Methodology of Vestibular Illusion Training Using a Flight Simulator

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Programme **Transport 2020+**

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Contents

Programme **Transport 2020+**

List of Abbreviations

Programme **Transport 2020+**

A	Airplane
ATC	Air Traffic Control
ATO	Approved Training Organisation
ATP (A)	Airline Transport Pilot (Airplane)
ATPL	Air Transport Pilot License
BIR	Basic Instrument Rating
BITD	Basic Instrument Training Device
CBIR	Competency Based Instrument Rating
CPL (A)	Commercial Pilot License (Airplane)
deg	Degrees (angle of rotation around a specific axis)
EASA	European Union Aviation Safety Agency
EU	European Union
FFS	Full Flight Simulator
FNPT	Flight and & Navigation Procedures Trainer
FSTD	Flight Simulation Training Devices
FTD	Flight Training Device
GYRO IPT	Gyro Integrated Procedures Trainer
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IR	Instrument Rating

IRI	Instrument Rating Instructor
MPL	Multi-crew Pilot Licence
NDB	Non-directional Beacon
PPL (A)	Private Pilot License (Airplane)
VMC	Visual Meteorological Conditions
VOR	Very High Frequency (VHF) Omnidirectional

1

Introduction

Spatial disorientation has historically been a contributing factor to numerous aviation accidents. Vestibular illusions, which cause misleading perceptions of motion or loss of orientation in space during flight, are an important yet to some extent overlooked area in the training of flight crews. The theoretical foundations for acquainting pilots with vestibular illusions exist and are included in the ground instruction for private, commercial, and airline transport pilot license applicants. The theory of vestibular illusions has been long-established; however, the application of this knowledge in practical training has never been fully realized. From available data, handling situations involving vestibular illusions is considered crucial, as correct identification and resolution of these illusions can mean the difference between a successful flight and a potentially hazardous situation, as demonstrated by the findings from some aviation accident investigations.

The human vestibular system, responsible for sensing balance and spatial orientation, can be deceived by various external influences, leading to illusions such as somatogravic, Coriolis, and somatogyral illusions. These can arise due to a variety of factors related to the misleading perception of reality and a discrepancy between visual and equilibrium senses, for example, under adverse weather conditions, in individuals with visual impairments, or when losing visual contact with the ground, both during the day and at night. These illusions can occur at various phases of flight, including critical ones.

Covering this area only in the theoretical aspect of training for certification can be seen as foundational, yet practical training provides much stronger resilience, as is the case in many other training areas. Experiments have shown that experienced pilot instructors can be just as susceptible to spatial disorientation as students in training. A research project aimed at developing training materials and a curriculum covering vestibular illusions, based on evidence, was initiated under the leadership of the staff from the Czech Technical University in Prague, Faculty of Transportation Sciences. Along with the ambition to create materials for successful implementation of practical training on vestibular illusions into the existing educational framework for pilots at an international level.

Objective of the Methodology

The aim of this methodology is to utilize the findings from research conducted by the Czech Technical University in Prague, in collaboration with the Institute of Aviation Medicine in Prague and supported by the Technology Agency of the Czech Republic within the research project CK02000321 of TACR TRANSPORT 2020+ Programme. This methodology compiles knowledge from the research project and provides evidence-based procedures for incorporating practical training on vestibular illusions into the initial instrument flight training for pilots. This is with the consideration that such training could, in the future, be recognized in terms of flight hours as part of the training for obtaining instrument flying qualifications, offering the practical benefit of spatial disorientation training on a simulator.

Dedication of the Methodology

This methodology is designed for certified pilot training organizations that offer practical training to achieve qualifications in instrument flying. It also serves as a valuable resource for students who possess limited practical and theoretical experience in their preparation for undertaking pilot duties. Additionally, this document is intended for use by training institutions seeking to enhance the capabilities and competencies of pilots.

2

Scientific Background

Programme **Transport 2020+**

The methodology is the result of project CK02000321, whose primary goal was to develop evidence-based methodologies and procedures to incorporate vestibular illusion simulators into pilots' initial training, in a manner that would allow acceptance of flight hours as part of pilots' training along with the benefit of practical spatial disorientation training. The project objectives were achieved through research activities, thus providing an evidence base for the methodology, as the incorporating of new procedures in areas characterized by a high degree of safety, particularly in aviation, requires evidence-based approaches and methods of investigation. Project activities and the overall solution approach were therefore designed in a way that reflects this approach. In this context, research activities were divided into two stages:

1. measurements involving experienced pilots (instructors), based on which final flight profiles were defined among other things, and
2. measurements involving pilots with varying levels of flight experience using the final flight profiles.

The primary goal of the first stage of the project was, besides finalizing flight profiles used in subsequent project activities, to collect expert opinions regarding the suitability of incorporating vestibular illusion simulators into pilots' practical training and simultaneously determining the appropriate phase of training in which the induction of vestibular illusions would be included. Expert opinions were collected through structured interviews with each participant in the first stage of the project. Twenty-five experienced pilots (instructors) participated in this stage, and their feedback serves as the primary basis for this methodology. Within each measurement, subjects completed three flight profiles, followed by their feedback [1]. This led, among other things, to the exclusion of the lean illusion from the final profiles, as subjects reported its unrealistic induction during flight. Based on collected information, two profiles [2] were then selected as the basis for the final profiles used in the subsequent stage of the project.

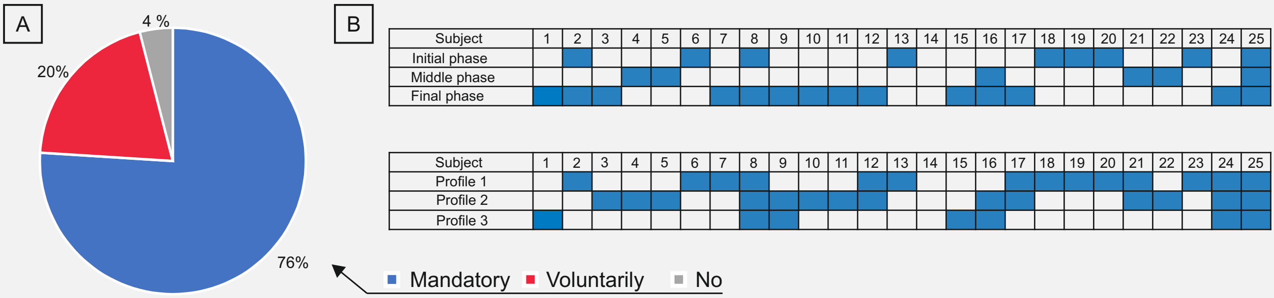
Four groups of pilots with different flight experiences, totaling 114 participants, participated in this stage, ranging from pilots in the early stages of IFR training to highly experienced pilots [3]. In this context, profiles were created to ensure that all pilots could fly these profiles without significant difficulty. Measurement also involved collecting additional signals such as cardiac and brain activity or subject stability. Detailed results are the subject of the project research report [4]. Each subject participated in two measurements approximately one week apart, each consisting of two simulator flights – one without illusions and one with illusions. After each measurement, structured interviews were conducted with subjects regarding the perceived intensity of each illusion and its effect on the subject. After the second measurement, the interview was further expanded to inquire whether the subject would like to be allowed to undergo simulator training for vestibular illusions as part of their training.

Project research report is available online at http://kld.fd.cvut.cz and/or upon request via email (sochavla@fd.cvut.cz).

