to rate their confidence from 1 to 5. The results showed a higher average for the video group, with an average of 3.28 for F1_Video. The control group F1_Theory_Baseline had an average of 3.15, as seen in Appendix 10.3.1. The group with the video input felt more confident to perform on their second flight.

The participants were asked to rate their own improvement for the second flight from 1 to 5. The video input group F2_Video rated their second landing with a 4 on average. While the F2_Theory_Baseline rated their second landing lower, with a 2.6 on average. When asked how helpful F2_Video found the video, most were satisfied. Every participant of F2_Theory_Baseline rated the textual theory to be helpful, but some answered that they would have liked more visual information.

When asked which part the participants re-read or re-watched more often during the preparation time, F1_Video mostly answered that they re-watched the scanning and gaze visualizations of the expert pilot. Besides that, they re-played the scenario before and after the AP, trim and flare, the glide slope, or AP. Out of F1_Theory_Baseline most of the participants answered that they re-read no sections of the text, except three student pilots answered that they re-read the trim and thrust part, the approach, and the summary.

F1_Video highlighted the most important part for their own learning process and understanding was the scanning and gaze visualizations of the expert pilot, then the summary of the most important points, and finally the overall structure of the video containing the theory and practical part. F1_Theory_Baseline answered mostly with no particular part, then with the summary, approach phase and trim and thrust part.

The participants were asked to rate their stress level and workload perception after the second flight. The F2_Video group rated their stress level to be a 2.8 out of 5 on average; F2_Theory_Baseline rated their stress level a 3.1 on average. After watching the video, F1_Video had a more precise perception of how they would perform the second landing, as they have rated themselves with a 3.6; F1_Theory_Baseline rated themselves with a 3.3 on average. F1_Video have rated themselves to have understood where to focus their attention to for their second flight with an average of 4.4; F1_Theory_Baseline answered with lower values, a 4.0 on average.

6 Discussion

This part contains the discussion of the results. It starts off with a broader discussion of the obtained results and then goes into depth with the discussion of the hypotheses. This chapter then finishes with the limitations of the thesis and an outlook on possible continuations of this work. During the experiments none of the pilots had any trouble performing the tasks that were asked of them. It was possible to apply the eye tracking glasses to the student pilots for each of the two landings in the simulator, except for participants with glasses (n=2). It was not possible for participants that relied on glasses to wear the eye tracking glasses combined with their own, since the Tobii eye tracking glasses had troubles to track the eye movements.

6.1 General Discussion

Starting with the boxplot of the velocity in Figure 11, considering first the video group F1_Video, the spread was lager for the group before watching the video than after. It is evident that the F2_Video had a better control over the approach speed than the group who read the theory. So therefore F2_Video improved more strongly compared to F2_Theory_Baseline. Although F2_Theory_Baseline improved after reading the text, they were still above the desired value. The vertical speed in Figure 12 was a little different, the baseline group was indeed better than video group, even after reading the theory. They managed to reduce their vertical speed after reading the theory. However, F2_Video did not improve after watching the video. This discrepancy of the F2_Video could be attributed to the pilots' inadequate understanding or inability to effectively incorporate with the delayed vertical speed. Another reason could be that the student pilots did not pay much attention to the vertical speed, because for their intuition, the velocity and setting of the correct AP were more important. Including the fact hereby, that after only two landings their mental model was not fully developed. Although the approach speed from F2_Video tended to be very good, it is obvious that the scattered plot showed different values. Neither of the two groups had managed land at the right point, not even after reading the theory or watching the video. This is probably since the flaring part was a little more difficult for every student, even for the F2_Video Group. Given this information, it appears that the learning video alone proved to be insufficient for the very last part of the landing. Embracing the principle of learning by doing, which involves dedicating more time to actively practice and acquire a new skill, could have been more advantageous. It is evident that merely completing two landings is not adequate for achieving mastery in the flaring technique.

The bar plot of the dwell time in Figure 14 showed that the AP was viewed the most on average by all four groups. However, there are differences between F2_Video and F2_Theory_Baseline.

After the video, F2_Video looked at the speed more often and F2_Theory_Baseline on the other hand, looked at the vertical speed more often after reading the theory. F2_Theory_Baseline gave more weight to the vertical speed, which is evident by looking at the boxplot of the vertical speed in Figure 12. F2_Theory_Baseline's spread is much denser after the theory than F2_Video in Figure 12 and F2_Theory_Baseline were able to maintain the vertical speed better on average, but still had a higher median than F2_Video. When looking at the dwell time it not surprising, because the Group F2_Theory_Baseline looked at the vertical speed more often than at the group F2_Video. Since the group F2_Video spend more time looking at the velocity after the video, it resulted in a much denser boxplot in Figure 11. In contrast, the expert pilot spent less time on the AOIs in total, as it is visible in the shorter dwell time bar plot in Figure 14. The expert pilot had the same requirements as the student pilots but despite this, resulted in a shorter dwell time bar plot. The expert had a very short dwell time on the velocity AOI and the vertical speed AOI. This was due to his quick eye exchange between the AOI's and the resulting short fixations. Even if he scanned the instruments or the AP, it required him less time for the scanning process. This way the information could be extracted faster. The student pilots gazed longer at a respective AOI, resulting in longer dwell times overall. Even the group who received the video (F2_Video) did not become faster in scanning the instruments and AP. It may also be the case that the expert pilot scanned his surroundings much faster than the student pilot and the eye tracking glasses did not register it as dwell time. The sampling rate was 50Hz as referenced in 4.3.3. These results confirm the findings of the studies Brams et al [22] and Li et al. [40], which stated that the dwell time revealed underlying processes. When comparing the dwell time of the experts to that of the student groups, it is apparent that the groups still dedicated a substantial amount of time to the instruments, even after watching the video. One possible reason for this is that the student pilots, despite receiving additional guidance before the second landing, still felt uncertain about the new surroundings. To achieve a shorter dwell time, more practice is necessary.

The three tasks given for the student pilots were deliberately chosen, to foster the scanning between the three AOI's and direct them to form a triangular strategy, since this strategy is a prerequisite for a good flying performance according to Haslbeck and Zhang [5]. The scanning patterns show two different results for the two groups. Group F2_Video was more concerned with the two AOIs velocity indicator and the aiming point. Even if the algorithm had to search for a scanning pattern starting with the vertical speed, it would first focus on the branch that exhibited specifically the aiming point or the velocity. The group F2_Video had much more eye exchanges between these two AOIs, which is a possible explanation to the corresponding boxplots and bar plots mentioned earlier. Group F2_Theory_Baseline, on the other hand, had a higher dwell time on the vertical speed as seen in the boxplot in Figure 14. The reason for this could be found in the scanning pattern. In appendix 10.5.4 it is visible that the students paid more attention to the vertical speed than to the velocity. This also explains why the spread in the boxplot from the velocity from F2_Theory_Baseline in Figure 11 is higher than in F2_Video. This could indicate that visual information is better received than textual information, as Chen [34] found. The findings are also underlined by the above-mentioned graphs. Interestingly, as can be seen in appendix 10.5.1 and 10.5.2, the two groups F1_Video before watching the video or F1_Theory_Baseline before reading the theory had a similar scanning pattern. After the second landing their scanning patter changed. Interestingly, the group who got to watch the video had a similar result to the expert in appendix 10.5.3 and 10.5.5.

This is further supported by the evaluation of the questionnaires, which showed that group F2_Video worked more intensively with the video by retrieving certain parts, such as the video with the expert's gaze visualized. This created a joint attention, as earlier described by Lefrançois [3] .This might have resulted in a more elaborate development of a mental model for the landing task, when looking at how the scanning pattern has solidified itself in the respective groups. Also, some students in group F2_Theory_Baseline mentioned that they would have liked more visual information and rated their stress level higher than F2_Video. The lack of knowledge about this was then evident in the scanning pattern, and can also be attributed to the fact, that their mental model has not yet been developed enough. When asked if it was clear where and when to focus their attention to and envisioning their goal for the task, group F2_Video answered with higher values than F2_Theory_Baseline. Also, after the surveys, group F2_Theory_Baseline found on average that their 2nd landing did not improve after the textual preparation. Contrasting this, F2_Video felt more comfortable before the 2nd landing and afterwards rated their landing with a higher value on average. This could reflect a higher level of self-efficacy - an expectation of competence that F2_Video developed because of their successful first landing experience and the positive feedback they received. In contrast, Group F2_Theory_Baseline's lack of improvement in their second landing suggests a lower level of self-efficacy, possibly due to their perceived failure in the first landing and the lack of positive reinforcement. These findings are consistent with the theoretical framework's proposition that personal achievement and feedback play an important role in shaping self-efficacy beliefs and subsequent behaviour change [44].

6.1.1 First Research Question and Hypothesis

RQ1: *Can visual scanning and the landing performance of novices be improved by a video-instruction including visualizations of the landing and gaze points from expert pilots as guidelines?*

The visual scanning can be improved by a video input, as it is evident in the scanning pattern and the evaluation from the questionnaire. Most participants of F1_Video have rated the visualization of the gaze points of the expert pilot to be the part that they replayed the most. The scanning of the student pilots was better guided by the video, which is evident when comparing their scanning pattern from F2_Video to the one of the experts. The spread and median from F1_Video to F2_Video increased, as well as from F1_Theory_Baseline to F2_Theory_Baseline. When comparing F2_Video to F2_Theory_Baseline, the spread and whiskers are smaller in F2_Theory_Baseline group. The smaller spread in F2_Theory_Baseline shows that this group had a better control of the vertical speed. Nevertheless, F2_Videos median was much closer to the desired target value of 500 feet/minute. Regarding the performance for the TAS, it improved from F1_Video to F2_Video much more than from F1_Theory_Baseline to F2_Theory_Baseline. F2_Video median was closer to the set goal of 63 knots than F2_Theory_Baseline's median with 66 knots on average. The spread from F1_Video decreased greatly and displayed almost no whiskers, compared to F2_Theory_Baseline who had a larger spread and whiskers. Improvement is also visible in the dwell time bar plot from F1_Video to F2_Video as they spent less time looking at the velocity and vertical speed indicator in the second flight. At the same F2_Video had a smaller spread in the velocity box plot, and they were able to fly closer to the target velocity of 63 knots than F2_Theory_Baseline. Furthermore, there was a larger increase in dwell time from F1_Theory_Baseline to F2_Theory_Baseline than from F1_Video to F2_Video. Summarizing, it can be said that research question 1 can be confirmed.

H1: *For the landing approach phase, student pilots' mental models and situation awareness development can be improved more effectively by using video as a support tool, which includes eye movements from expert pilots, compared to standard textual instructions on how to land the aircraft. This results in a better performance.*

As it is evident from the survey, the pilots from F1_Video were able to better visualize their target and the task at hand for their second flight, than group F1_Theory_Baseline. Also, the fact that the second part of the video was re-watched the most by F1_Video, shows that the experts eye movement help to build the learners mental model and situation awareness more effectively than textual instructions. This implies that the video format was more helpful to support learning. Some participants of group F1_Theory_Baseline have answered that they would have liked to have more visual support, underlines this result. As discussed above, the performance of F2_Video improved after watching the video. Hypothesis 1 can be confirmed.

6.1.2 Second Research Question and Hypothesis

RQ2: *Can inexperienced student pilots learn how to accurately scan and perform a landing by the visualization of an expert model in a video?*

This research question can be confirmed, since the student pilots from F2_Video have a similar scanning pattern as the one from the expert, at their second landing. As most participants from F1_Video have rated the gaze points from the expert to be the most helpful part of the video for them, it can be said that the visualizations have helped them improve their own scanning and performance. Again, the spread for F2_Video was larger than for F2_Theory_Baseline, but the median was closer to the target value in group F2_Video. The improvement in performance is also visible in the results from the task of holding the target TAS of 63 knots, as F2_Video have obtained closer values to the set goal than F2_Theory_Baseline.

H2: *Visualizations such as videos help student pilots learn by giving them a condensed set of information that can be played back repeatedly. This can increase a student's engagement, improve their learning efficiency, and enhance the information transfer when they see a realistic scheme on how the landing is done by an expert as a role model.*

F1_Video re-played parts of the video more often, than F1_Theory_Baseline have re-read parts of the text. The first group has rated the part that was the most helpful for their understanding to be the visualizations of the experts scanning, while the participants from F1_Theory_Baseline mostly answered that they had no particular part in mind. After watching the video, when asked if the participants understood how they would achieve the goal and make the second landing, participants in F1_Video rated their own perception much higher than F2_Theory_Baseline. It can be said that the information transfer, learning efficiency and engagement with the video format was higher for F2_Video, which confirms hypothesis 2.

6.1.3 Third Research Question and Hypothesis

RQ3: *Is there a difference in dwell time between inexperienced pilots during a flight simulator session before and after a video input as a learning tool?*

This research question is partially rejected, since there is only a minor difference in dwell time from F1_Video to after watching the video and performing the second flight for F2_Video. As mentioned before, F2_Video group spent more time dwelling on the AP and less time on the velocity and vertical speed. This is visible in the bar plots in Figure 14, when comparing the two video groups with each other. When comparing the results from F2_Video to the expert, there is no reduction in dwell time visible. The differences in the results from F1_Video to F2_Video are not distinctive enough and do not support research question three.

H3: *Unexperienced pilots have a longer dwell time in a flight simulator training session when landing for the first time, as they may require more time for information processing and decision making. After watching the learning video, the student pilots have a shorter dwell time compared to students with no video input.*

Considering the first part of the third hypothesis that deals with information processing, many participants have answered in the questionnaire that they felt very insecure about their first flight. Only four pilots out of F1_Video and three out of F1_Theory_Baseline answered that they felt prepared for the simulator before their first flight and four pilots of F1_Video and F1_Theory_Baseline group answered that they felt confident enough to perform a good landing for their first flight, based on just receiving the manual as an input. From this low response rate, it can be derived that the pilots felt very insecure and unprepared for the first flight. Consequently, the participants took longer to make a decision as it was not very intuitive yet for the student pilots. After the second flight the participants have rated their confidence with a 3.28 for F2_Video and a 3.15 for F2_Theory_Baseline. This shows an increase in confidence for the video group, but the dwell time does not show any reduction.

When comparing the dwell time from the first flight F1_Video and F1_Baseline to each group's second flight F2_Video and F2_Baseline, not a big difference in dwell time is visible. Overall, the total dwell time is slightly higher in F2_Video and F2_Theory_Baseline than in their first flight, F1_Video and F1_Theory_Baseline, which shows an increase of the total dwell time. F2_Video and F2_Theory_Baseline both dwelled the most on the AP, and almost the same amount on V and VS. Since the difference in the two groups are only a few seconds, the differences are not meaningful. Overall, the dwell time did not decrease after watching the video for F2_Video compared to F2_Theory_Baseline.

Comparing the dwell time to the one of the experts, it is evident in Figure 14 that the expert had a shorter dwell time overall, a total of 0.85 seconds, with the AP having the highest dwell time. It is expected that when with more flying experience the student pilots will have shorter overall dwell times. The expected improvement in information extraction speed could not be realized within the first flight after the video training session. Concluding this, hypothesis three is rejected.

6.1.4 Fourth Research Question and Hypothesis

RQ4: *What are the visual scanning patterns of novice pilots in the cockpit during a landing approach?*

It was possible from the obtained data to create a probability tree and evaluate the visual scanning pattern that have occurred the most often, as seen in appendix 10.5. For each group three probability trees were evaluated, each starting with a different AOI. The most frequent sequences of each probability tree are the following:

F1_Video: (appendix 10.5.1)

- AP→V→AP→V (32%)
- V→AP→V→AP (37%)
- VS→AP→V→AP (32%)

F1_Theory_Baseline: (appendix 10.5.2)

- AP→V→AP→V (31%),
- V→AP→V→AP (34%)
- VS→AP→V→AP (28%)

F2_Video: (appendix 10.5.3)

- AP→V→AP→V (38%),
- V→AP→V→AP (40%),
- VS→V→AP→V (30%) and VS→AP→V→AP (30%)

F2_Theory_Baseline: (appendix 10.5.4)

- AP→VS→AP→V (21%) und AP→VS→AP→VS (21%)
- V→VS→AP→V (28%)
- VS→AP→VS→AP (28%)

H4: *Since the student pilots are inexperienced with landing, the scanning pattern is not yet as accurate as the experts, but after the learning video, the student pilots' scanning patterns change to match the expert's scanning pattern. Eye tracking data is compared with an expert.*

The fourth hypothesis suggest that the scanning pattern of the student pilots changed after watching the video input and becomes more similar to the one of the experts. After the first flight, the group F1_Video and F1_Theory_Baseline have a very similar scanning pattern, with F1_Video having higher agreements for all three branches. (see appendix 10.5.1 and 10.5.2) It is visible in the results that after the second flight and the training input (see appendix 10.5.3), the scanning pattern from F2_Video changed to match the experts (see appendix 10.5.5), but the percentages are lower. This means that the scanning pattern has intensified after the video, which is visible in the second flight for F2_Video. The scanning pattern in the second flight from F2_Theory_Baseline (see appendix 10.5.4) is not like the one of the experts. The data from the eye tracking and the scanning pattern probability tree evaluation confirm this hypothesis, that the video input lead the student pilots scanning pattern to match the one from the expert.