As shown in Fig. 2.1-A, 76 % (19) of instructors were in favor of the mandatory integration of vestibular illusion simulators into ab-initio training. Given that pilot trainees undergo solely theoretical training, subjects emphasized the significance of allowing trainees to pre-experience potential scenarios, noting that such exposure aids in better recall, heightened future vigilance, and proactive avoidance of similar situations. In total, 20 % (5) of instructors would also agree to its introduction into training, but only on a voluntary basis. They reported that there is not enough time in the training and it has not been necessary so far, but the experience was interesting and it would be good to have the opportunity to try such things. Another reason for integration only on a voluntary basis was the financial burden. Only one instructor (4 %) was against the integration of vestibular illusion simulators into training because he felt that the illusions were not realistic. The results are supplemented with an overview of training phases into which instructors would subjectively integrate the vestibular illusion simulators (Fig. 2.1-B) [5, 6].

In the second stage of the project, following their experience with the vestibular illusion simulator, pilots were able to develop a comprehensive understanding of the dangers and effects of vestibular illusions. As a result, the majority of subjects would appreciate the opportunity for practical training in vestibular illusions through simulated profiles as part of their aviation training. Regarding the integration into training, vestibular illusion simulators were recommended to be implemented by 96.491 % (110) of respondents, not recommended by 2.632 % (3), and 0.877 % (1) did not respond [4].

In conclusion, the project activities were designed to validate the selected approach for inducing vestibular illusions and to establish an evidence base for this methodology through an experimental approach. The majority of subjects across all levels of experience would support the introduction of mandatory or optional training of vestibular illusions through simulated profiles in a simulator. This underscores the urgency of the issue of vestibular illusions training which is currently limited and theoretical.



Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Initial phase		🟦				🟦		🟦					🟦					🟦	🟦	🟦			🟦		🟦
Middle phase				🟦	🟦											🟦					🟦	🟦			🟦
Final phase	🟦	🟦	🟦				🟦	🟦	🟦	🟦	🟦	🟦			🟦	🟦	🟦							🟦	🟦

Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Profile 1		🟦				🟦	🟦	🟦				🟦	🟦				🟦	🟦	🟦	🟦	🟦		🟦	🟦	🟦
Profile 2			🟦	🟦	🟦			🟦	🟦	🟦	🟦	🟦				🟦	🟦				🟦	🟦		🟦	🟦
Profile 3	🟦							🟦	🟦						🟦	🟦								🟦	🟦

Figure 2.1: Summary of respondents' answers regarding the incorporation of vestibular illusion training into IFR training (A) along with specific responses regarding the incorporation of profiles into the phases of IFR training (B).

3

Vestibular Illusions Induction

Vestibular illusions, play a critical role in understanding the challenges pilots may face regarding spatial orientation during flight. These illusions arise from discrepancies between actual flight conditions and the pilot's perception, often due to the complex interactions within the human vestibular system located in the inner ear. This system, responsible for maintaining balance and spatial orientation, can be easily misled under certain flight conditions, leading to potentially dangerous situations [7, 8, 9]. The induction of vestibular illusions in a controlled environment, such as a flight simulator, is essential for training pilots to recognize and counteract these misleading sensations [7].

ⓘ Detailed information regarding specific vestibular illusions, including their characteristics and principles, as well as conditions in which they may occur, is further described in relevant literature, for example [7, 8, 9].

This chapter is dedicated to the methodology of inducing vestibular illusions, which has been experimentally verified. Specifically, it involves a description of the principle of induction of Somatogravic, Coriolis and Somatogyral Illusion.

The relevant vestibular illusions

Somatogravic Illusion: Occurs during rapid acceleration or deceleration, leading pilots to perceive an incorrect pitch attitude.
Coriolis Illusion: Triggered when a pilot moves their head during a turn, roll, or pitch.
Somatogyral Illusion: Arises from sustained turns, where the pilot might feel as though the aircraft has stopped turning.

3.1 Somatogravic Illusion Induction

The methodology for understanding and simulating the somatogravic illusion is rooted in the vestibular system's response to linear acceleration. This phenomenon occurs when the pilot misinterprets forward acceleration as an ascent, a confusion stemming from the vestibular system's inability to distinguish between acceleration due to movement and the gravitational force. This illusion is particularly pronounced in conditions with limited external visual cues, such as during night flights or under Instrument Meteorological Conditions (IMC), where the horizon is obscured.

The confluence of these perceptions leads the pilot to feel as though the aircraft is climbing, prompting a natural reaction to push the control columns forward to halt the ascent. If this illusion occurs close to the ground during the takeoff phase, the forceful push forward could result in a ground collision.

Conversely, during rapid deceleration without visual references or at night, pilots may feel that the aircraft is descending, instinctively pulling the control stick back. Such a sudden pull could exceed the critical angle of attack, leading to a stall and potentially a crash. Lack of sufficient altitude and time to recognize and correct the descent would increase the risk of terrain collision.

The vestibular system, integral to experiencing the somatogravic illusion, consists of the semicircular canals, which detect angular accelerations, and the otolith organs (saccule and utricle), which are sensitive to linear accelerations and gravity. When an aircraft accelerates, particularly during takeoff or rapid in-flight accelerations, the otolith organs may interpret this as the aircraft tilting upwards due to the indistinguishable forces of acceleration and gravitational pull. Without clear visual indicators, this can lead pilots to believe the aircraft is pitching up more than it is, potentially causing them to lower the nose of the aircraft inappropriately. This reaction could dangerously reduce altitude or even initiate a descent, illustrating the critical nature of understanding and training to counteract the somatogravic illusion for flight safety.

Specific acceleration thresholds for triggering the somatogravic illusion vary among individuals, but the illusion is generally more pronounced with higher rates of acceleration. While exact thresholds can vary, accelerations as low as 0.2 g (where g is the acceleration due to Earth's gravity, approximately 9.81 $\mathrm{m/s^2}$) have been reported to induce vestibular illusions, including the somatogravic illusion. The sensation can be so convincing that pilots may perceive a pitch angle significantly different from the aircraft's actual attitude, potentially leading to dangerous flight conditions if not correctly countered by visual or instrument cues.

In the methodology for inducing the somatogravic illusion, it is essential to recognize the limitations of flight simulators that are restricted to rotational movements around their axes and are incapable of generating direct linear acceleration. Consequently, the approach adopted involves creating a perceived discrepancy between the pitch angle as experienced by the pilot and the pitch angle as indicated by the flight instruments. This discrepancy is engineered by adjusting the simulator cabin's tilt to exceed the perceptual threshold for detecting motion, effectively simulating the somatogravic illusion.

The critical impacts of the somatogravic illusion are most likely to occur during takeoff and the subsequent climb, justifying the simulation of this illusion during these phases. The student pilot is cleared for takeoff, possibly through pre-recorded instructions. After liftoff and while climbing over the runway in the departure direction, if the longitudinal pitch exceeds 5 degrees, the simulator initiates a pitch-up movement of the cabin by +12°. This results in an angular acceleration of 1.3 °/s^2 and a maximum rotational velocity of 4 °/s. Immediately achieving 12° pitch, the simulator cabin returns to its initial position of 0°, achieving this with an angular deceleration of 0.3 °/s^2 and a rotational speed of 1 °/s. A schematic representation of the mechanics of inducing the somatogravic illusion is illustrated in Figure 3.1.

Although the principle of inducing the somatogravic illusion is primarily associated with the takeoff phase of flight here, the mechanics of creating this illusion can also be applied to other flight phases that involve changes in altitude.

This method for inducing the somatogravic illusion was employed during the experimental phase of the project. This methodological principle ensures a realistic simulation of the illusion, providing an essential training experience for recognizing and responding to somatogravic illusions in flight. The specified values have been validated as effective for eliciting this illusion on the GYRO IPT II, but this principle of illusion induction is possible with other simulators as well, assuming the technical requirements are met to achieve the aforementioned mechanics of illusion induction.