6.2 Limitations

Some limitations have been encountered during this project. Overall, it would have been of great interest to carry out the measurements for a long-term study and with a greater number of participants. This would have made it possible to collect even more specific data, which might have led to even clearer and statistically more significant results. Due to the time restriction, it was not possible to measure different scenarios, which would certainly have been interesting. There were limitations not only in terms of time, but also in terms of equipment. The eye tracking data, which consists of a dynamic video, can only be evaluated with a static image. With a manoeuvre like flying turns, the eye tracking glasses had difficulty recognizing the correct gaze points and fixations. That resulted in no detection points at all or gaze points in wrong locations that had to be corrected manually. The eye tracking glasses also had difficulties in capturing the gaze of spectacle wearers.

Most of the studies from literature reviewed have taken two equal groups. Nevertheless, the studies by Chen [34] and Xiong et al. [28] were chosen as an example to form two unequal groups. It was more advantageous for this study because more people were meant to watch the video.

It must be noted that the initial group of 22 people was split into the two respective groups. These two groups then consisted of 12 people for the video group and 10 people for the theory baseline respectively. This also means that some statistic methods used, for instance the boxplot, may not be fully representative yet, since it takes more people to extract a population’s true value.

6.3 Future Research

This chapter contains possible future research to expand this study. The use of eye tracking could aid the rapid improvement of a student pilots training process by providing instructors references of the student pilots current status and adjust the training plan and formulations [28]. It could have been interesting to see, how the scanning pattern differs, if more external factors are implemented in the simulation as side wind for instance or a runway incursion. It would have been intriguing to fly turns with different conditions or even a whole volte, to expand the study. Additionally, it would have been a great challenge to test scenarios such as an emergency procedure that could arise during a real flight, which would increase the workload. It would further have been interesting to incorporate different meteorological conditions into the measurements and the simulator environment. The study of Spady [31] stated that the scanning pattern would not change tremendously for experienced airline pilots, but it would be intriguing to learn how external factors such as meteorological conditions would affect the student pilots scanning. Future research can delve deeper into the underlying mechanisms of a student pilots mind under real life conditions and explore additional factors that may influence the attention, to gain a more comprehensive understanding of these complex cognitive processes.

7 Conclusion

Summarizing this project, the findings confirm the first, the second and the fourth research question and the corresponding hypothesis, providing valuable insights into the impact of a learning video with scanning visualizations from an expert. While the third research question is partially rejected the third hypothesis is fully rejected. It is important to note that that rejection suggests the need for further investigation and adjustments for further studies. It can be said that the experiments were successful, and the data evaluation went smoothly. The analysis of the eye tracking data revealed improvements in the group that received the video input, indicating the importance of the visual demonstrations in pilot training. It can be said that pilots who have been trained in this manner with the video tutorial are not only better in the flight performance but also more diligent.

The opportunity to continue the work of Haslbeck and Zhang [5] and the possibility to determine the scanning pattern of the novice pilots was intriguing. The scanning pattern observed were particularly noteworthy, as they revealed significant pattern and changes in the two main groups within a short timeframe. The project showed how the attention of people can be positively influenced with a simple learning video and how the focus can be properly increased with simple means. The scanning patterns observed in the video group reflects a more efficient allocation of attention, which is crucial for preventing errors and maintaining the situation awareness. This study provides insights into the efficiency of specific training interventions such as a video tutorial and highlights the importance of including visual scanning pattern and performance demonstration from an expert pilot. The findings indicate that the incorporation of a learning video into a pilot training program can positively impact a pilot’s skill, understanding, and thus reduce human error during the approach phase. According to the results of this study, it is essential to provide comprehensive and targeted training materials to student pilots, to improve their skills, mental models, and situation awareness.

An integration of eye tracking glasses in the training of a VFR pilot can certainly help to develop a good and safe scanning and to prevent possible bad habits immediately. One of the biggest efforts will be that each pilot school will have to develop a learning video for its own airfield, while being careful not to personalize it too much to its own surroundings. Pilots should develop a stable scanning procedure that allows them to land at other airfields as well.

After the learning video has been created, the eye tracking glasses can be used during each training session. This will allow the instructor to view the scanning pattern directly during the debrief and provide constructive feedback. If the student has additionally the chance to compare his scanning techniques with those of an instructor, the learning progress will certainly be more noticeable within a few sessions. This is also the special feature that distinguishes this project, which allows the student pilot to see an active scanning pattern from an expert and try to reproduce it.

8 Outlook

This simulator experiment should be replicated with more participants, other external influences, or an increase in tasks for the pilots. Another possibility is to test the training concept further in a real airplane under real flight conditions. This would require more flight hours for the student pilots.

It is recommended that every flight school creates a learning video tailored for their own airfield and thus picks up the students at the beginning of their career. This way, an elaborate mental model can be built up from the beginning, which can be helpful in hectic situations. It would be interesting to develop further videos, such as different type of video content or variations in instructional methods to further optimize the effectiveness of the training videos. This could contain for example the different phases of flight such as the take-off or certain situations that may occur during the flight. Since this video was created specifically for the approach phase at Buochs airfield, it would be interesting to see if separate videos were created for each airfield in the future, or if a general video was created that could be generalized and applied to all airfields. It would have been interesting to compare the scanning behaviour of the student pilots before the second flight with that of an expert. It would be advisable to conduct a long-term study and accompany the student pilots for several months to expand this thesis and generalizability of the findings. Subsequently, continued research in this area will help to contribute to improve pilot training and enhance aviation safety.

9 Literature

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10 Appendix

10.1 Manual for the simulator at the ZHAW

As part of the bachelor thesis at the ZHAW, participants with no aviation background are invited to use the simulator to perform a landing. The most important parameters of the simulator are presented in this manual.

Notes on the procedure

The first landing in the simulator is a familiarisation flight, you fly a full volte. (See Figure 4 in the appendix)

The measurement starts directly upon landing

- During the measurement, you also receive eye-tracking glasses that measure your eye movement.

Goals in the Simulator:

- 2 Landings for our thesis
- Compliance with the following parameters
    - 63 kt
    - 500 ft/min
    - Aiming point as a focus

Parameter in the Simulator

Aiming Point: Is the point on the runway that will be fixed during landing. For this airport it will be the tip of the arrow. (See Figure 1 and Figure 3 in the appendix)

Velocity [kt]: Is an indicator that shows how fast or slow you are flying.

Vertical Speed [ft/min]: Indicates how fast the climb or descent rate is.

Altimeter [ft]: Is the altitude display showing how high you are above a reference surface.

Artificial Horizon: The artificial horizon is an aid to the pilot if the natural horizon is not apparent.

Flaps setting: Are used during take-off and landing. The screen shows which flaps setting is currently in use during the flight.

Pedals: Used only during take-off and landing.

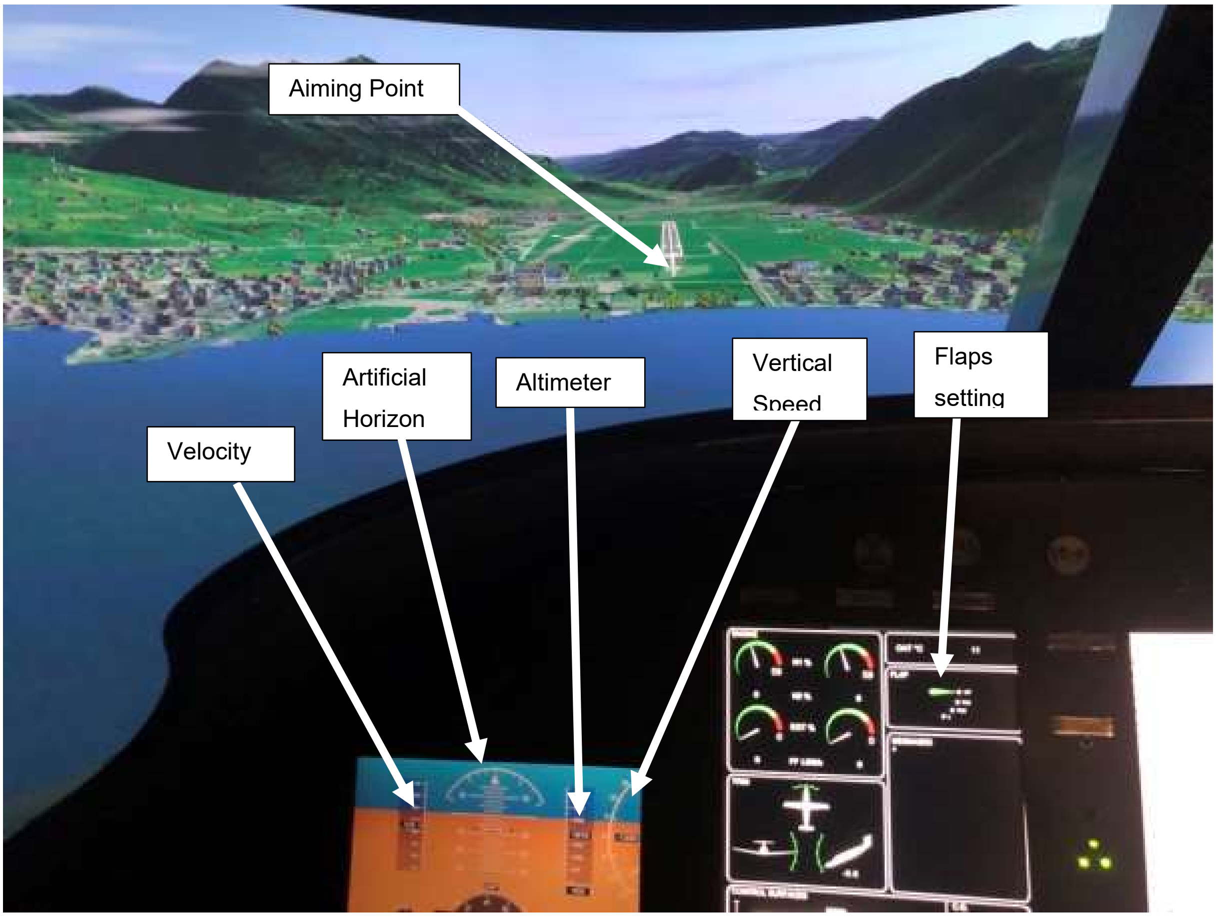


Figure 1: Cut from RedSim Cockpit

Thrust: The thrust lever controls the power of the engine. It is responsible for the preheating movement.

Flaps: There are 3 flap settings.

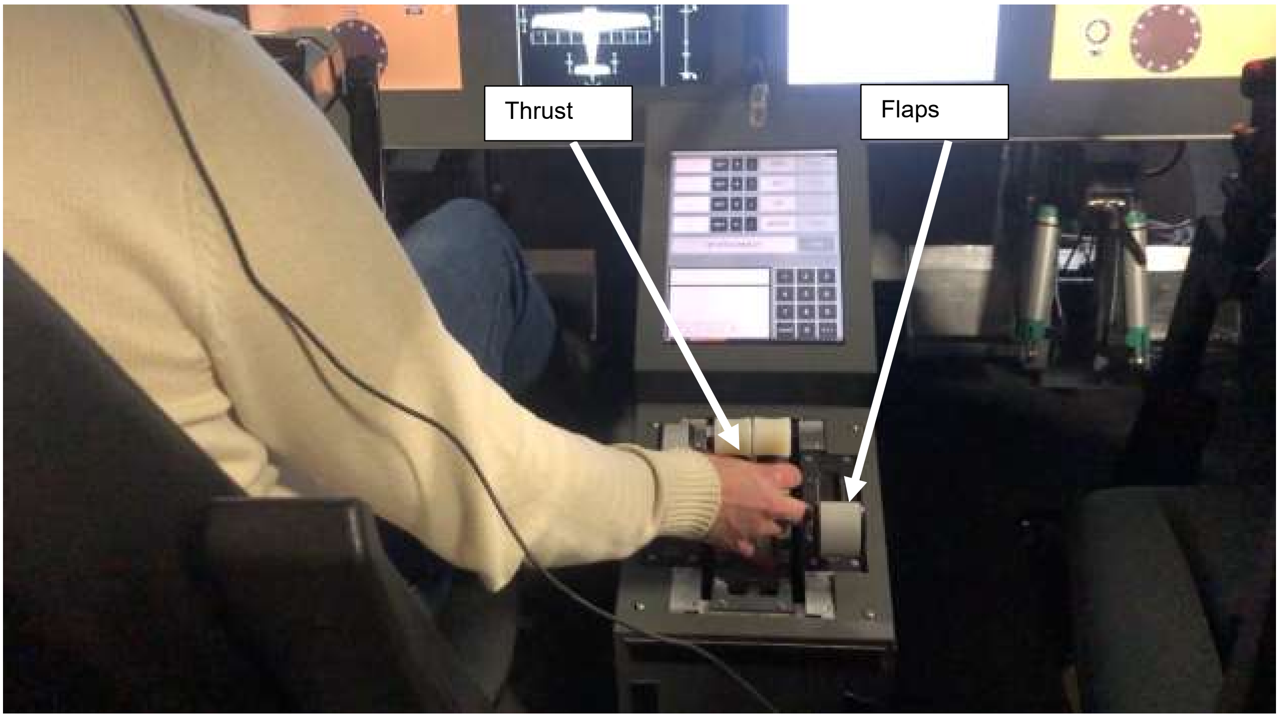


Figure 2: Cut from RedSim Cockpit

Flaren: Just before Touchtown → Above the Aiming Point→Thrust lever back →Pull the control horn slightly.

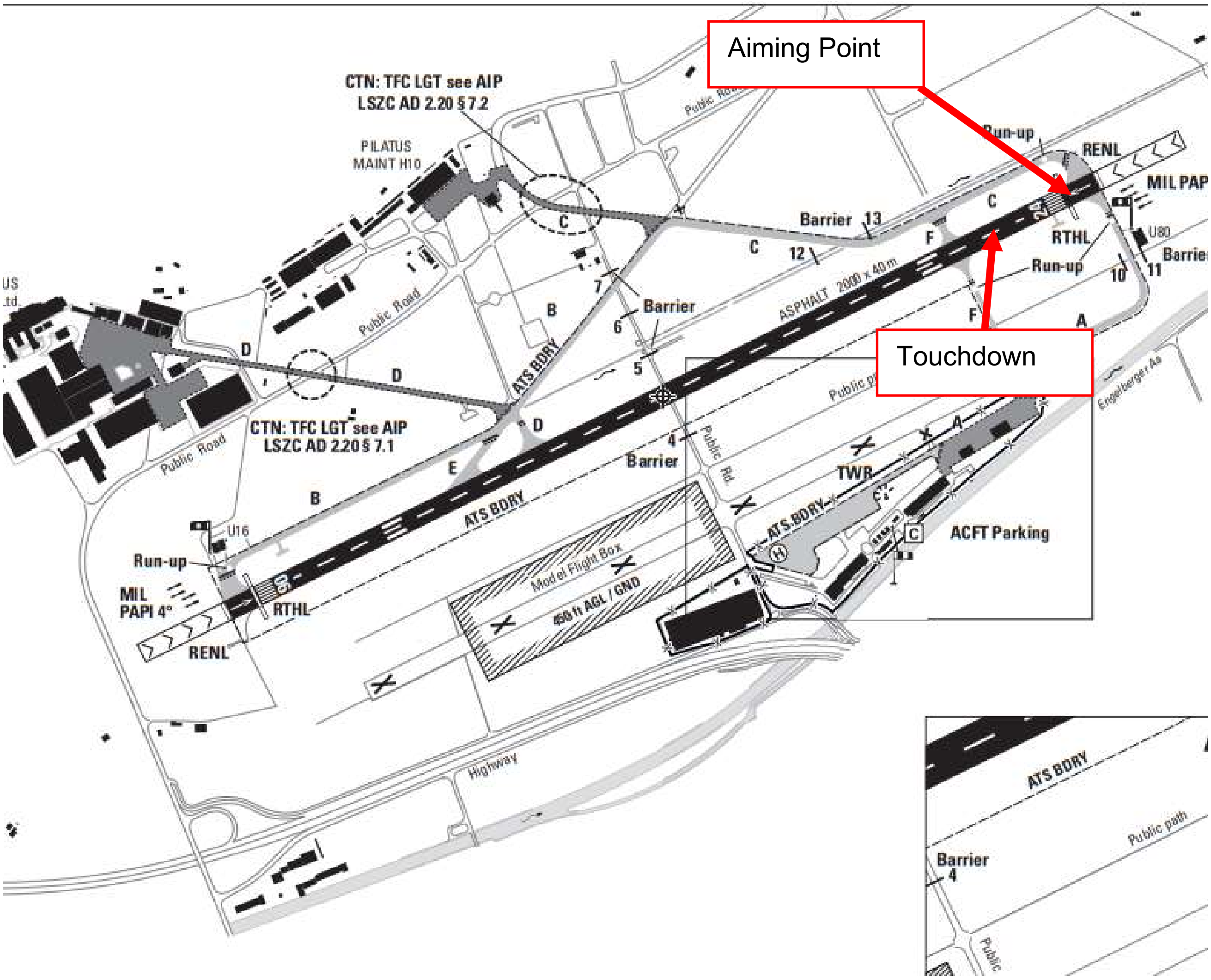


Figure 3: Aerodrome Chart of the Airfield Buochs

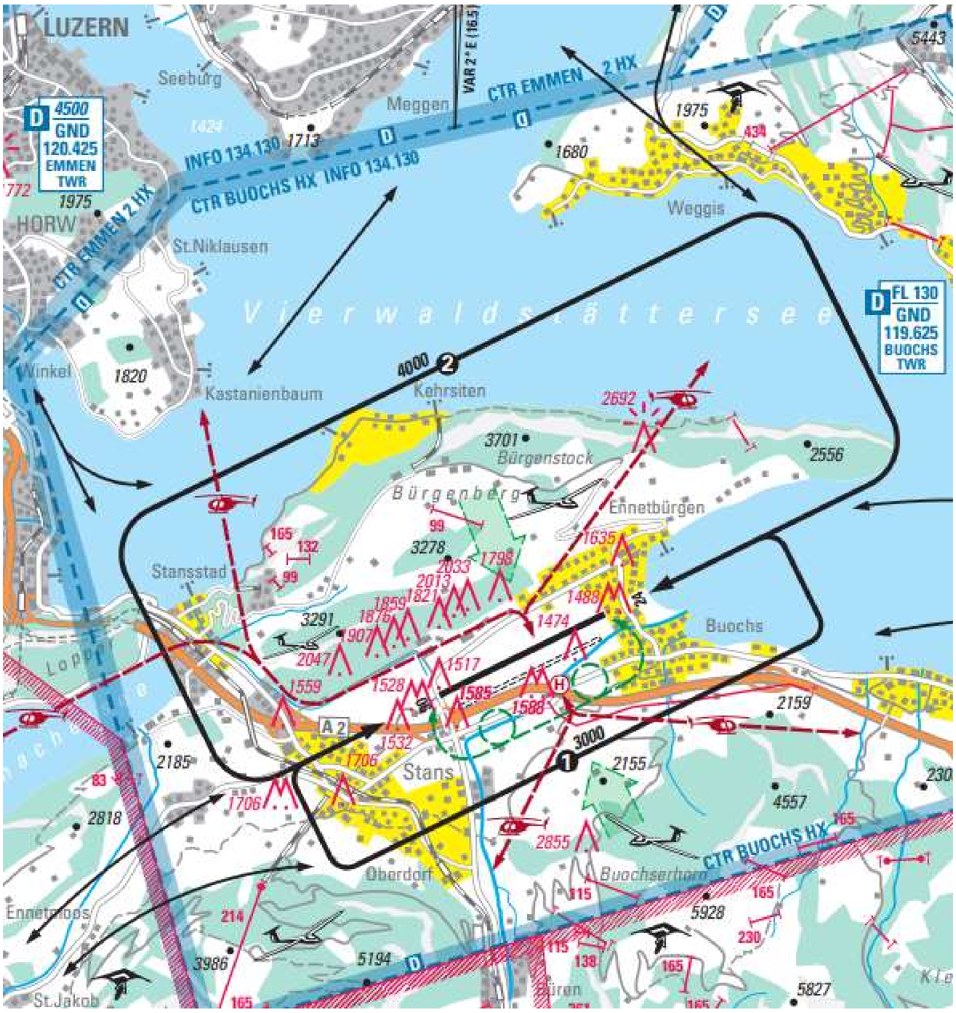


Figure 4: VAC of the Airfield Buochs

10.2 Theory for the learning video/Theory for Group 2

Congratulations on your first landing!

Before the second landing is performed, more theory is given. The individual parameters presented in the manual are now explained in more detail here.

Glide slope and vertical speed:

The glide angle is also referred as the optimal path, which is marked from the point of descent, until the aircraft touches down on the runway. This value is mostly given in degrees. An optimal glide slope during landing is 3°, however this value depends on the obstacles between the approach and the runway.

Another method which can be used to determine if one is climbing or descending is the vertical speed, given in feet per minute. This parameter indicates how fast the pilots is climbing or descending. Note, that the vertical speed indicator has a delay of about 3-5 seconds.
For the landing approach, a vertical speed of 500 ft/min should be maintained.

Velocity:

The approach speed is essential during landing and one of the most important parameters for a safe landing. The approach speed of 63 knots should be maintained throughout the landing. To lose speed, pull the control horn. To increase speed, push the control horn. Care should be taken not to fly too slow or too fast. Both configurations can have a negative effect on the landing.

What is a Stall?

If you pull the control horn for too long, you increase the risk of getting into a stall. A stall is when the airflow detaches from the wings and lift will be greatly reduced, making the aircraft uncontrollable.

What happens if the approach is too fast?

If you fly the approach with an increased speed, the kinetic energy cannot dissipate fast enough, when touching down. The forces cannot be absorbed by the wheels, which can lead to an accident.

The Aiming Point:
Now let’s have a look at the aiming point.

The Aiming Point is a point on the runway that is aimed at by the pilot during the approach. The aiming point should not be confused with the touchdown zone.

If during the approach you have the impression that you will land after the aiming point, pull back the throttle and push the control horn slightly forward.

Conversely, if during the approach you have the impression of landing short of the aiming point, then push the throttle forward and pull slightly back on the control horn.

During these actions, the speed should still remain the same.

The Trim control:
To keep the aircraft always in the same attitude without excessive force on the control horn, there is a trim function. If you press it slightly forward while you are on approach, the aircraft will be stabilized in the desired position.

Pedals
The pedals are mainly used during take-off and landing to keep the aircraft straight in crosswind conditions. As soon as you touch down on the ground, you no longer need the control horn, only the pedals.

Flaps settings:
The flaps are set during approach and take-off. There are 3 configurations. It is important to note that as soon as a flap is set, the nose of the aircraft automatically pulls down slightly.

The Flare:
The section just before touchdown is called flaring. As soon as you are above the aiming point, pull the throttle all the way back and at the same time pull slightly on the control horn. Focus on the end of the runway.

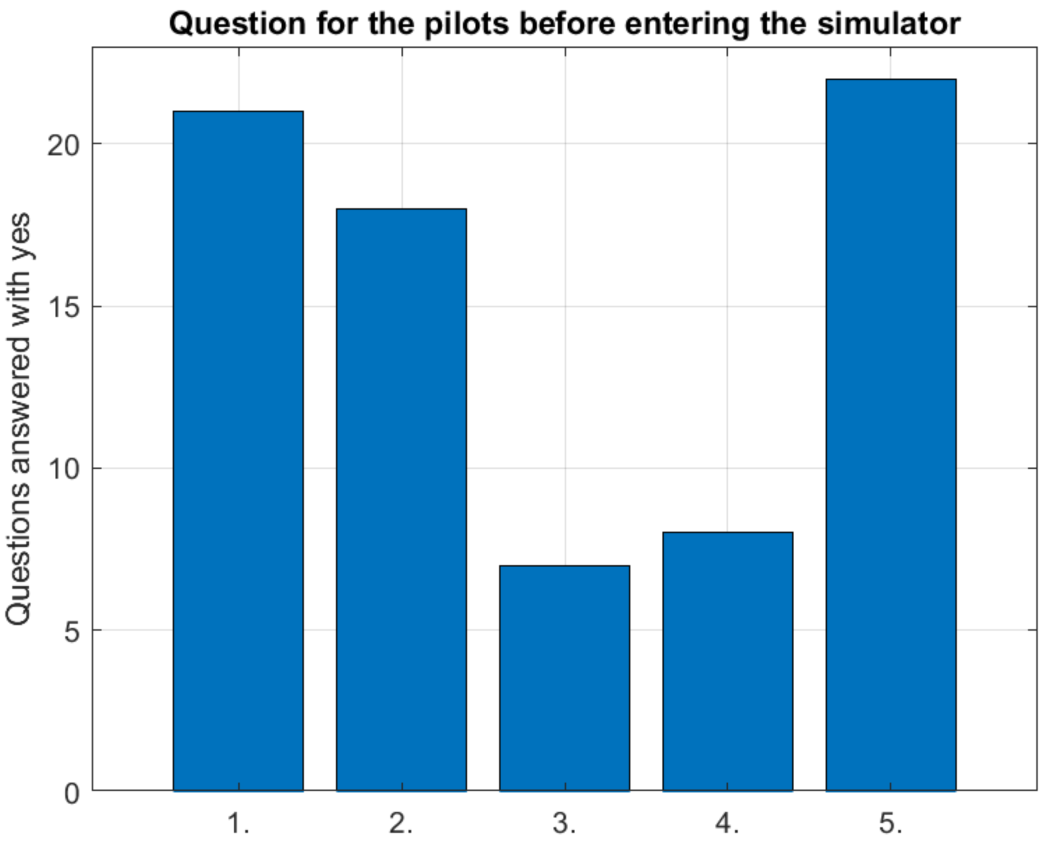
Summary of the most important characteristic for landing in the simulator
Now let’s sum up what you should remember for the approach and landing.

1) The approach speed of **63 knots** shall be maintained.
2) The **aiming point should** be targeted most of the time.
3) The vertical speed of **500 feet per minute** should be maintained. Experienced pilots land intuitively at this speed.
4) The flaps are set during landing and flared just before touchdown.
5) The pedals are not needed for this simulation.

10.3 Questionnaires

10.3.1 Questions for groups F1_Video and F1_Theory_Baseline

1. Did you read the manual? (Yes=1 / No=0)
2. Was the manual helpful? (Yes=1 / No=0)
3. Did you feel prepared enough for the simulator with the manual? (Yes=1 / No=0)
4. Did you feel confident to perform a good landing with the theory given? (Yes=1 / No=0)
5. Was anything missing (knowledge wise etc.)? (Yes=1 / No=0)



10.3.2 Questionnaire for Group F2_Video

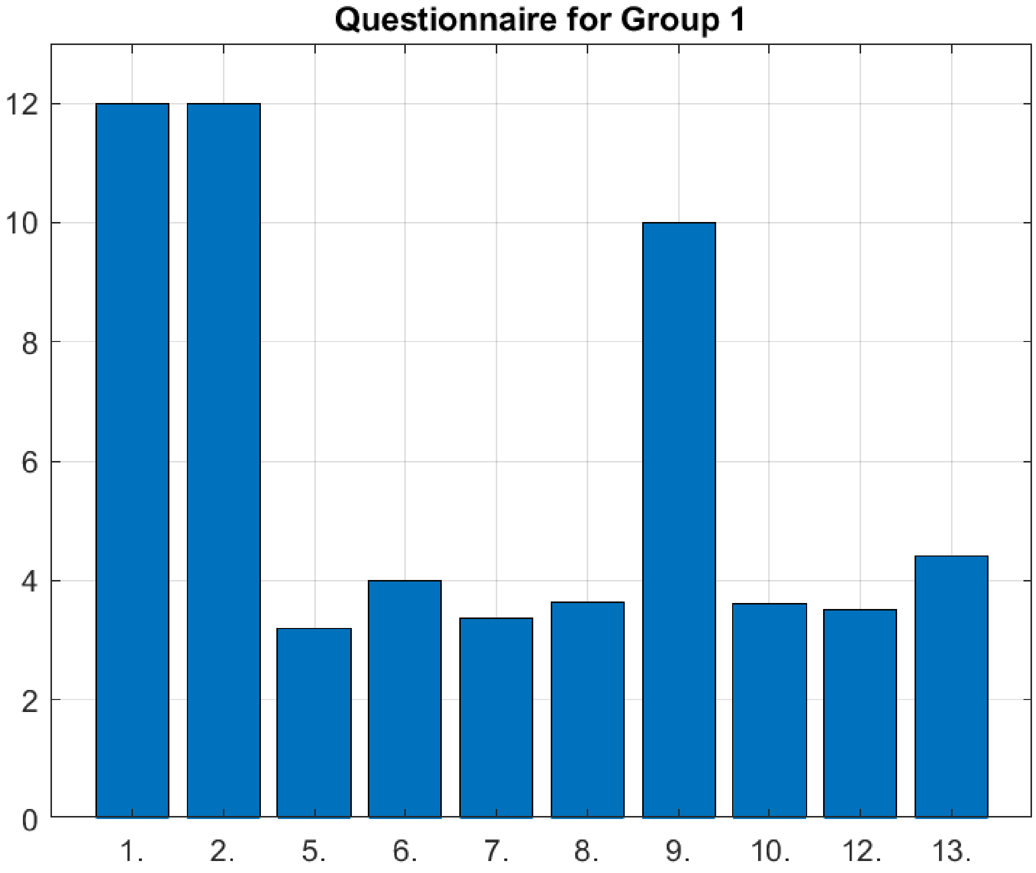
Question for the pilots who have seen the video - And after the 2nd Landing

1. Was the theory helpful? (Yes=1 / No=0)
2. Do you feel more prepared for your next flight? (Yes=1 / No=0)
3. Which part is most useful for the learning process?
4. Which part did you rewind more often before entering the simulator?
5. How confident you feel about your next landing? (1-5)

After the 2nd Landing

6. What has changes since the last and this landing?
7. Please rate the landing after reading the textual theory? (1-5)
8. Did you feel more confident during this session? (1-5)
9. Was something missing in the theory? (Yes=1 / No=0)

10. How high was your workload/stress level during landing? (1-5)
11. How do you estimate your proportion of checking the aiming point … % and Instrumentes …%
12. How clear was your plan for the second approach? (1 roughly-5 all the necessary steps were clear)
13. Was it clear, where and when to focus your attention to. (1-5)"