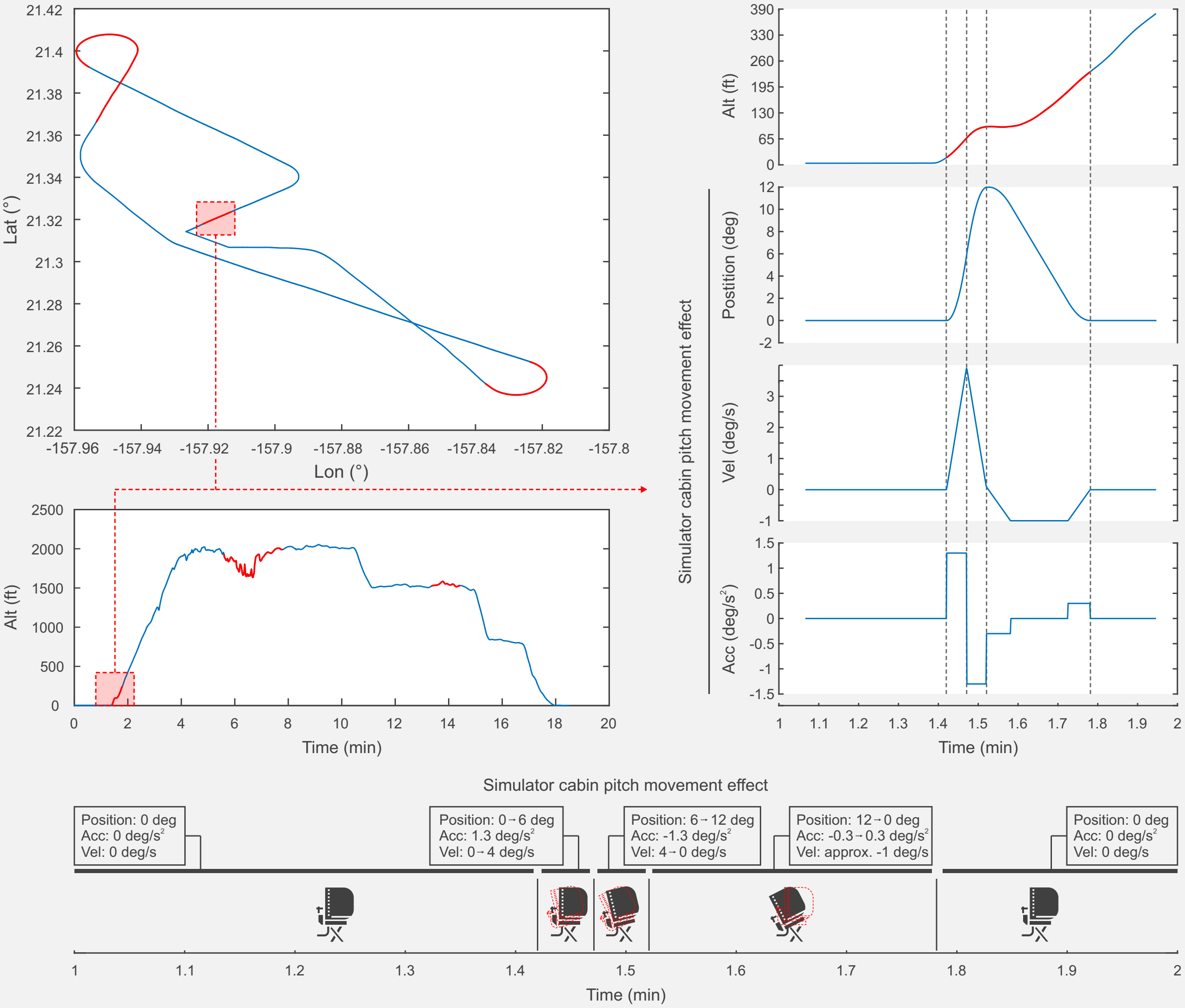


Figure 3.1: Principle of inducing the somatogravic illusion

3.2 Coriolis Illusion Induction

The Coriolis illusion is one of the most disorienting and dangerous phenomena that pilots can encounter, especially under conditions where visual references to the horizon are unavailable. This illusion is intricately tied to the inner ear's vestibular system, which plays a crucial role in maintaining balance and spatial orientation. Understanding the Coriolis illusion requires a deeper dive into its underlying mechanics, its impact on pilot perception, and strategies for mitigation.

At the heart of the Coriolis illusion are the semicircular canals located in the inner ear. These three canals are oriented in three planes: roll, pitch, and yaw. They contain a fluid called endolymph and hair-like sensors (hair cells) that detect rotational movements of the head. When the head rotates, the fluid lags behind due to inertia, bending the hairs, and sending signals to the brain that are interpreted as motion.

During steady flight, the fluid in the semicircular canals stabilizes, and no motion is detected by the hair cells. However, if a pilot makes a head movement during a turn or any maneuver involving angular acceleration, the fluid dynamics within these canals change. If the head moves about an axis different from the aircraft's axis of rotation, the endolymph's movement can stimulate sensors in more than one canal, creating a complex and misleading sense of rotation.

This false sense of rotation can be profoundly disorienting. Pilots might perceive that they are pitching, rolling, or yawing in a different direction than the aircraft's actual motion. This misperception can lead to a loss of spatial orientation known as spatial disorientation. The Coriolis illusion is particularly dangerous because it can persuade pilots that they need to correct the aircraft's attitude even when no correction is needed, potentially leading to inappropriate control inputs that could compromise flight safety.

The Coriolis illusion underscores the conflict between vestibular inputs and visual or somatosensory inputs. In the absence of visual cues, the brain may rely more heavily on the faulty vestibular inputs, exacerbating the potential for spatial disorientation. Cognitive factors, including expectation and attention, can also influence the experience of the Coriolis illusion. Pilots expecting level flight may be more susceptible to disorientation when an unexpected turn and subsequent head movement induce the illusion.

The illusion is induced during a turn involving a change in course of at least 180°, as directed by air traffic control or an instructor. During the aircraft's turn in the simulation, the simulator device performs a rotation around its axis. This rotation achieves a total rotational speed of 60°/s with angular acceleration of $2°/s^2$, lasting a total of 30 seconds. After this period and once the condition that the aircraft is in the midst of a turn is met, the trainee pilot receives an audio command to read and announce a sequence of numbers located behind their shoulder. The label with the sequence of numbers is placed below the natural field of vision, forcing a head movement downward. This command compels the pilot to make a significant head movement, both towards and back along a trajectory that stimulates the vestibular apparatus, leading to sensations associated with the Coriolis illusion. The initial head movement is forced in the direction of the simulator's rotation.

The rotation of the simulator continues, either until a condition is met, such as completing a turn to a specific course, or another condition. In the context of the illusion itself, this is not important; however, the aim is to create a sensation of turning, so it is recommended to maintain the simulator's rotation in constant mode until the completion of the turn.

From this point, the simulator device begins to decelerate from a rotational speed of 60°/s at a rate of $1°/s^2$ for 60 seconds until a rotation of 0°/s is achieved. A schematic representation of the mechanics of inducing the somatogravic illusion is illustrated in Figure 3.2.

ⓘ The presented method for inducing the Coriolis illusion is based on a significant head rotation with the necessary pivoting of the entire body, involving a 180° head turn. This approach was experimentally designed in such a manner to maximize the effect on the vestibular apparatus. However, this does not imply that head rotation cannot be based on a different principle, such as reaching for a navigation map, etc. The intensity of the experience from this illusion, however, may vary.