10.3.3 Questionnaire for Group F2_Theory_Baseline

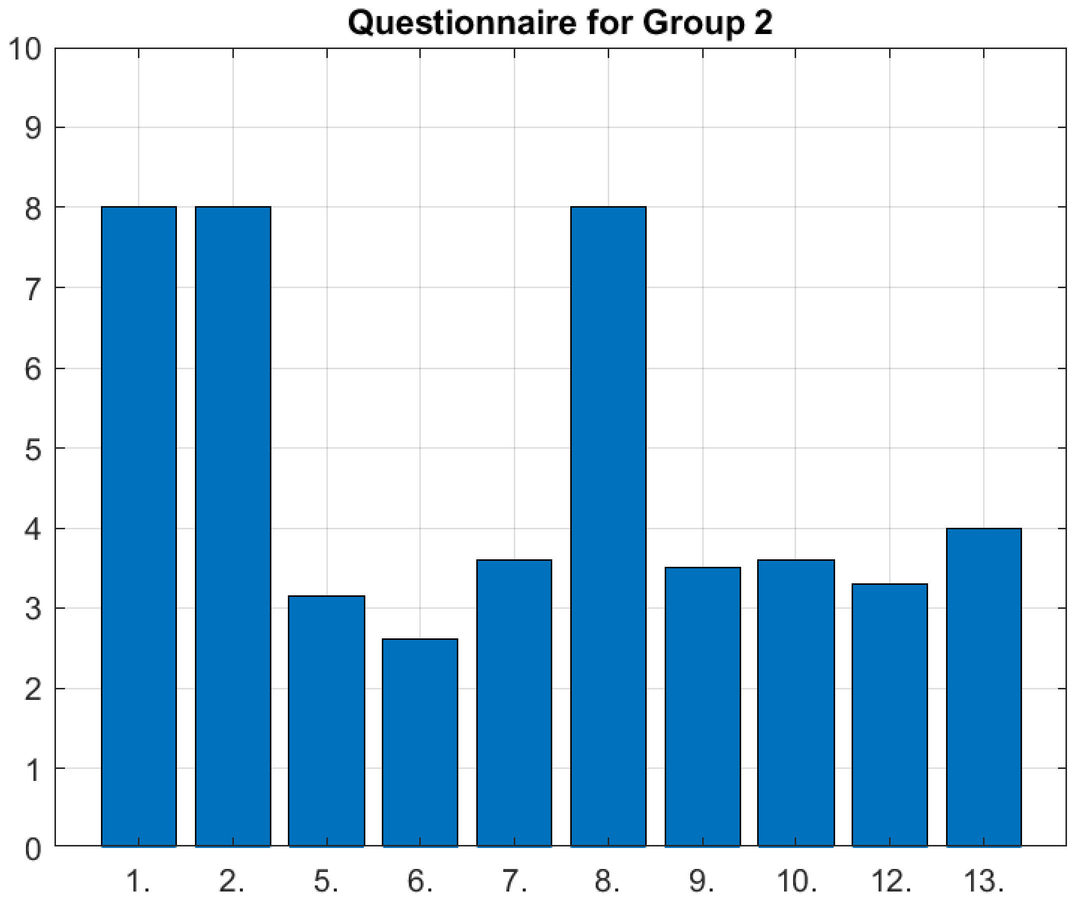
Question for the pilots after reading the textual theory-And after the 2nd Landing

1. Was the theory helpful? (Yes=1 / No=0)
2. Do you feel more prepared for your next flight? (Yes=1 / No=0)
3. Which part is most useful for the learning process?
4. Which part did you re-read more often before entering the simulator?
5. How confident you feel about your next landing? (1-5)

After the 2nd Landing

6. What has changes since the last and this landing? (1-5)
7. Please rate your landing before and after textual theory? (1-5)
8. Did you feel more confident during this session? (1-5)
9. Was something missing in the theory? (Yes=1 / No=0)

10. How high was your workload/stress level during landing? (1-5)
11. How do you estimate your proportion of checking the aiming point … % and Instrumentes …%
12. How clear was your plan for the second approach? (1 roughly-5 all the necessary steps were clear)
13. Was it clear, where and when to focus your attention to. (1-5)"



10.4 POD Calculation

The final has been extended from 1.225 nautical miles to a route $[s]$ of 2.2 nautical miles (4074 meters). As the approach speed $[v]$ is 63 knots (32 m/s), the first step is to calculate the time $[t]$.

1) $t = \frac{s}{v} = \frac{4074m}{\frac{32m}{s}} = 125.7s = 2.09min$

The next step is calculating the amount of altitude $[\Delta h]$ the pilot can lose, given a vertical speed $[v_v]$ of 500 feet per minute and a descent time of 2.09 minutes.

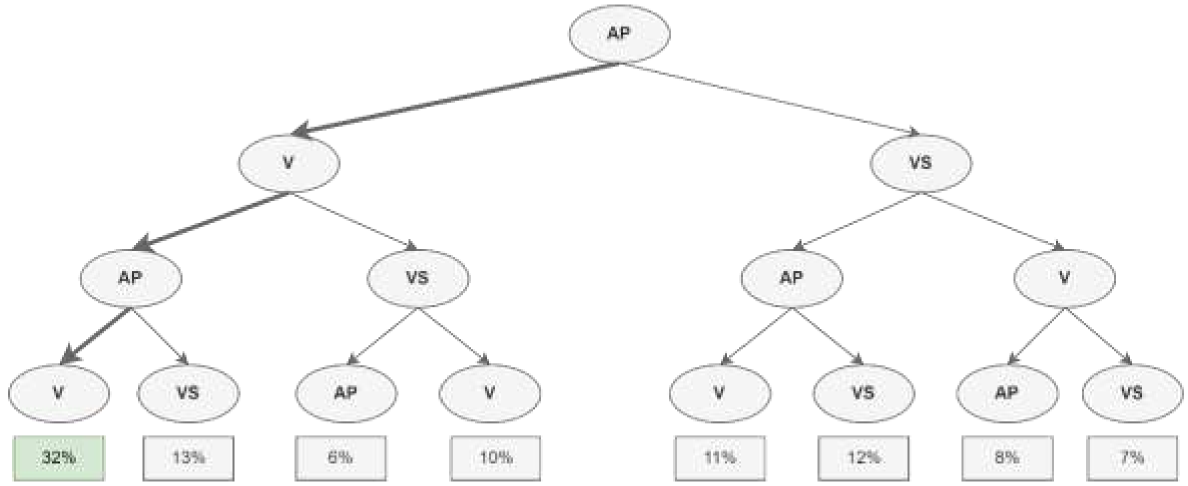
2) $\Delta h = t * v_v = 2.09min * \frac{500ft}{min} = 1047.5ft$

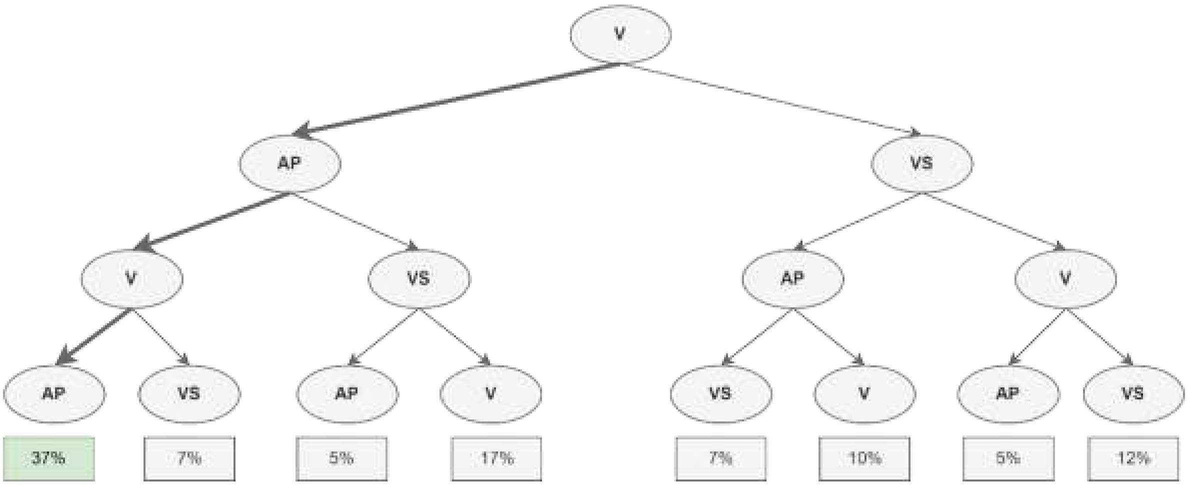
The last step was to add these 1047.5 feet to the altitude of the airfield and to obtain the new circuit altitude [CA], POD.

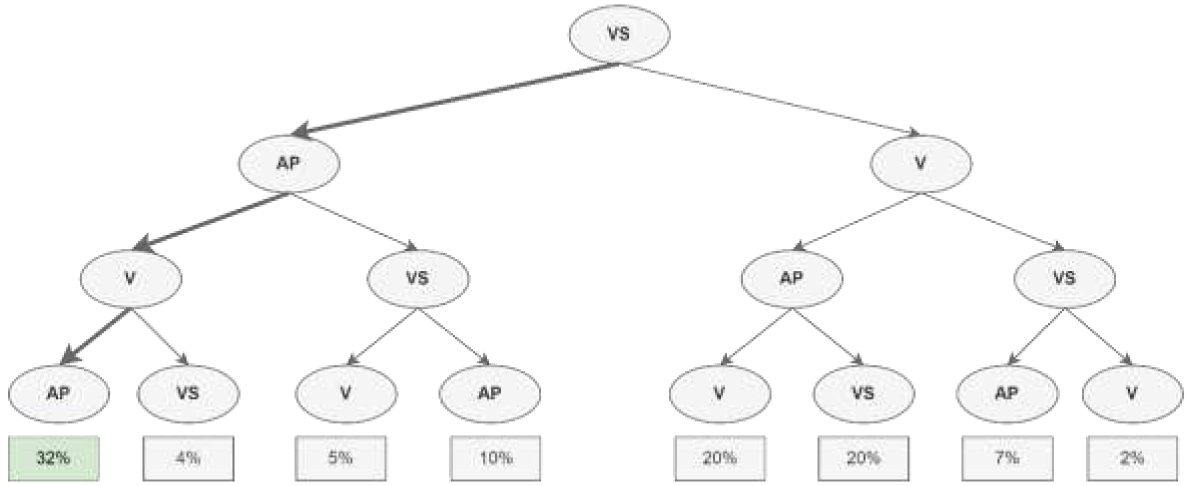
3) $CA = 1475ft + 1047ft = 2522ft$

10.5 Scanning pattern

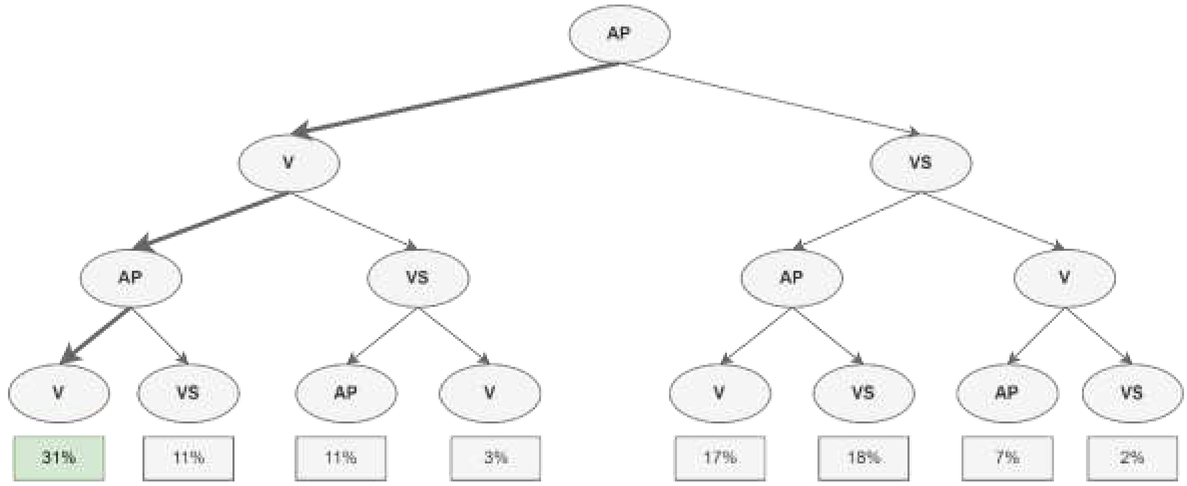
10.5.1 Scanning pattern of F1_Video

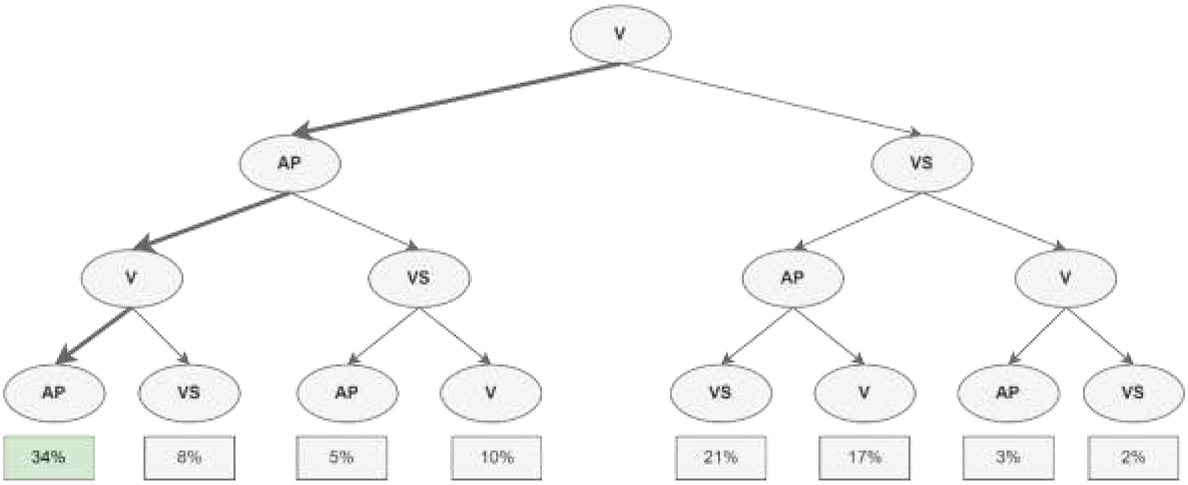


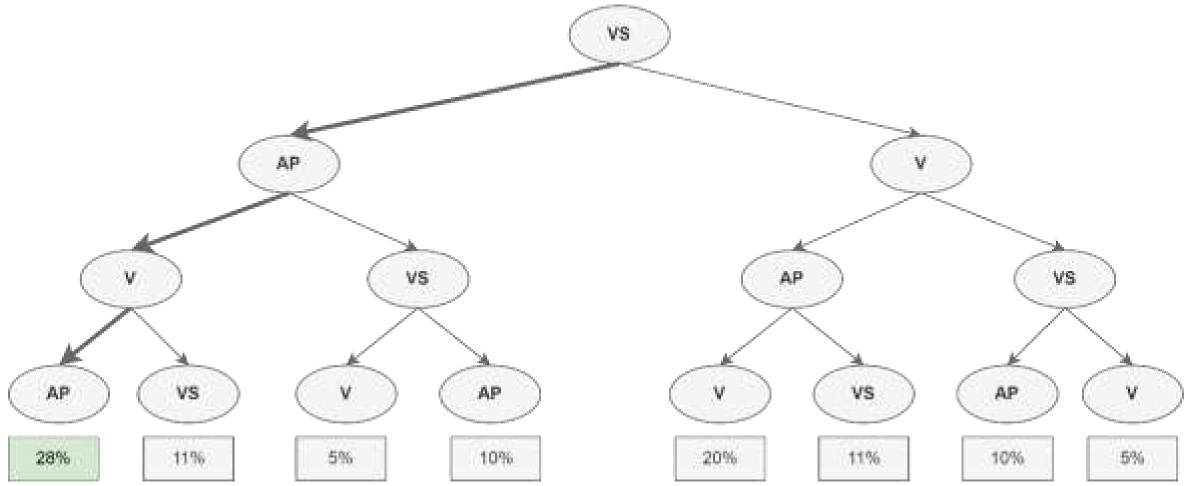




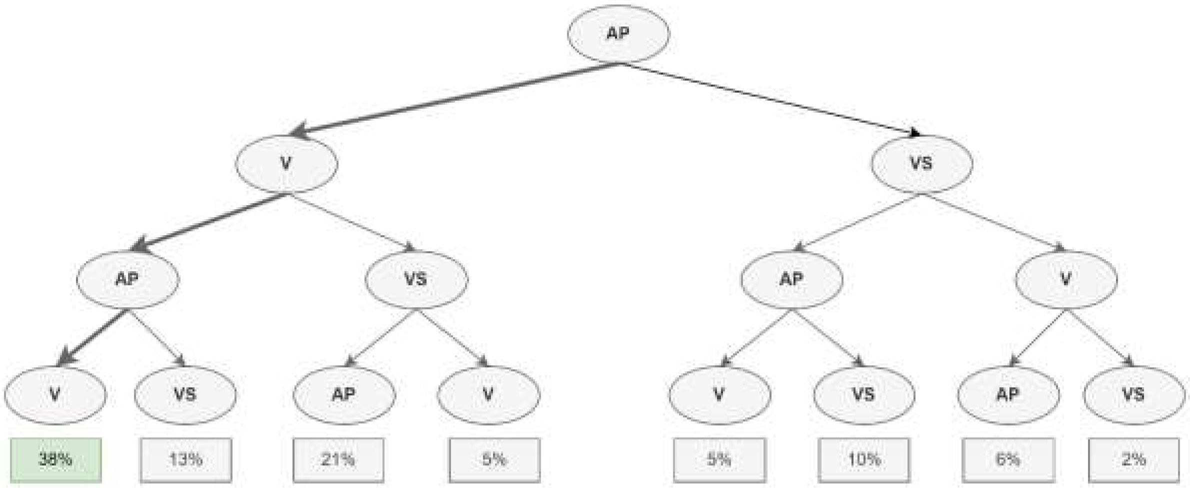
10.5.2 Scanning pattern of F1_Theory_Baseline

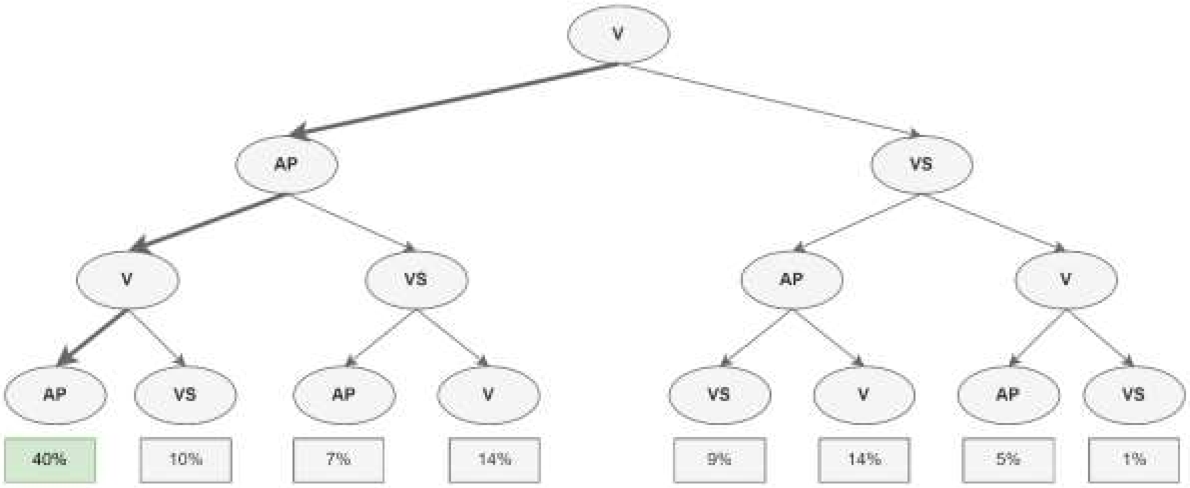


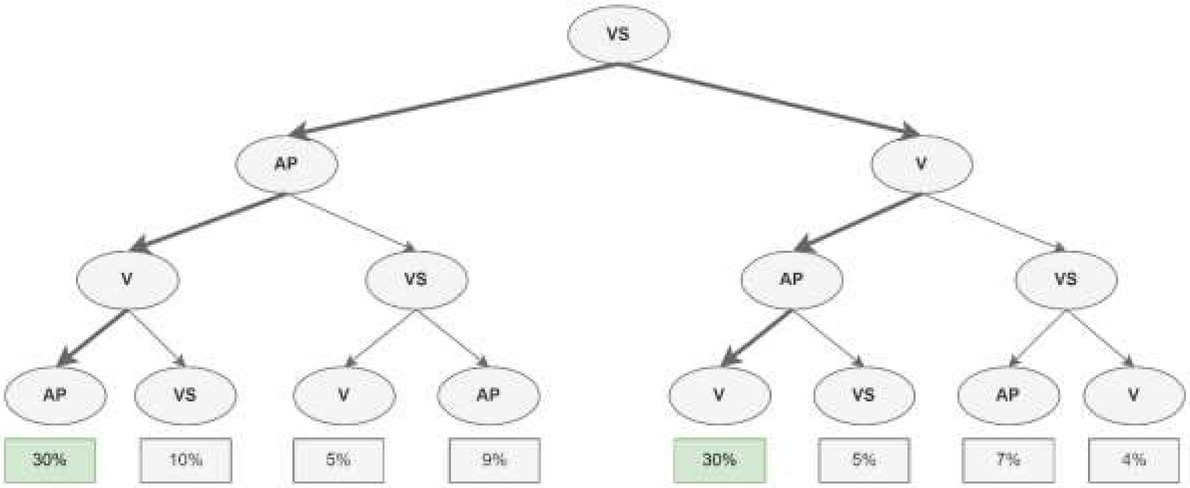




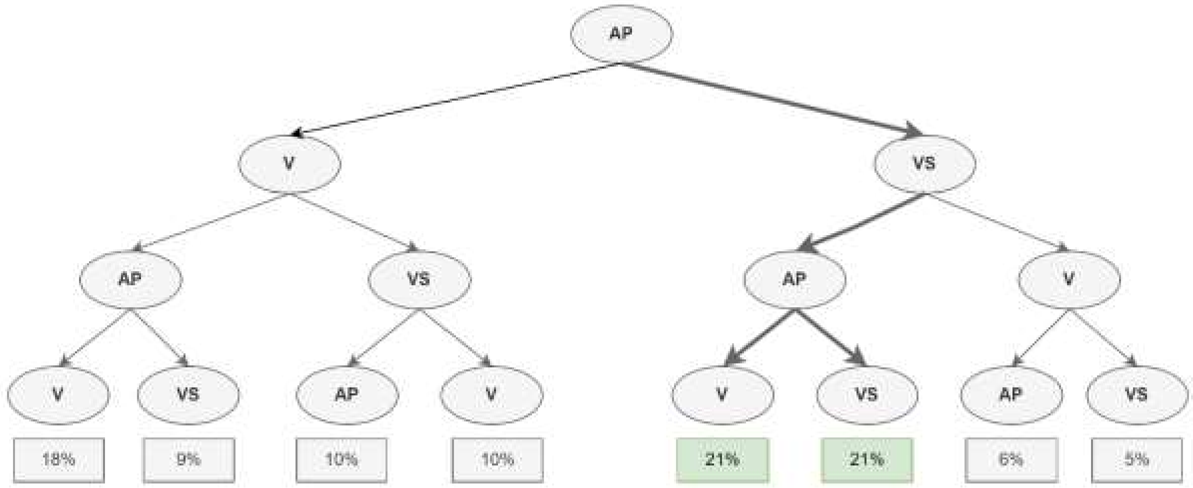
10.5.3 Scanning pattern of F2_Video

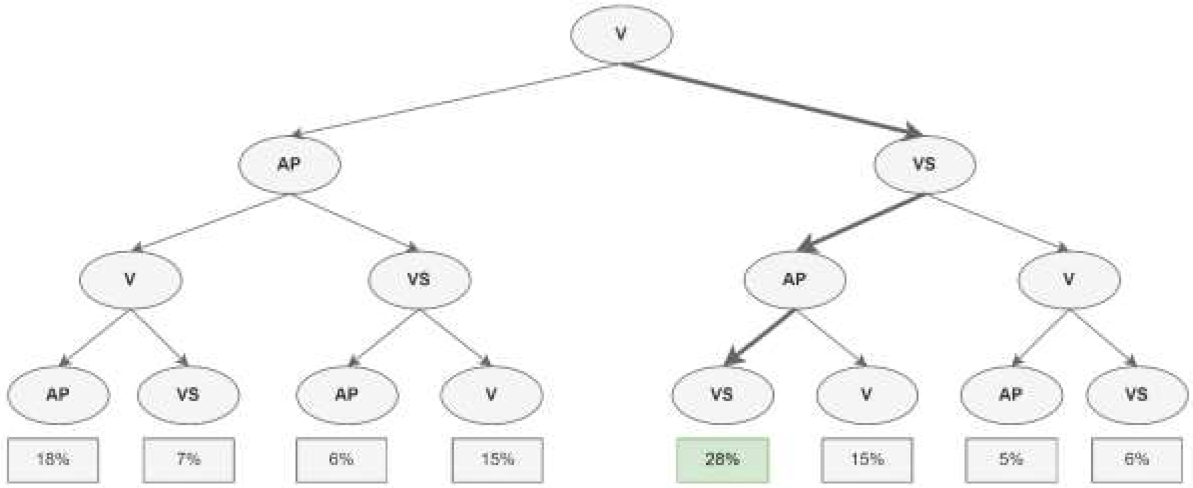


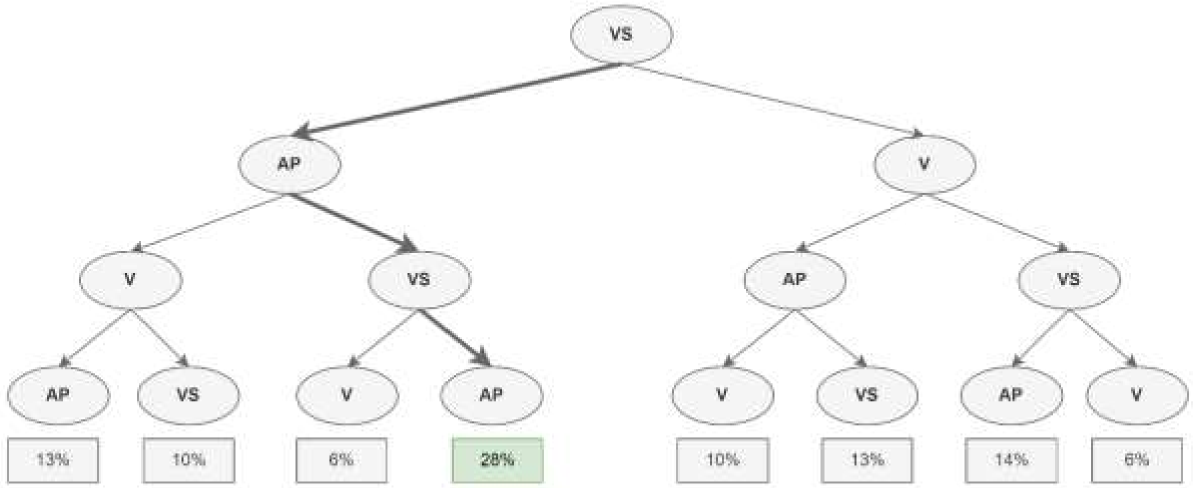




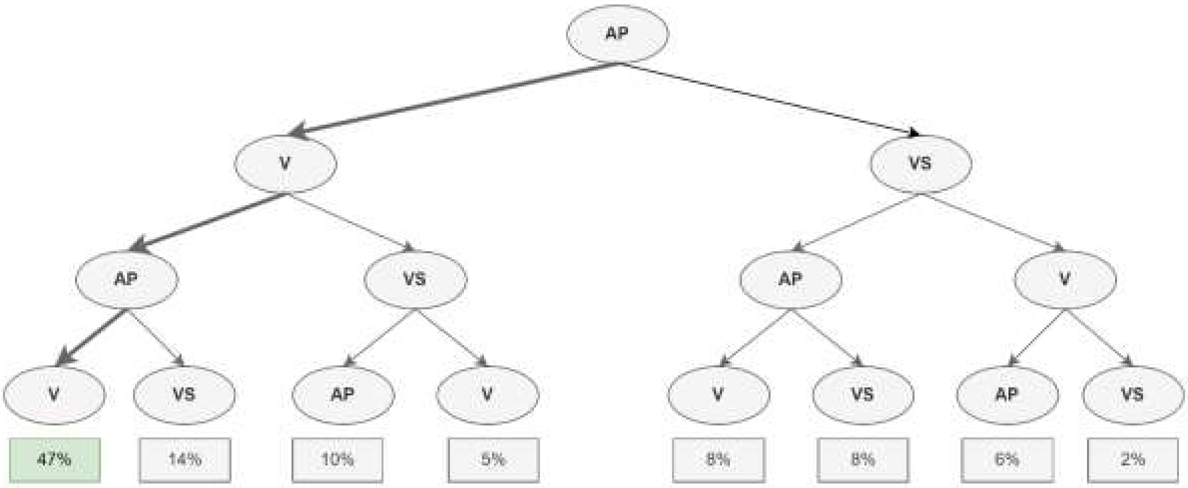
10.5.4 Scanning pattern of F2_Theory_Baseline