This method for inducing the Coriolis illusion was employed during the experimental phase of the project. This methodological principle ensures a realistic simulation of the illusion, providing an essential training experience for recognizing and responding to Coriolis illusions in flight. The specified values have been validated as effective for eliciting this illusion on the GYRO IPT II, but this principle of illusion induction is possible with other simulators as well, assuming the technical requirements are met to achieve the aforementioned mechanics of illusion induction.

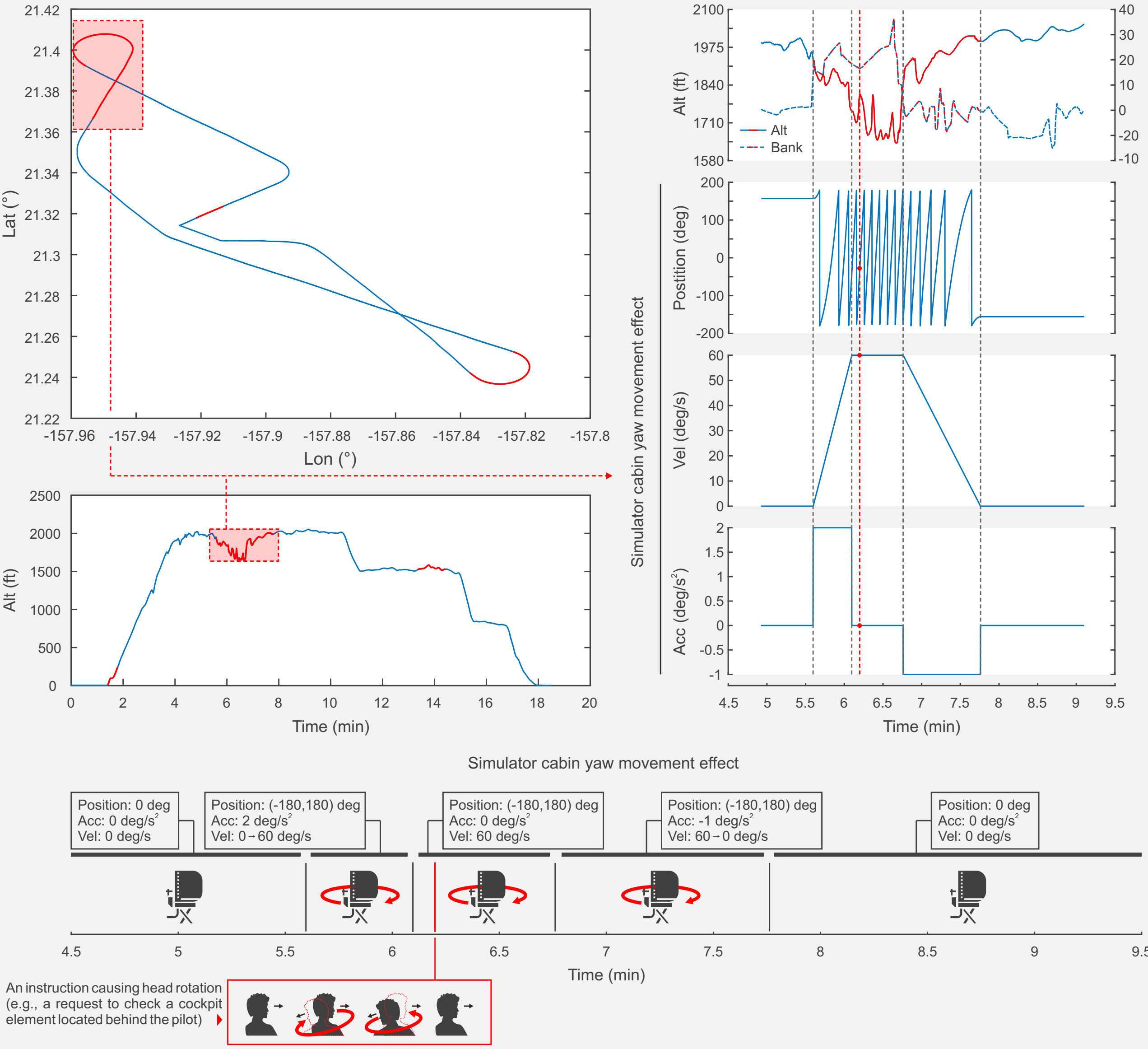


Figure 3.2: Principle of inducing the Coriolis illusion.

3.3 Somatogyral Illusion Induction

The mechanics of somatogyral illusions involve the physiological and perceptual responses of the vestibular system to angular motion, particularly during flight maneuvers that include turns, rolls, or pitches. Understanding these mechanics is crucial for grasitating how these illusions can lead to spatial disorientation in pilots.

During steady, uniform flight, the fluid within the semicircular canals moves at the same rate as the canals themselves, resulting in no sensation of rotation. However, when an aircraft enters a turn, the initial angular acceleration causes the fluid to lag, bending the cupula and creating the sensation of turning. If the turn continues at a constant rate, the fluid catches up with the movement of the canal, the cupula returns to its upright position, and the sensation of turning fades, even though the turn is still ongoing.

When the turn ceases and the aircraft returns to straight flight, the fluid's inertia causes it to continue moving, bending the cupula in the opposite direction and potentially creating a false sensation of turning in the opposite direction or not turning at all.

The somatogyral illusion is induced during a turn with a course change of at least 150° in any direction (right or left) to a predetermined course. This should ensure sufficient time for the induction of the illusion. A crucial element in inducing this type of illusion is the relatively slow initiation of the simulator into rotational motion to achieve high rotation speeds. In the research, this acceleration was experimentally set at $1.5°/s^2$, achieving a rotational speed of 60°/s over 40 seconds. The rotation of the simulator should begin by bringing the aircraft into a steady turn. The rotation speed of 60°/s should continue until the maneuver is completed, i.e., until the aircraft starts to level towards the target course. The low initial acceleration and maintenance of a constant rotation speed of the simulator contribute to the relatively rapid stabilization of the fluid in the vestibular apparatus's semicircular canals.

In the context of inducing a somatogyral illusion, a key moment is the exit from the turn, thus the phase of leveling the aircraft into level flight. At the moment the aircraft levels into level flight, there is a rapid deceleration of the simulator and termination of its rotation within 5 seconds (corresponding to a deceleration value of $12°/s^2$). This rapid deceleration leads to a sudden and disorienting change in the vestibular input to the pilot. This abrupt shift can cause the pilot to experience a powerful sensation of continuing the turn or starting a turn in the opposite direction, even though the aircraft has already leveled off. This mismatch between what the pilot feels (due to the vestibular inputs) and what is actually happening (as shown by the flight instruments) challenges the pilot's spatial orientation.

An important aspect that can contribute to the experience of the illusion, or potentially disrupt control, is the inclusion of an instruction that diverts the pilot's attention away from the instruments indicating the aircraft's position in space during the phase of rapid deceleration. However, since this is not a demonstration of the Coriolis illusion, incorporating head movement is not appropriate. In the context of experimental measurements carried out, it has proven effective to issue an instruction to "report airspeed." This means that during rapid deceleration and while leveling the aircraft into level flight, the pilot's attention is diverted to the airspeed indicator.

The concept described above is schematically illustrated in Figure 4.1.

ⓘ Inducing the somatogyral illusion in this case is described along with a distraction of attention, which, however, may not be implemented. This action, however, increases the likelihood of spatial disorientation resulting from this illusion.