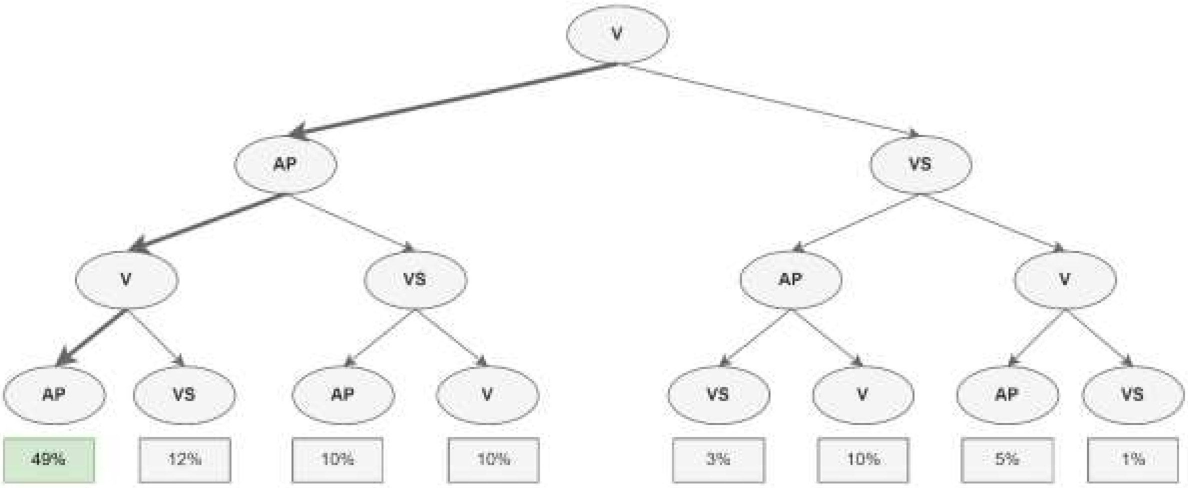


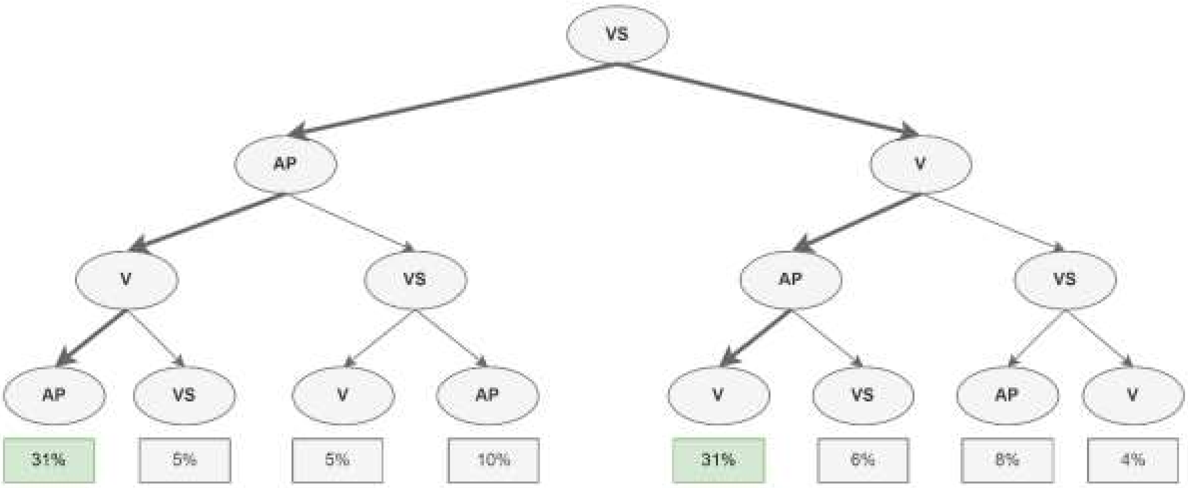




10.5.5 Scanning pattern of an Expert

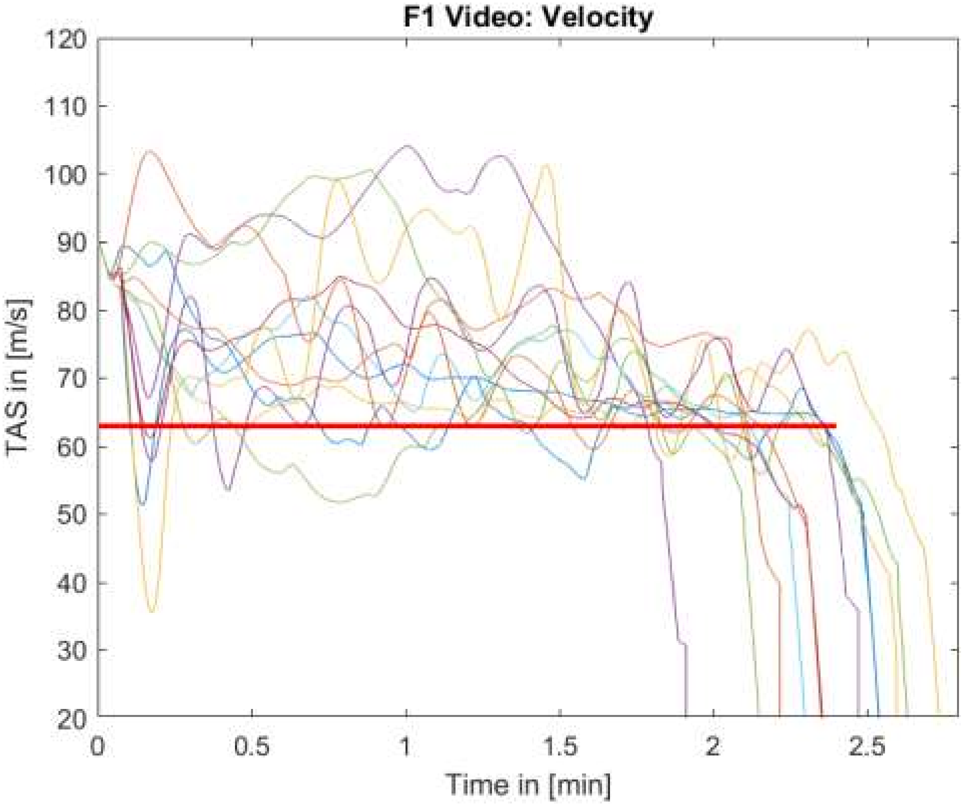


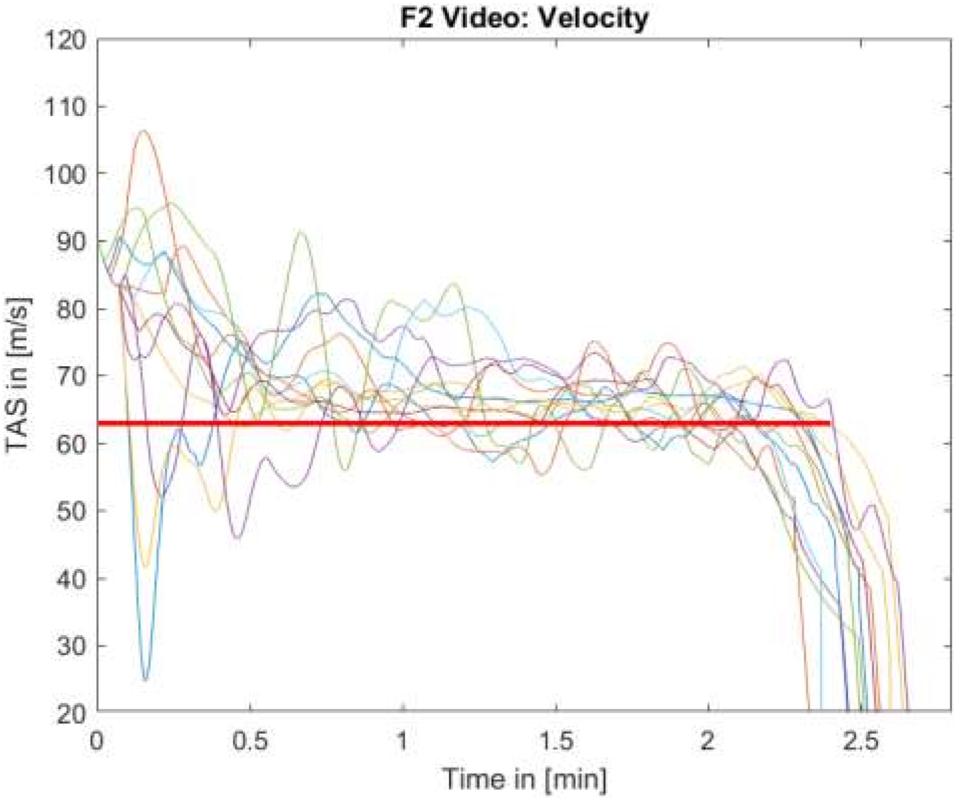


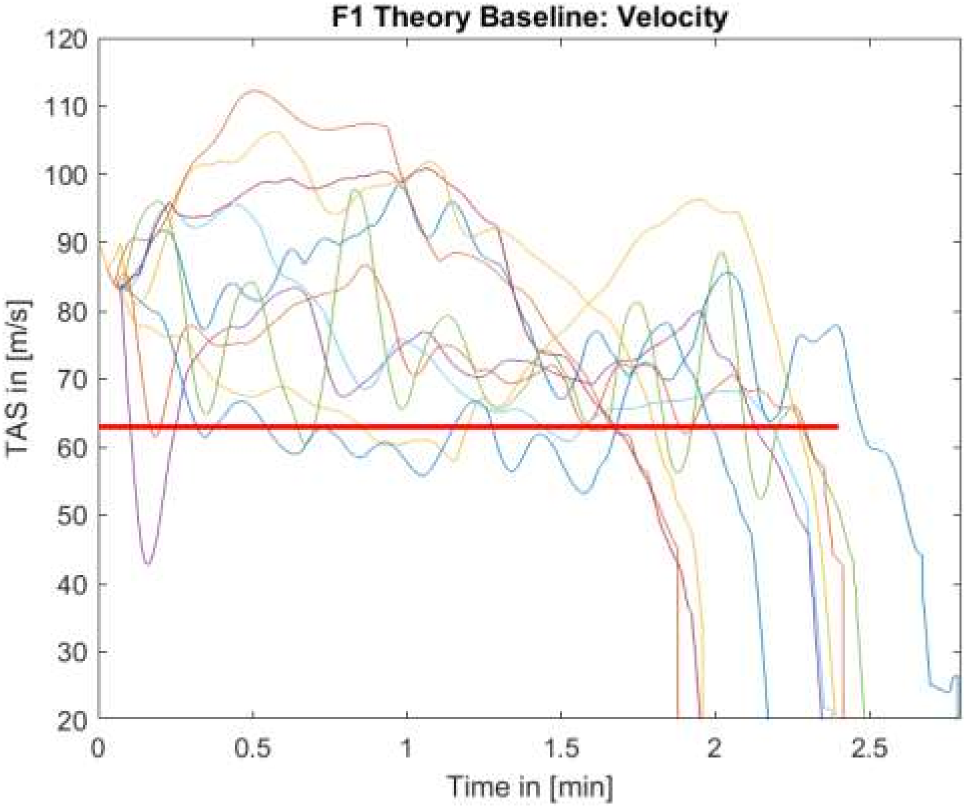


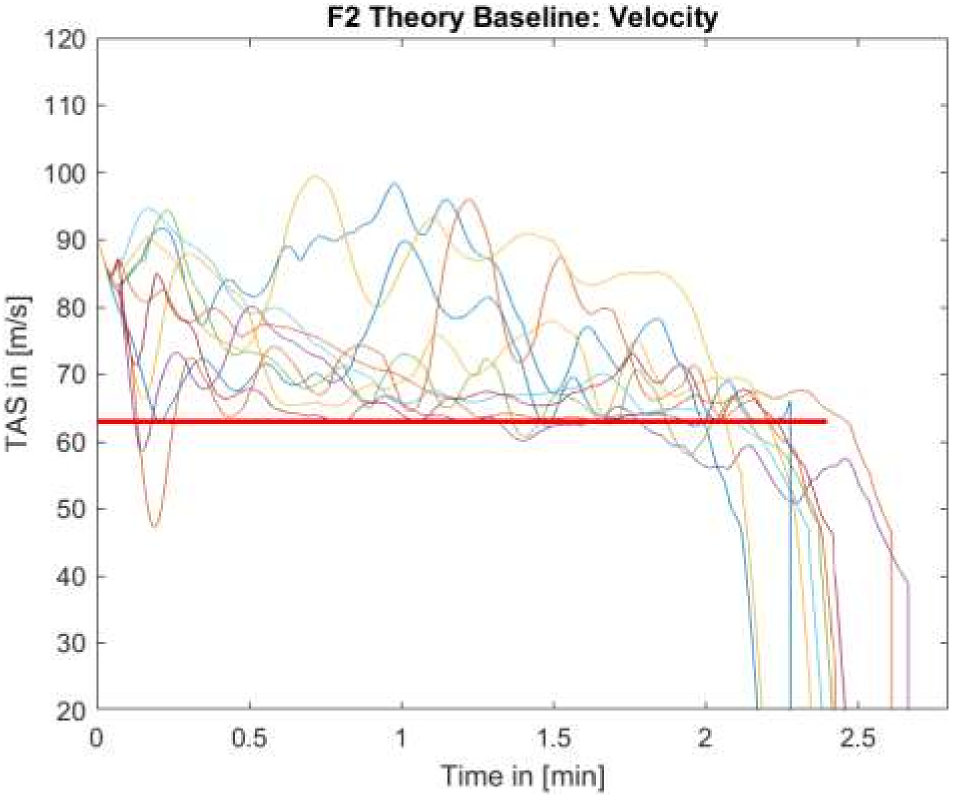
10.6 Variables from the simulator

10.6.1 Velocity

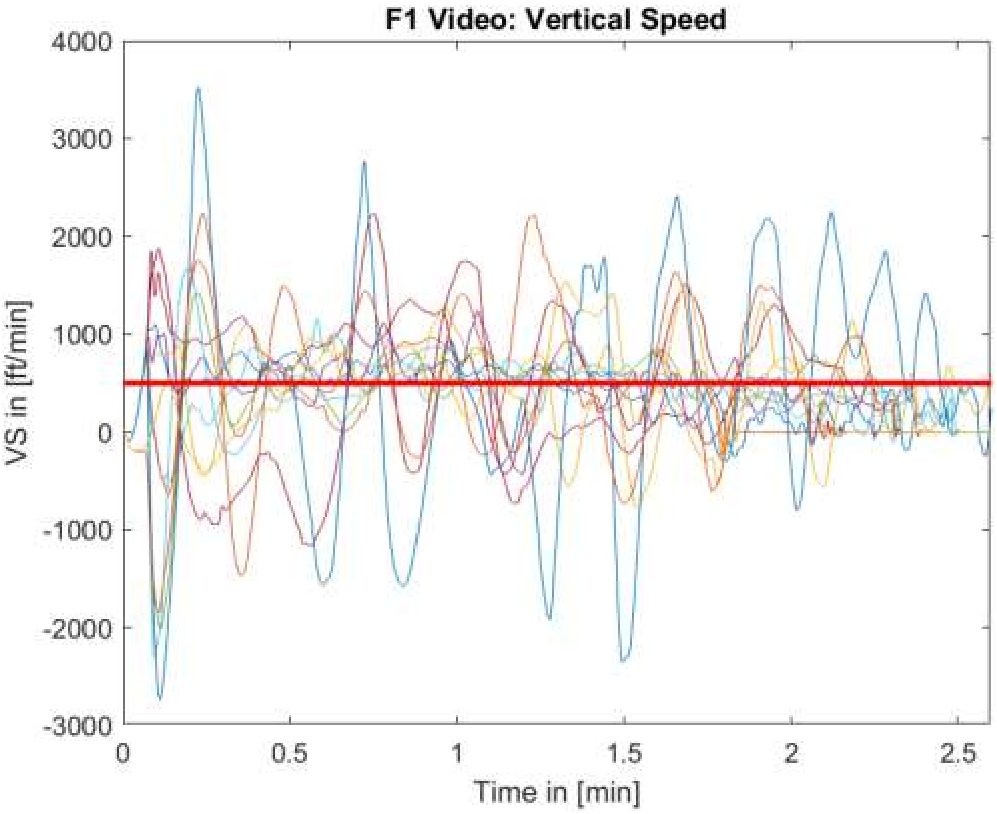


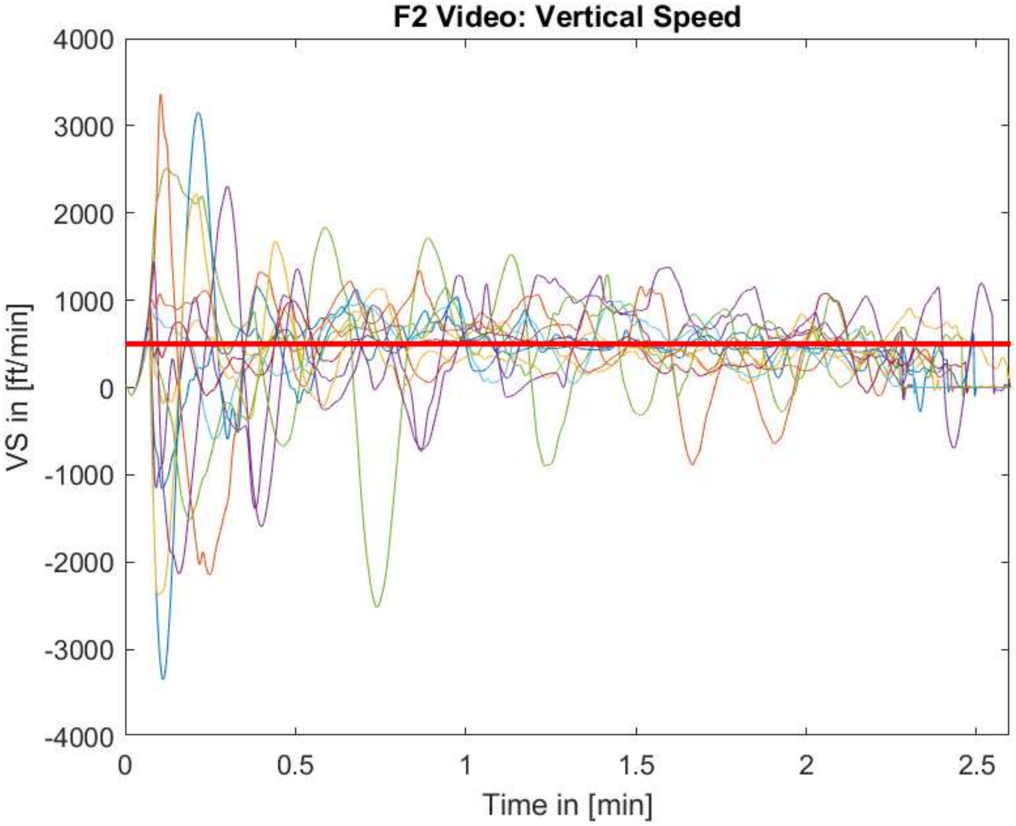


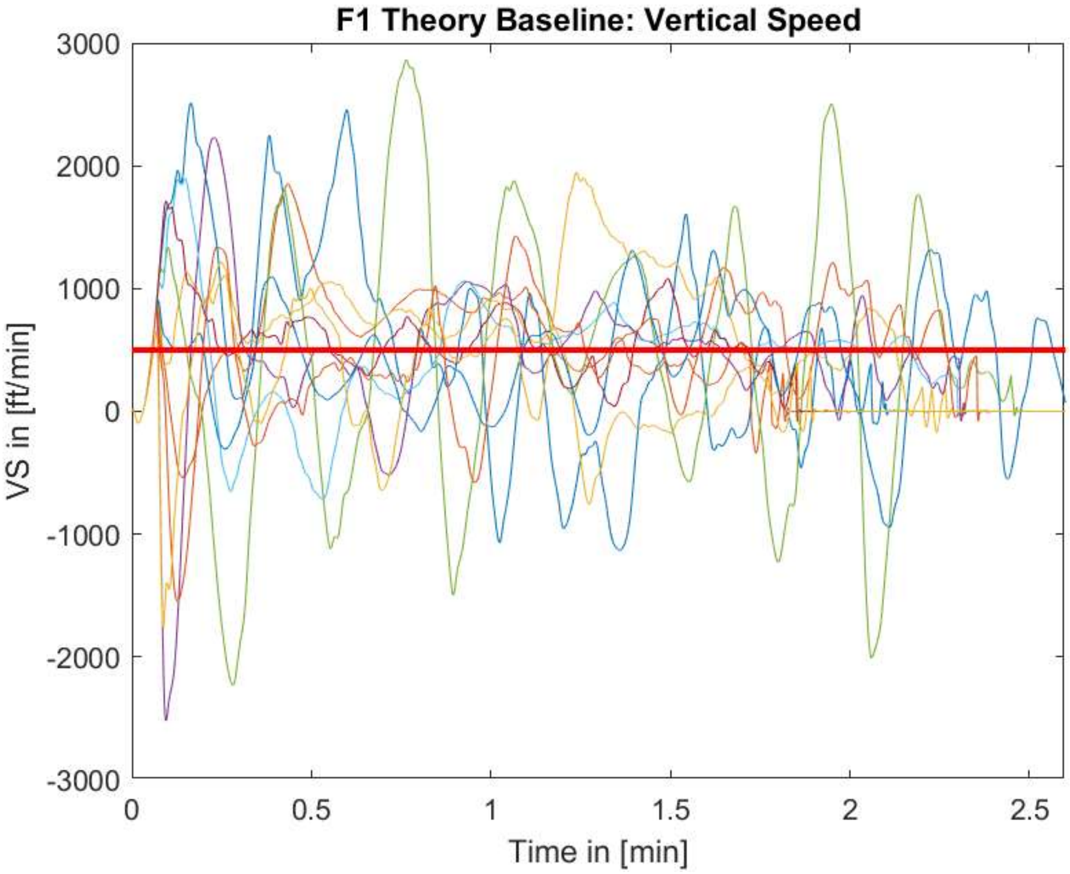

F1 Theory Baseline: Velocity
TAS in [m/s]
120
110
100
90
80
70
60
50
40
30
20
0
0.5
1
1.5
2
2.5
Time in [min]

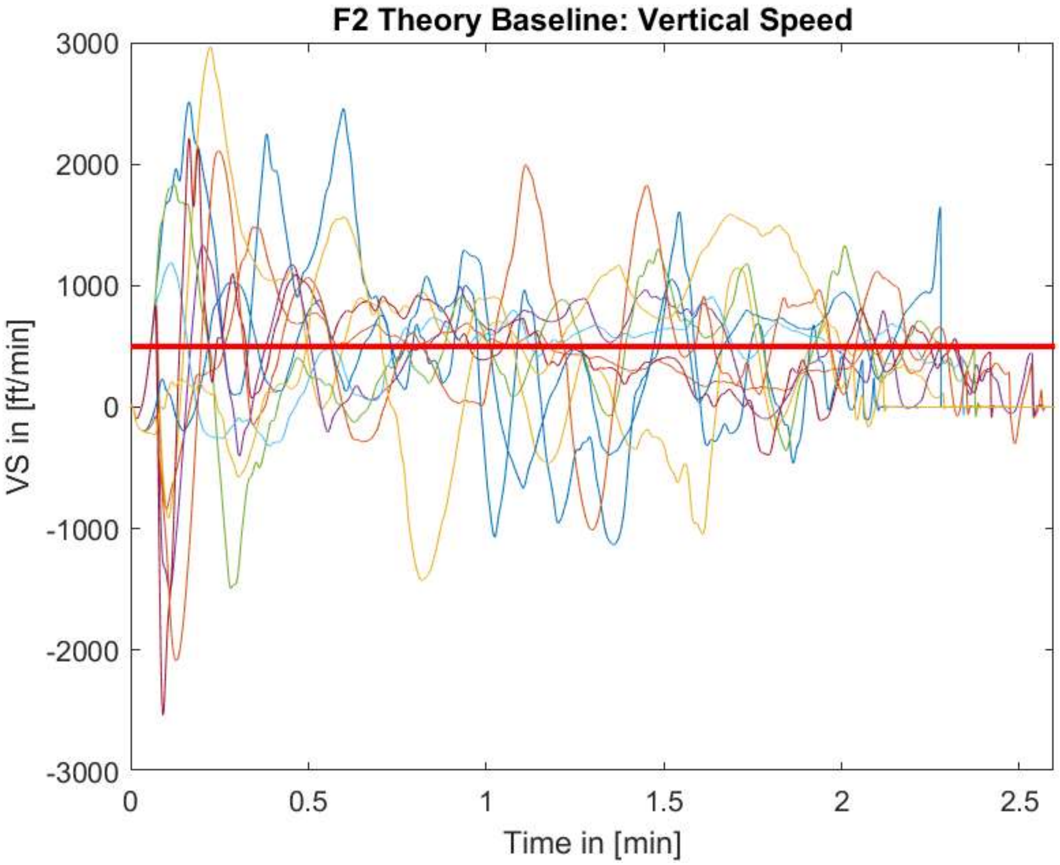

F2 Theory Baseline: Velocity
TAS in [m/s]
120
110
100
90
80
70
60
50
40
30
20
0
0.5
1
1.5
2
2.5
Time in [min]

10.6.2 Vertical Speed

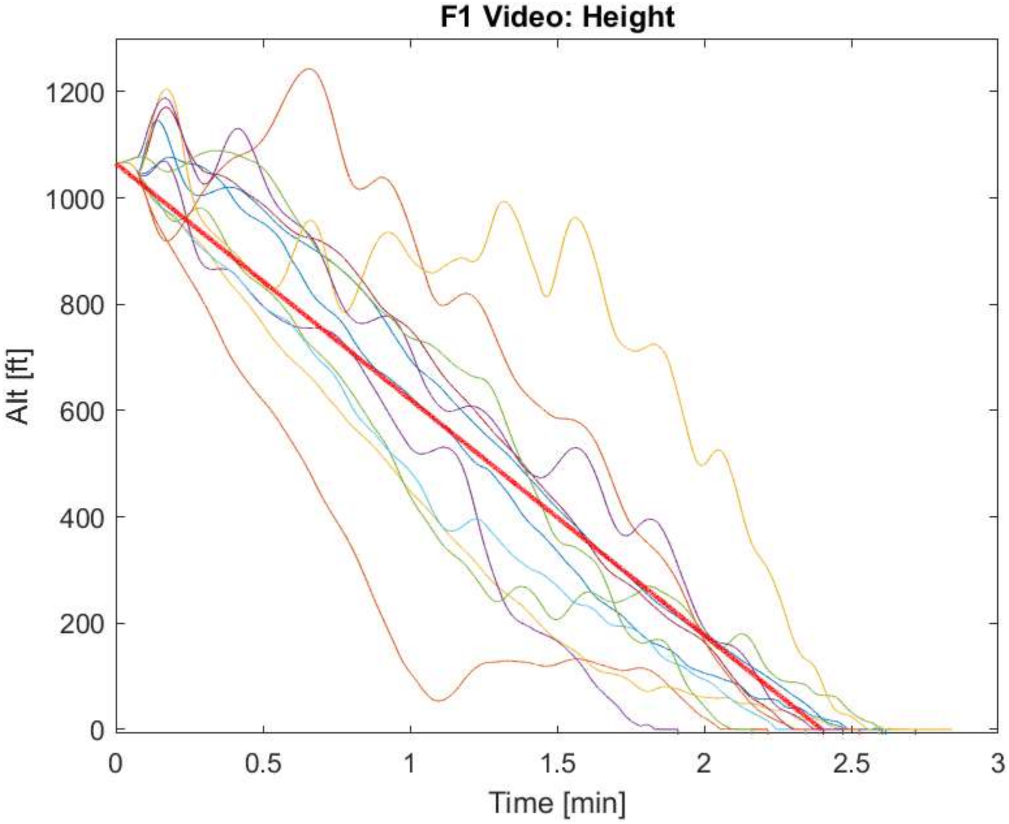





F1 Theory Baseline: Vertical Speed
3000
2000
1000
0
-1000
-2000
-3000
VS in [ft/min]
0
0.5
1
1.5
2
2.5
Time in [min]


F2 Theory Baseline: Vertical Speed
3000
2000
1000
0
-1000
-2000
-3000
VS in [ft/min]
0
0.5
1
1.5
2
2.5
Time in [min]

10.6.3 Height


F1 Video: Height
Alt [ft]
Time [min]
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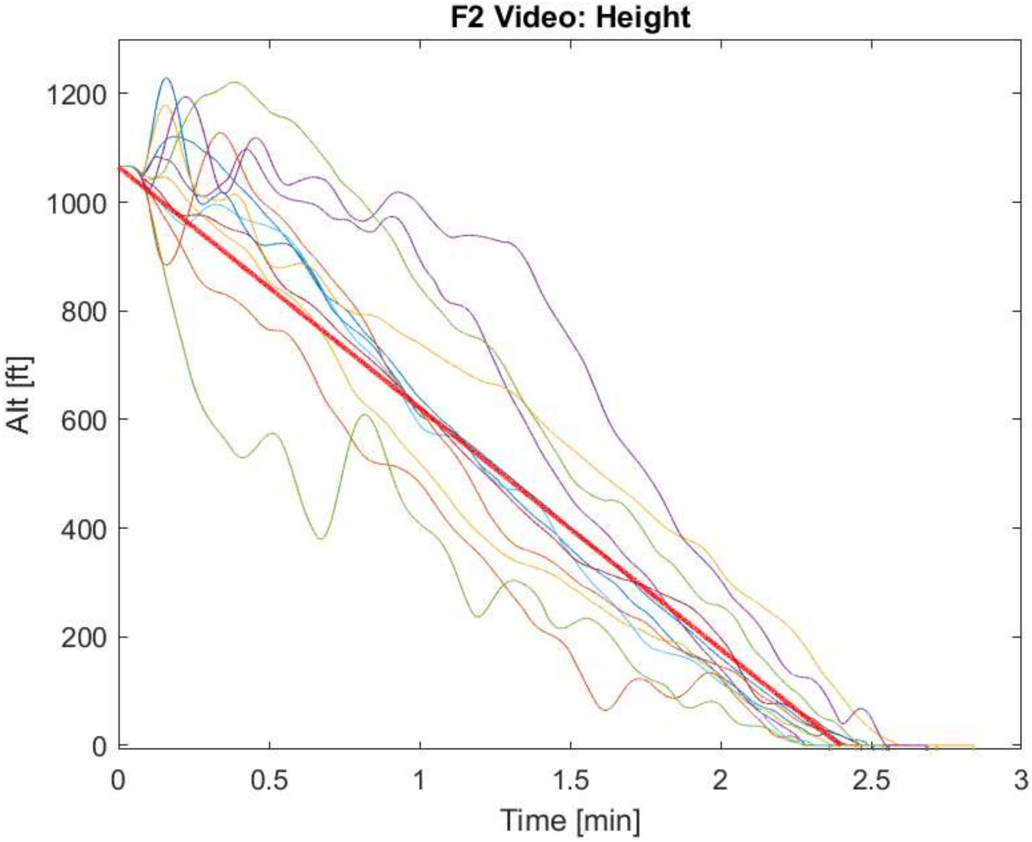
200
400
600
800
1000
1200
0
0.5
1
1.5
2
2.5
3


F2 Video: Height
Alt [ft]
Time [min]
0
200
400
600
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1200
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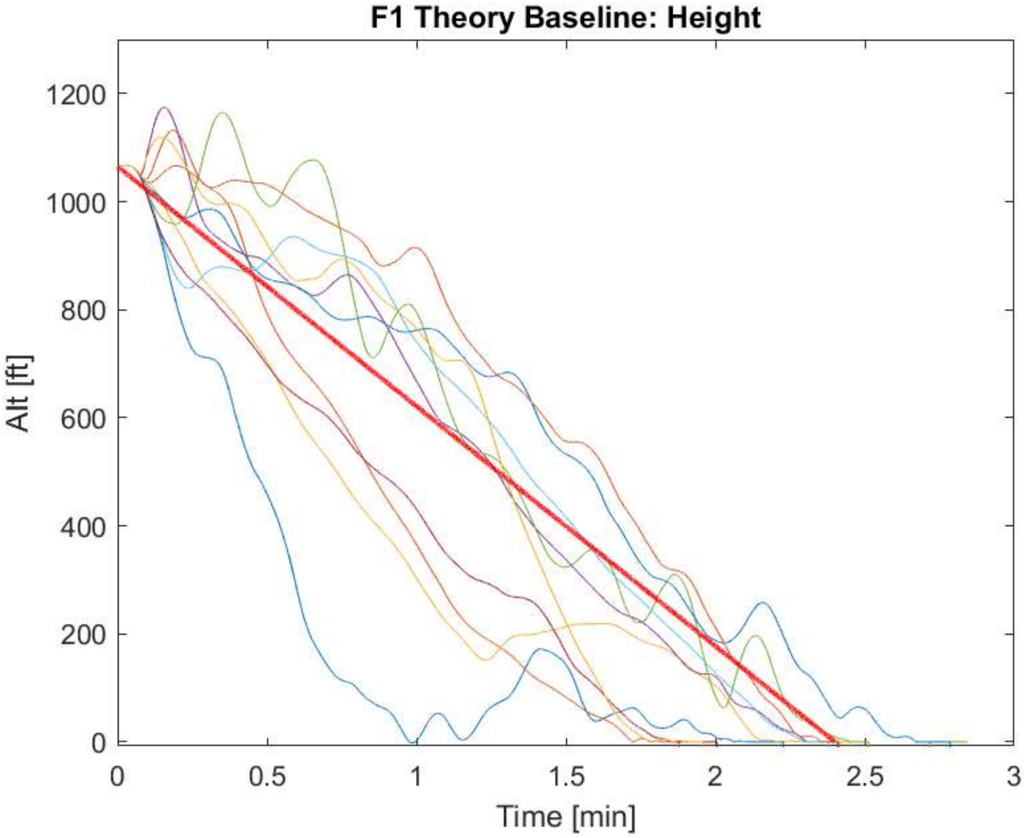
0.5
1
1.5
2
2.5
3