This method for inducing the Somatogyral illusion was employed during the experimental phase of the project. This methodological principle ensures a realistic simulation of the illusion, providing an essential training experience for recognizing and responding to Somatogyral illusions in flight. The specified values have been validated as effective for eliciting this illusion on the GYRO IPT II, but this principle of illusion induction is possible with other simulators as well, assuming the technical requirements are met to achieve the aforementioned mechanics of illusion induction.

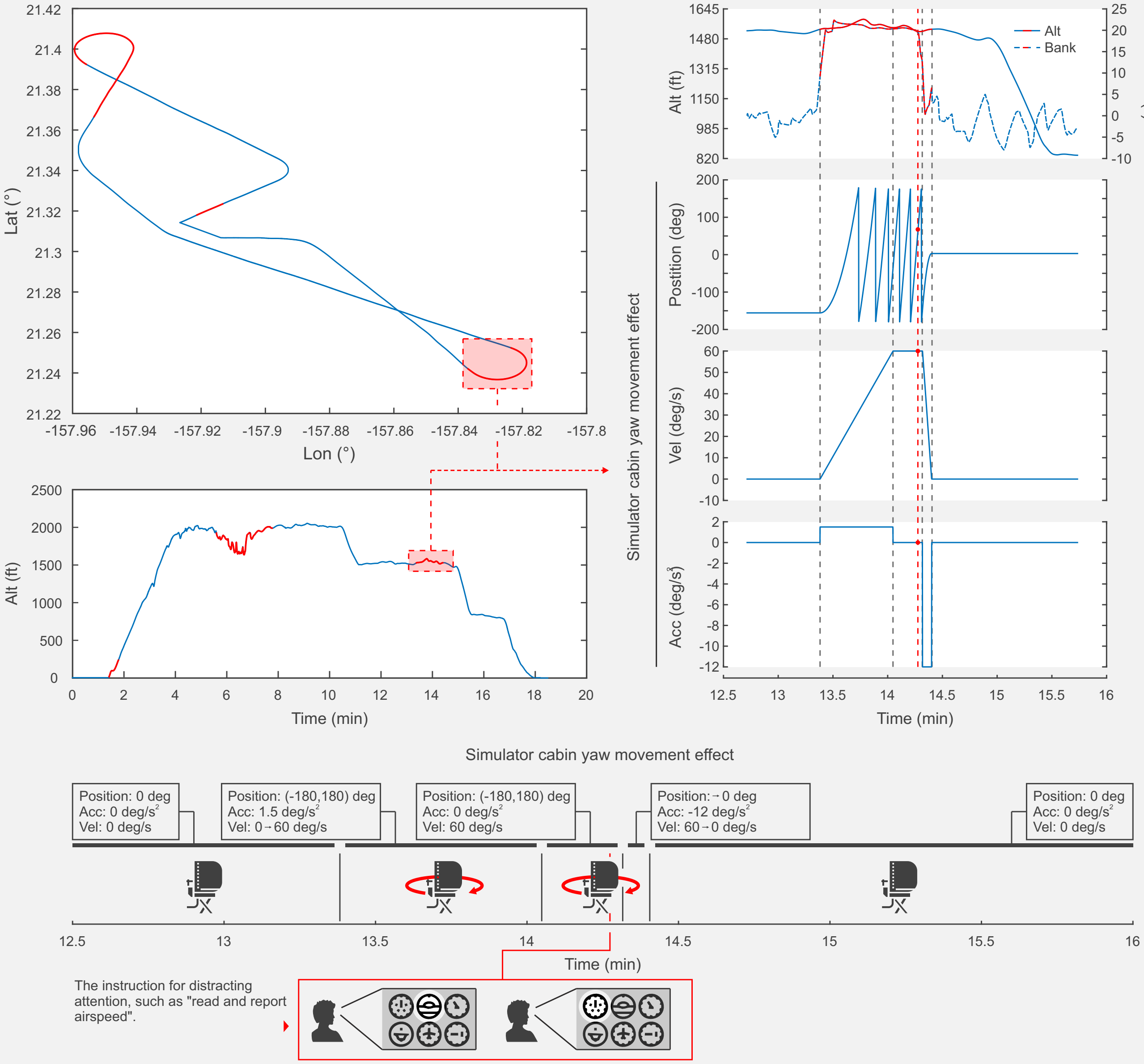


Figure 4.1: Principle of inducing the Somatogyral illusion.

4

Implementation into Training

Programme **Transport 2020+**

The essence of instrument flight training, as delineated by Part-FCL standards, is to meticulously equip pilots with the proficiency required for mastery over Instrument Flight Rules (IFR) and navigation through Instrument Meteorological Conditions (IMC). This facet of pilot training is indispensable for ensuring operational safety and precision in visibility-compromised environments.

Currently, aviation training institutions are offering an array of seven targeted instrument flight training programs, notably including courses designed for aspirants of the Instrument Rating Instructor (IRI) qualification. These programs are tailored for holders of the Commercial Pilot License (CPL), Multi-Crew Pilot License (MPL), and Private Pilot License (PPL), embedding them within the comprehensive educational framework necessary for the Airline Transport Pilot License (ATPL), MPL, and CPL credentials. Integral to the advanced phase of pilot training, these instrument flight modules mandate the completion of up to 50 hours of rigorous training. This immersive instruction not only imparts essential theoretical knowledge but also facilitates extensive practical experience in instrument-based navigation, thereby equipping pilots with the capabilities to adeptly manage flights under IMC according to IFR, a cornerstone of professional aviation competency.

In the context of integrating vestibular illusions training, emphasis has been placed on training aimed at acquiring instrument qualifications. This focus is attributed to the trainings included in integrated programs being similarly structured to specified trainings, yet distinguished by an increased allocation of time dedicated to dual and Student Pilot in Command (SPIC) flight hours.

Instrument flight training

- Instrument flight training integrated into professional pilot training programs:
  - Integrated ATPL (Airline Transport Pilot License) training
  - Integrated CPL (Commercial Pilot License) + IR (Instrument Rating) training
  - Integrated MPL (Multi-Crew Pilot License) training
- Instrument flight training as a standalone modular course:
  - IR (Instrument Rating)
  - CBIR (Competency-Based Instrument Rating)
  - BIR (Basic Instrument Rating)
- Training for instructors to obtain the IRI (Instrument Rating Instructor) qualification.

The course for obtaining an independent IR qualification consists of two modules, which can be taken separately or combined:

- Basic Instrument Flight Module - this includes 10 hours of instrument time, of which up to 5 hours can be instrument ground time on a BITD, FNPT I or II, or FFS. Upon completion of the Basic Instrument Flight Module, the candidate will be issued a course completion certificate.
- Procedural Instrument Flight Module - Up to 40 hours of the required instrument time may be conducted on an FNPT II for a single-engine IR. For a multi-engine IR under EASA regulations, the required instrument time could involve up to 45 hours of simulator time on an FNPT II or an FFS for the theoretical knowledge and flight training parts of the course.

Up to a certain number of hours can be credited towards the IR on an FNPT I, but this is typically less than what can be credited when using an FNPT II. The commonly accepted limit for FNPT I in many IR courses is up to 10 h ours, but this can vary based on national regulations and specific course approvals.

ⓘ EASA, in Regulation 1178/2011 [10] under Part-FCL, sets out the basic requirements for various types of training with precise definitions of elements and time allocation for phases (integrated training) or modules (modular training) to obtain the IR qualification. Given the complexity of EASA regulations and possible amendments, it’s always a good practice to consult the latest version of Part-FCL or the training organization for the most current requirements and allowable simulator hours for IR training.

EASA Part-FCL does not prescribe specific simulator syllabi for Instrument Rating (IR) training but sets out the framework and requirements that training organizations must follow to ensure pilots achieve the necessary competencies for IR. The detailed syllabus for IR training, including the use of simulators, is developed by the Approved Training Organizations (ATOs) in accordance with EU regulations and EASA guidelines.

However, EASA Part-FCL does specify the competencies that need to be acquired and the minimum training hours, including the use of Flight Navigation Procedure Trainers (FNPTs) or Flight Simulation Training Devices (FSTDs), for various licenses and ratings, including IR. The syllabus created by ATOs must cover:

- Theoretical Knowledge: Subjects related to instrument flying, such as IFR regulations, navigation, meteorology, flight planning, and the use of IFR equipment.
- Flight Training: Practical skills necessary for flying under IFR, including basic instrument flight patterns, navigation procedures, approach and landing procedures under IFR, and emergency procedures.

The above indicates that the simulator component of training can be quite variable across different training providers. Therefore, to maintain the integrity of simulator training without necessitating changes and while retaining the benefit of providing theoretical and practical experience with vestibular illusions, the approach to introducing such training must be ATO-oriented. This means that if a specific ATO wishes to offer such training while preserving the approved simulator syllabus, its quality, and integrity, this process should be implemented as described below.

4.1 Methodology for Integration by ATOs

Based on the significant advantages identified through our research regarding the incorporation of disorientation simulators into Instrument Rating (IR) training, a refined approach for the integration of vestibular illusion training is proposed. This approach is designed for implementation both directly by Approved Training Organizations (ATO) and in collaboration with third-party entities equipped with simulators capable of inducing vestibular illusions. The aim is to seamlessly enhance pilot preparedness for spatial disorientation within the existing IR training framework, ensuring the approved curriculum remains undisturbed. The methodology recommended is outlined as follows:

Identification of Integration Points
A thorough examination of the current IR simulator training syllabi is recommended to be conducted to pinpoint where vestibular illusion training could most effectively be inserted, with a focus on scenarios prone to inducing spatial disorientation.

Development of Modules for Vestibular Illusion Training
Specialized supplemental modules are advised to be developed, which can be integrated into the existing syllabi. It is suggested that these modules be customized to utilize in-house equipment for ATOs with direct access to capable simulators. For ATOs engaging in third-party collaborations, the development of adaptable modules to the specifications and capabilities of third-party simulators is recommended, ensuring a uniform training experience.

Strategy for Effective Communication
The articulation of the benefits of integrating disorientation simulator training, both for in-house implementation and through third-party collaboration, is proposed. Emphasis should be placed on how this training augments the current IR curriculum by providing practical experiences with vestibular illusions, thereby enhancing safety and pilot proficiency.

Planning for Flexible and Strategic Scheduling
Strategic planning for the scheduling of disorientation simulator sessions is suggested, with an emphasis on complementing the existing training schedule. For third-party collaborations, considerations for logistics, including simulator access times and travel requirements, are recommended to minimize disruption.

Alignment with Regulatory Standards and Documentation
Engagement with aviation regulatory authorities to ensure compliance with existing training standards for the integration of vestibular illusion training, whether conducted in-house or through a third party, is advised. The maintenance of compliance documentation for both ATOs and their third-party partners is essential.

Preparation and Support for Instructors
Comprehensive preparation of instructors for delivering the vestibular illusion training modules is proposed. This includes specific training for ATO instructors and, where applicable, for third-party instructors tasked with conducting sessions for ATO trainees.

Framework for Continuous Evaluation and Improvement

The establishment of a framework for the ongoing evaluation of the effectiveness of vestibular illusion training is recommended, utilizing feedback and performance data from students. This framework should accommodate both ATO-direct and third-party facilitated training scenarios, allowing for the iterative refinement of training modules.

In this context, it's essential to establish minimum requirements for the material and technical provisions necessary for this type of training, along with the minimum competencies expected of student pilots.

Minimum requirements for integration

Instrument Familiarity: Students should be familiar with basic cockpit instruments and understand how to interpret them, especially those critical for IFR operations.

Spatial Orientation Basics: An understanding of spatial orientation and the common types of disorientation pilots may face, even if they haven't experienced them firsthand.

Upeset prevention and emergency procedures awareness: Knowledge of standard emergency procedures, especially those related to recovering from unusual attitudes or instrument failures.

IFR Regulations: A basic understanding of IFR regulations and procedures.

Advanced Simulators: Access to flight simulators capable of accurately reproducing the conditions under which vestibular illusions occur. These simulators should allow for the simulation of various flight attitudes, accelerations, and visual environments. These simulators should be capable of generating angular accelerations and rotational movements within the minimum ranges as described in Chapter 3 of this document. The simulator must be certified to at least the FNTP I level to ensure that such training is recognized as part of the required flight hours.

Simulator Software: Software that includes scenarios specifically designed to induce vestibular illusions, such as somatogravic, somatogyral, and Coriolis illusions, and allows for the customization of training sessions to address specific learning objectives.

Minimum Instrument Time Duration: Based on the data provided by research, the minimum duration for practicing vestibular illusions is set at one hour of pure instrument time. This includes familiarization with the simulator as well as the execution of the specific flight scenario.

Qualified Instructors: Instructors with specialized training in delivering vestibular illusion training, including a deep understanding of the physiological and psychological aspects of spatial disorientation.

Educational Materials: Comprehensive training materials that cover the theory behind vestibular illusions, including their causes, effects, and mitigation strategies.

Safety Protocols: Established safety protocols for conducting vestibular illusion training, including procedures for aborting a simulation if a student becomes overly disoriented or distressed.

Feedback and Debriefing Tools: Tools and protocols for providing detailed feedback and debriefing after simulation sessions, allowing students to understand their performance and learn from the experience.

4.2 Representative Example for BIR

In this example, a concise approach to the introduction of vestibular illusion practice is presented for the case where a flight school has implemented a training program according to Part-FCL - AMC2 to Appendix 6 Modular training course for the IR.

Excercises

Exercise 1 - 0:30 hours

• basic instrument flying without external visual cues • horizontal flight; power changes for acceleration or deceleration • maintaining straight and level flight • turns in level flight with 15 ° and 25 ° bank, left and right • roll-out onto predetermined headings

Exercise 2 - 0:45 hours

• repetition of exercise 1 • additionally climbing, descending, maintaining heading and speed • transition to horizontal flight • climbing and descending turns

Exercise 3 - Instrument pattern: 0:45 hours

• start exercise, decelerate to approach speed, flaps into approach configuration • initiate standard turn (left or right) • roll out on opposite heading, maintain new heading for 1 minute • standard turn, gear down, descend 500 ft/min • roll out on initial heading, maintain descent (500 ft/min) and new heading for 1 minute • transition to horizontal flight, 1000 ft below initial flight level • initiate go-around • climb at best rate of climb speed

Exercise 4 - 0:45 hours

• Repetition of exercise 1 and steep turns with 45° bank • recovery from unusual attitudes

Exercise 5 - 0:45 hours

• Repetition of exercise 4

Exercise 6 - 0:45 hours

• radio navigation using VOR, NDB or, if available, VDF • interception of predetermined QDM, QDR

Exercise 7 - 0:45hours

• Repetition of exercise 1 and recovery from unusual attitudes

Exercise 8 - 0:45 hours

• Repetition of exercise 1 • turns, level change and recovery from unusual attitudes with simulated failure of the artificial horizon or directional gyro

Exercise 9 - 4:15 hours

Repetition of exercises 6 and 8

In this training, which is competency-based and may be only 10 hours and designed for PPL (Private Pilot License) holders, the implementation of vestibular illusion practice into Exercise 9 is considered, assuming the conditions described in the previous chapter are met. This implementation emphasizes the repetition of radio navigation using VOR.