F1 Theory Baseline: Height
Alt [ft]
1200
1000
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Time [min]
0
0.5
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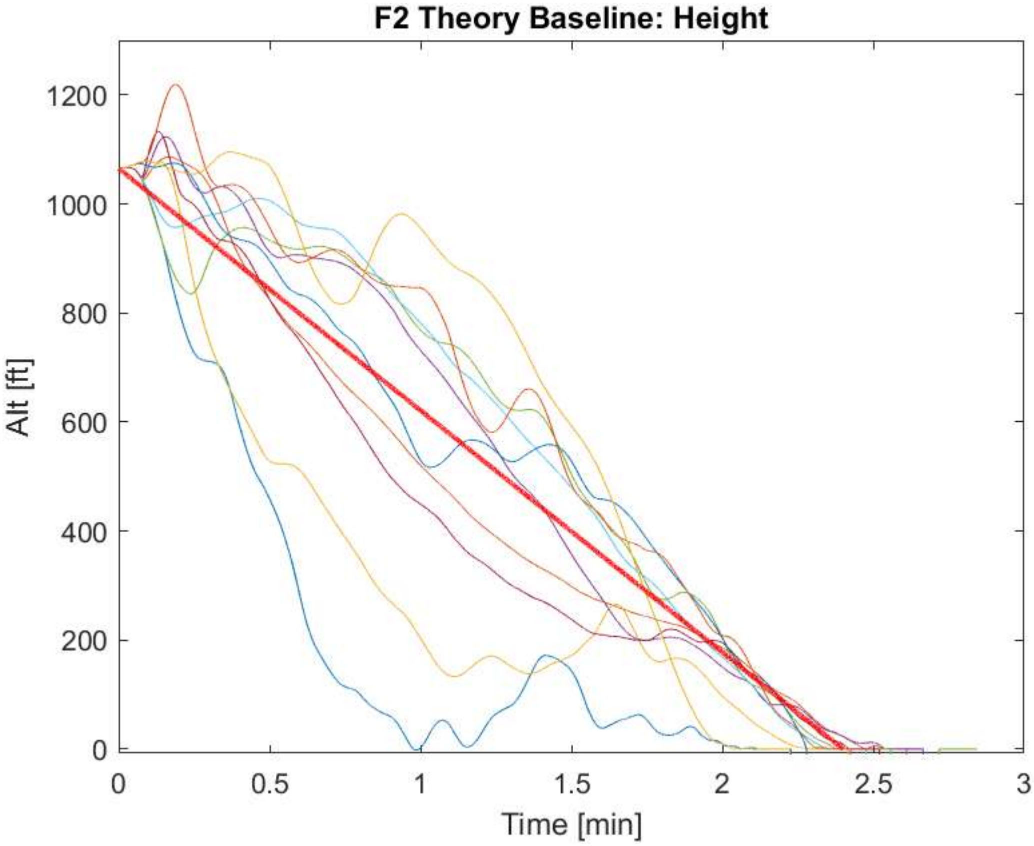
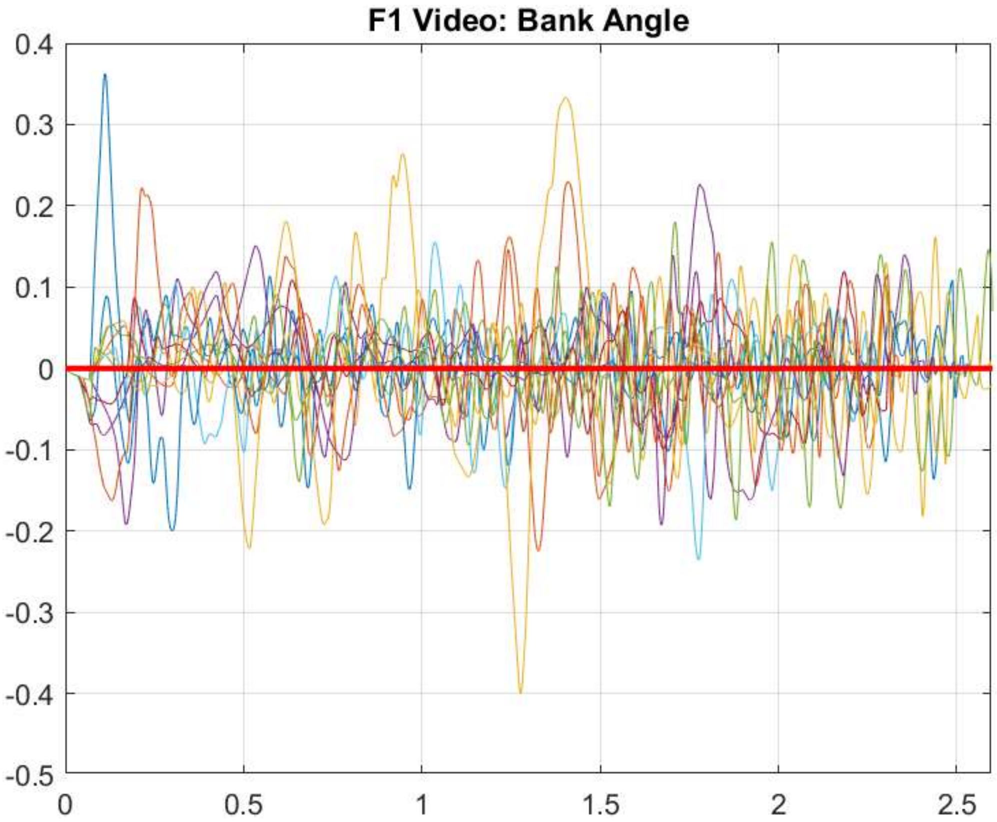
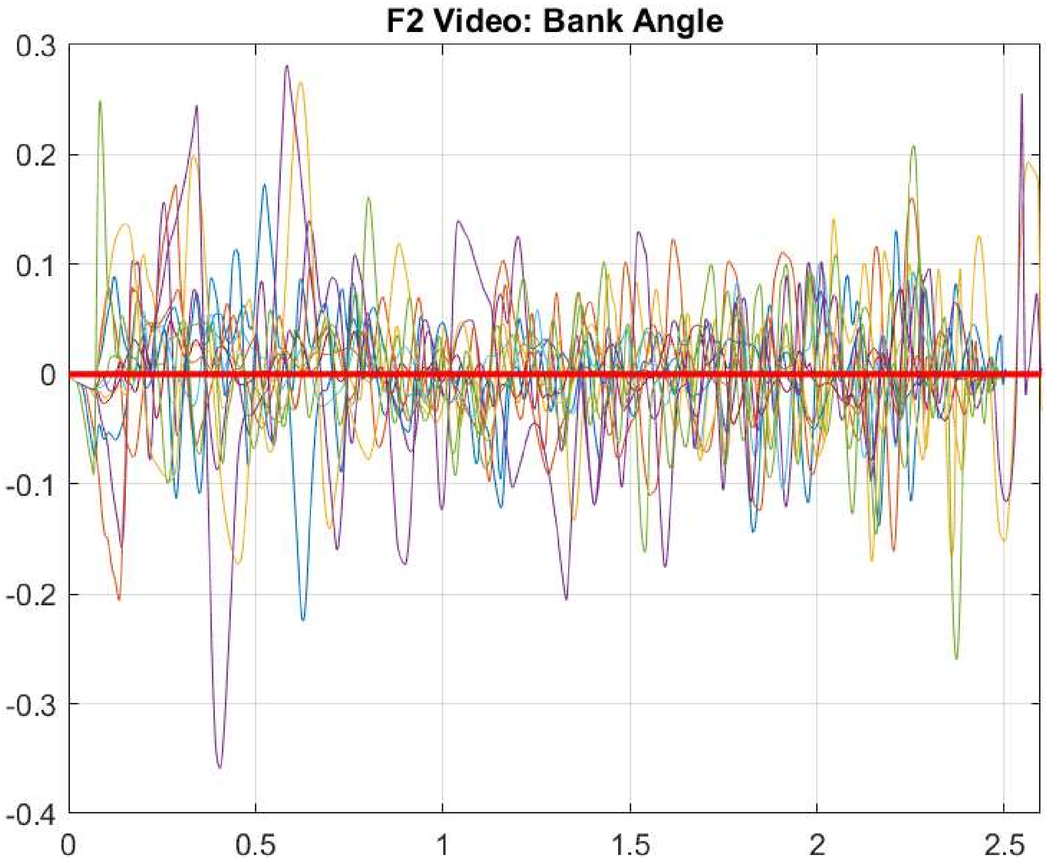
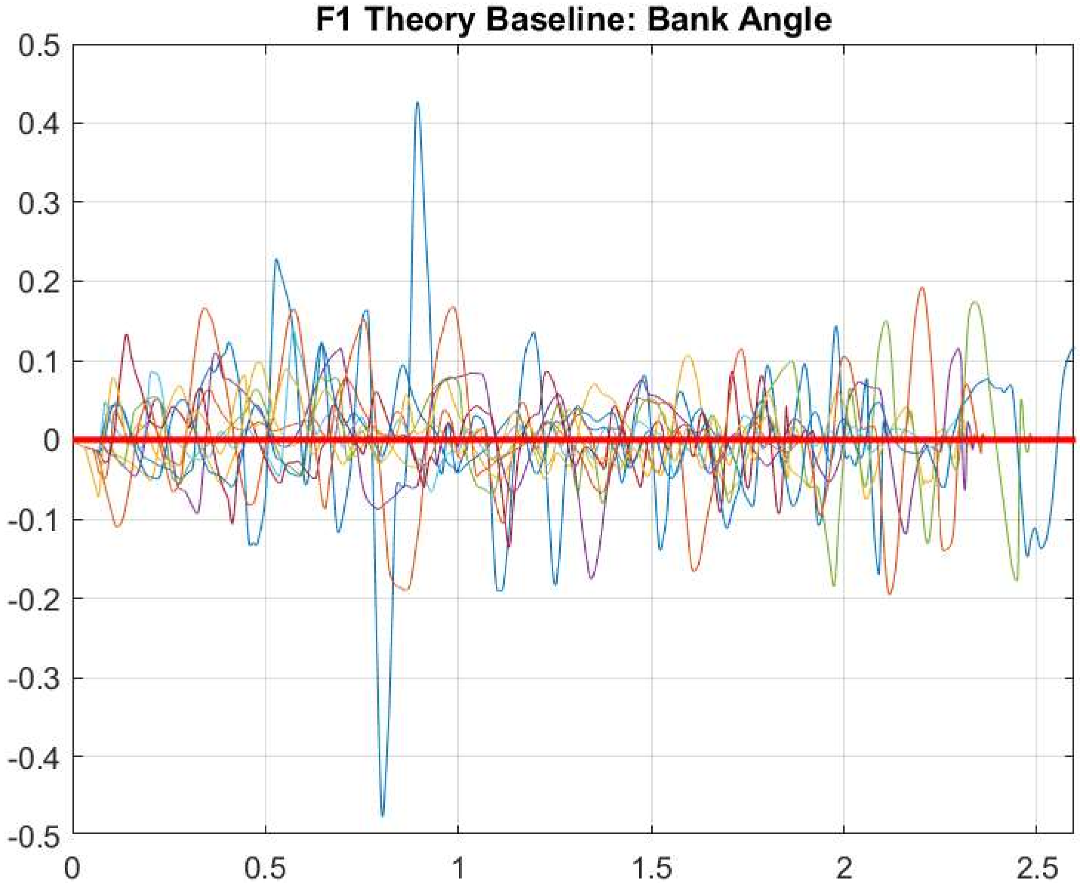
3


F2 Theory Baseline: Height
Alt [ft]
1200
1000
800
600
400
200
0
Time [min]
0
0.5
1
1.5
2
2.5
3

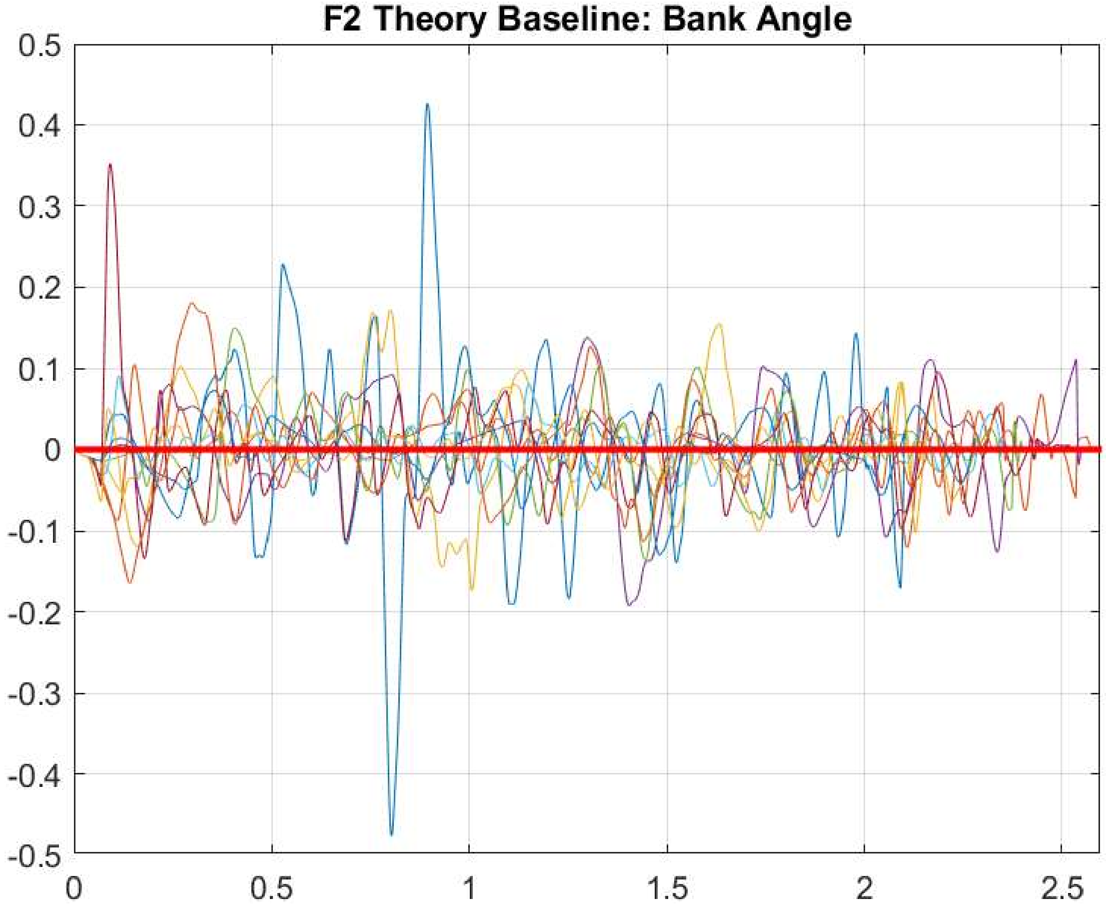
10.6.4 Bank Angle







F1 Theory Baseline: Bank Angle



F2 Theory Baseline: Bank Angle

10.7 Cockpit mix

The cockpit mixes in Figure 15 is intended to show which of the three AOIs was viewed most frequently in percent, this serves as a supplement to the previous bar plot. Here as well, the aiming point was viewed most frequently between the three AOI categories. However, the aiming point was looked at more often in groups 1 and 2, at around 78% and 80% respectively, while in group 0 it was 75%. The velocity was around 15% for group 0, which then dropped to 10% for group 1 and 12% for group 2. The vertical speed was given the least attention, as it was 9% for group 0, 8% for group 1 and 11% for group 2. This Figure 15 also shows that group 2 paid slightly more attention to the vertical speed than group 1.

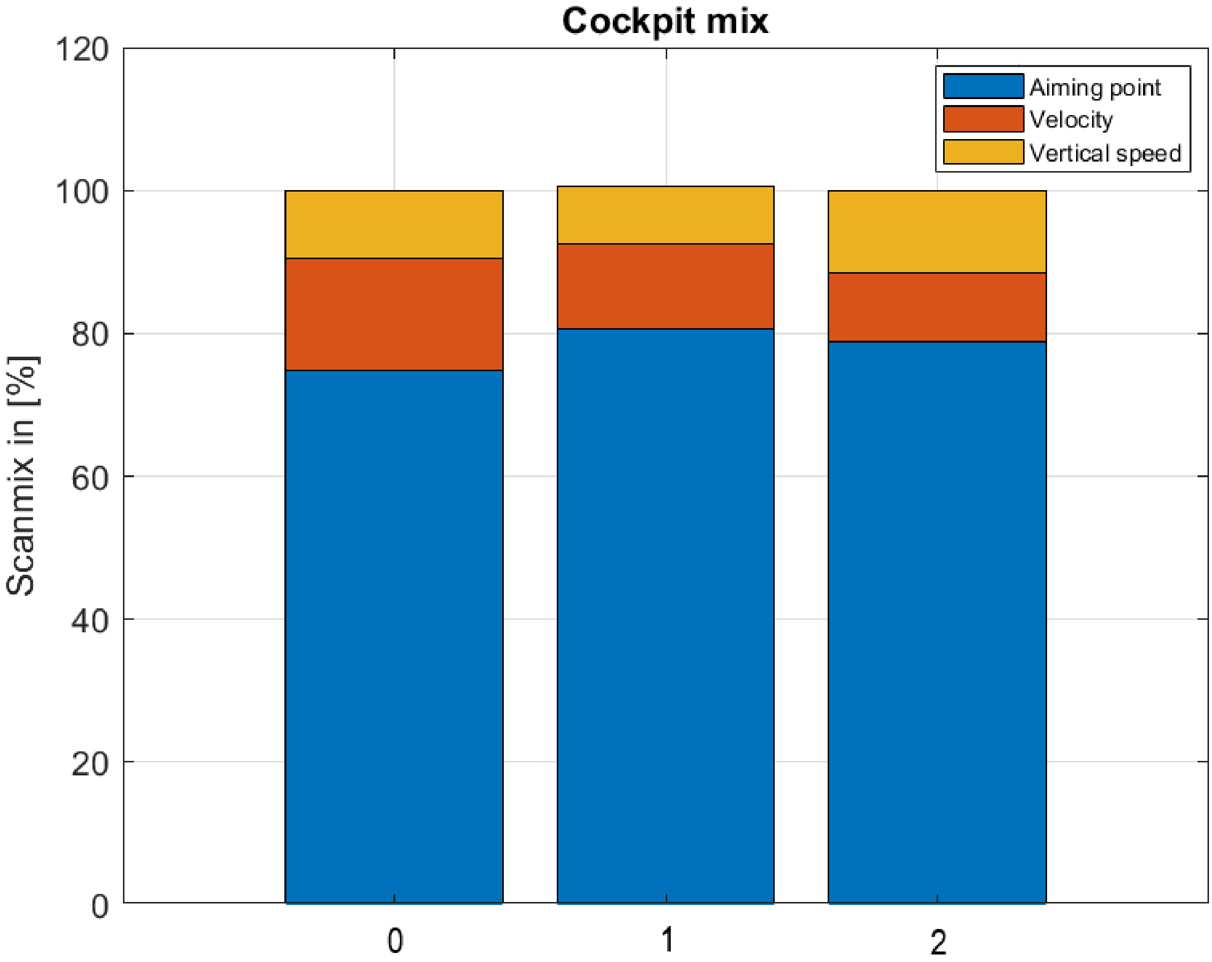


Figure 15 This figure shows three bar plots of the average scan mix of the participants. The scan mix on the y-axis is measured in percentage and the x-axis represents the groups. The bar plots are divided into three categories which are the aiming point in blue, the velocity in orange and the vertical speed in yellow. As it is visible, the largest part of each bar plot is the fixation time on the aiming point.