Course of the Exercise

- Briefing (not included in the time allocation)
- Familiarization with the simulator (20 min)
- Profile without illusions (20 min)
  - Instrument departure according to ATC instructions
  - En-route flight following radio navigation aids
  - Arrival
  - Approach and landing
- Profile with illusions (20 min)
  - Instrument departure according to ATC instructions
  - Induction of the somatogravic illusion during takeoff
  - En-route flight following radio navigation aids
  - Induction of Coriolis and Somatogyral illusions
  - Arrival
  - Approach and landing
- Debriefing (not included in the time allocation)

The tasks set for the pilot trainee within the 60-minute duration are clearly defined. It involves instrument flight training in meteorological conditions suitable for instrument flight, flying to or from a VOR radio navigation aid, and following directives for directional or altitude flight trajectories from air traffic control. The primary goal is to experience somatogravic, Coriolis, and somatogyral illusions during a simulated flight. The session also includes improving instrument flight skills and practicing radionavigation. Throughout this exercise, two flight profiles are executed: one without illusions and one with implemented illusions. The profiles are comparable in nature but are not identical. The induction of illusions occurs in the second profile. This approach allows for a debriefing session where flight segments suitable for inducing specific illusions can be compared. Additionally, by executing two different flight profiles, the possibility of becoming overly familiar with a particular flight path is eliminated.

Twenty minutes are allocated for familiarization with the training equipment for a pre-flight run, as it is highly likely that the candidate will not be fully acquainted with this device, its features, and characteristics. During these 20 minutes, the candidate will test the sensitivity of the controls, get used to the layout of the cockpit instruments and their reading, or possibly refresh the basics of radionavigation.

In both specific flight profiles, takeoff and landing occur at Daniel K. Inouye International Airport. In the case of the flight with induced illusions, the delays between individual illusions are chosen so that the vestibular system of the trainee can return to its normal state, preventing excessive accumulation of the effects of individual illusions.

4.2.1 Briefing and Debriefing

In addition to appropriate theoretical preparation on the vestibular system and its illusions, it is necessary to acquaint the trainee with the flight profile during pre-flight preparation before each exercise. The profile should be thoroughly analyzed by segments and individual parts to ensure clarity. It is recommended not to disclose to the trainee which parts of the course will have illusions induced. The recommended time allocation for the pre-flight briefing is 30-60 minutes.

For the correct function of the automatic triggering of illusions and the fulfillment of conditions, it is advisable to remind the trainee to adhere to the instructions as precisely as possible, maintaining a speed of -5 to +10 knots, altitude within ± 150 feet, course within $\pm 5°$, and to use the standard rate of turn for instrument flying (3°/s), thus the corresponding bank angle in turns (for given class of aircraft).

If the trainee significantly deviates from the given instructions or does not maintain the proper bank angle during turns, the instructor should provide assistance through a verbal command; otherwise, the programmed conditions might not be met, and illusions may not trigger correctly or might activate at an inappropriate time.

The debriefing should be sufficiently long to evaluate the flight. The duration can be adjusted based on an agreement between the trainee pilot and the instructor according to personal needs. Assuming that the entire flight, flight data from the instruments, and control movements are recorded, this information can be used to reconstruct the flight. This allows for a demonstration of how flight parameters changed during the illusion and afterward.

4.2.2 Profile Without Illusions

For the initial flight, the runway's physical characteristics are set to a width of 150 ft, with zero longitudinal and lateral slope, and a length of 8000 ft. Runway, approach, and landing lights are turned on, as well as the tower lighting, with the intensity set to 50%. A low cloud layer with a base at 100 ft extends up to 4000 ft.

Cloud types are defined for the middle and upper layers, but their sky coverage is set to 0/8, meaning they have no effect. Wind is set to zero knots at all altitudes. Visibility for takeoff is set to 0.3 nautical miles with a thickness of 1000 ft. The air temperature is 32.22 °C and the air pressure is 1013.21 hPa.

After a verbal confirmation of readiness for takeoff between the participant and instructor, the simulation starts. Thirty seconds after the simulation starts, a message is initiated with the command for takeoff from runway 04R, followed by instructions to maintain the runway heading and climb to an altitude of 1500 ft. Fifty-five seconds after the simulation starts, it is verified whether the aircraft is at a higher longitude than 21° 19’ 50.00". If so, an instruction is played for a left turn to a heading of 300° and to climb to 2000 ft. This is followed by a check, sixty seconds after the simulation starts, to confirm that the aircraft is above 2000 ft in altitude and at a lower latitude than -157° 56’ 60.00". The flight continues with a recording instructing a right turn to a heading of 190.

Later in the flight, a command is issued to fly directly to the HNL VOR navigational beacon. Ninety-seven seconds after the simulation starts, it is verified that the heading is greater than 195°, and whether the bank angle is less than 8°, then at +163 seconds after the simulation starts, it is verified that the distance from HNL VOR is less than 2 miles. A command is then issued to turn left to a heading of 110° after passing HNL VOR. One hundred sixty-five seconds after the simulation starts, it waits for the condition that the aircraft’s heading is less than 122°. Then, a voice command is issued to descend to an altitude of 1500 ft. It is also checked whether the latitude is less than -157° 49’ 48.00”. If so, a command is issued to turn right to a heading of 315°.

From the time +241 it checks whether the aircraft’s heading is more than 320°. This is followed by a command to descend to 800 ft. At the time +262, it waits for the condition that the longitude is more than 21° 17’ 57.00”. This leads to a command for a left turn to a heading of 260° with clearance to land on runway 26R.

The program settings for the flight profile are presented below.

ⓘ The indicated times do not represent real flight time. They are guidelines for executing commands of the simulator software in differential mode.

Example of flight profile without illusions

Voice Message

Start Time	*30.00 s*	Message Name	*DF_2CAST_2_01.wav*
Duration	*10.19 s*	Volume	*50*
Message: "*Oscar Kilo Romeo Alpha Lima runway 0 4 right cleared for take off, when airborne maintain runway heading and climb altitude 1 thousand 5 hundred feet*"			

Condition

Start Time	*55.00 s*	Condition	*Latitude > 21° 19' 50.00"*

Voice Message

Start Time	*56.00 s*	Message Name	*DF_2CAST_2_02.wav*
Duration	*5.81 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn left heading 3 0 0 and climb altitude 2000 ft*"			

Condition

Start Time	*58.00 s*	Condition	*Altitude (MSL) > 1950.00 ft*

Condition

Start Time	*59.00 s*	Condition	*Longitude < -157° 56' 60.00"*

Low Level Clouds

Start Time	*60.00 s*	Type	*AltoCumulus*
Coverage	*8/8*	Base	*1000 ft*
Height	*4000 ft*	Slope	*0 deg*
Axis Heading	*0 deg*		

Visibility

Start Time	*60.00 s*	Condition	*Clear*
Visibility Distance	*5 mi*	Top	*200 ft*
BrownOut	*Disabled*	WhiteOut	*Disabled*

Voice Message

Start Time	*61.00 s*	Message Name	*DF_2CAST_2_03.wav*
Duration	*3.09 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn rght heading 190*"			

Voice Message

Start Time	*161.00 s*	Message Name	*DF_2CAST_2_05.wav*
Duration	*4.15 s*	Volume	*50*
Message: "*Oscar Alpha Lima, continue direct Hotel November Lima V O R*"			

Condition

Start Time	*163.00 s*	Condition	*Distance < 2.00 mile(s) from Lat : 21° 18' 29.91*

Voice Message

Start Time	*164.00 s*	Message Name	*DF_2CAST_2_06.wav*
Duration	*5.62 s*	Volume	*50*
Message: "*Oscar Alpha Lima, after passing Hotel November Lima V O R turn left heading 110* "			

Condition

Start Time	*165.00 s*	Condition	*Heading < 122.00 deg*

Voice Message

Start Time	*185.00 s*	Message Name	*DF_2CAST_2_06_5.wav*
Duration	*4.03 s*	Volume	*50*
Message: "*Oscar Alpha Lima, descend altitude 1 thousand 5 hundred feet* "			

Condition

Start Time	*186.00 s*	Condition	*Longitude > -157° 49' 48.00"*

Voice Message

Start Time	*189.00 s*	Message Name	*DF_2CAST_2_07.wav*
Duration	*3.43 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn right heading 3 1 5*"			

Condition

Start Time	*241.00 s*	Condition	*Heading > 320.00 deg*

Voice Message

Start Time	*261.00 s*	Message Name	*DF_2CAST_2_08.wav*
Duration	*3.58 s*	Volume	*50*
Message: "*Oscar Alpha Lima, descend altitude 8 hundred feet*"			

Condition

Start Time	*262.00 s*	Condition	*Latitude > 21° 17' 57.00"*

Voice Message

Start Time	*263.00 s*	Message Name	*DF_2CAST_2_09.wav*
Duration	*6.25 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn left heading 2 6 0 and runway 2 6 right cleared to land*"			

4.2.3 Profile With Illusions

For the flight profile with illusions, the physical characteristics of the runway are set to a width of 150 feet, zero longitudinal slope, zero lateral slope, and a length of 8000 feet. Runway, approach, and landing lights are turned on, as well as the tower lighting, with the intensity set to 50 percent. The low cloud level starts at an altitude of 100 feet with a thickness of 4000 feet. Cloud types are defined in both the middle and upper layers, but their sky coverage is set to 0/8, so they have no effect. Wind is set to a speed of zero knots at all possible altitudes. Visibility for takeoff is set to a distance of 0.3 nautical miles with a thickness of 1000 feet. The air temperature is 32.22 °C, and the air pressure is standard at 1013.25 hPa.

After verbal confirmation between the student and instructor regarding readiness for takeoff, the simulation is initiated. At simulation start time +30 seconds, a message is played with the command for takeoff from runway 08R, followed by instructions to maintain runway heading after takeoff and climb to an altitude of 1500 feet. At simulation start time +32 seconds, the somatogravic illusion is triggered when the longitudinal pitch is positive and exceeds 5 degrees.

From simulation start time +54 seconds, it is verified whether the condition that the aircraft's altitude is more than 1450 feet is met. If so, an instruction is played for turning right to a course of 160°. The fulfillment of the condition that the aircraft's course is greater than 167° is checked from simulation start time +70 seconds. The flight continues with the playback of a command to climb to an altitude of 2000 feet. From simulation start time +91 seconds, it is checked whether the condition of the altitude being more than 1950 feet is met, and the weather is reset. Visibility at ground level up to 200 feet is improved to 5 nautical miles. The low cloud setting remains at the initial setup. In the next phase, a recording with the command to turn left to a course of 270° is played. The execution of the Coriolis illusion with previously described angular velocities follows.

In the subsequent phase of the flight, a command is issued to fly directly to the HNL VOR navigation device. From simulation start time +215, respectively +216, it is verified whether the condition that the lateral pitch is less than 5° and the distance from HNL VOR is less than 2 miles is met. Next, a command is issued to turn left to a course of 250° after passing HNL VOR. From simulation start time +218 seconds, it is awaited for the condition that the aircraft's course is less than 262° to be met. Following this, a verbal command to descend to an altitude of 1500 feet is given. At the same time, it is checked whether the condition that the geographical latitude is less than -158° 1’ 48.00” is met. If so, a command is issued to turn left to a course of 045°. Then, the somatogyral illusion is applied to the flight.

From simulation start time +292 seconds, a check is conducted to ensure that the aircraft’s course is less than 60 degrees. This is followed by a command to descend to an altitude of 800 feet. From simulation start time +313 seconds, it is awaited for the condition to be met that the geographical longitude is more than 21° 17’ 57.00”. Subsequently, a command is issued for a left turn to a course of 080 degrees with clearance to land on runway 08R.

The program settings for the flight profile are presented below. The mechanics of inducing illusions are in accordance with the methodology in Chapter 3.

ℹ The indicated times do not represent real flight time. They are guidelines for executing commands of the simulator software in differential mode.

Example of flight profile with illusions

Voice Message

Start Time	*30.00 s*	Message Name	*DF_2CAST_1_01.wav*
Duration	*10.13 s*	Volume	*50*
Message: "*Oscar Kilo Romeo Alpha Lima runway 0 8 right cleared for take off, when airborne maintain runway heading and climb altitude 1 thousand 5 hundred feet*"			

Condition

Start Time	*31.00 s*	Condition	*Pitch Angle > 5.00 deg*

Pitch

Start Time	*32.00 s*		
Position	*12.00 deg*	Velocity	*4.00 deg/s*
Acceleration	*1.30 deg/s˛*	Duration	*6.08 s*

Pitch

Start Time	*38.00 s*		
Position	*0.00 deg*	Velocity	*1.00 deg/s*
Acceleration	*0.30 deg/s˛*	Duration	*15.68 s*

Condition

Start Time	*54.00 s*	Condition	*Altitude (MSL) > 1450.00 ft*

Voice Message

Start Time	*69.00 s*	Message Name	*DF_2CAST_1_02.wav*
Duration	*3.13 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn right heading 1 6 0*"			

Condition

Start Time	*70.00 s*	Condition	*Heading > 167.00 deg*

Voice Message

Start Time	*90.00 s*	Message Name	*DF_2CAST_1_03.wav*
Duration	*3.42 s*	Volume	*50*
Message: "*Oscar Alpha Lima, climb altitude 2 thousand feet*"			

Condition

Start Time	*91.00 s*	Condition	*Altitude (MSL) > 1950.00 ft*

Low Level Clouds

Start Time	*92.00 s*	Type	*AltoCumulus*
Coverage	*8/8*	Base	*1000 ft*
Height	*4000 ft*	Slope	*0 deg*
Axis Heading	*0 deg*		

Visibility

Start Time	*92.00 s*	Condition	*Clear*
Visibility Distance	*5 mi*	Top	*200 ft*
BrownOut	*Disabled*	WhiteOut	*Disabled*

Voice Message

Start Time	*114.00 s*	Message Name	*DF_2CAST_1_04.wav*
Duration	*3.37 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn left heading 2 7 0* "			

Condition

Start Time	*115.00 s*	Condition	*Heading < 170.00 deg*

Condition

Start Time	*116.00 s*	Condition	*Roll Angle < -5.00 deg*

Yaw

Start Time	*117.00 s*	Command Type	*Velocity*
Position	*-60.00 deg/s*	Velocity	*2.00 deg/s*
Acceleration	*30.00 s*		

Condition

Start Time	*148.00 s*	Condition	*Heading < 45.00 deg*

Voice Message

Start Time	*149.00 s*	Message Name	*DF_2CAST_1_05.wav*
Duration	*7.30 s*	Volume	*50*
Message: "*Oscar Alpha Lima, can you read the number on the plate? The plate is located on the left panel slightly behind you*"			

Condition

Start Time	*150.00 s*	Condition	*Heading < 275.00 deg*

Condition

Start Time	*151.00 s*	Condition	*Roll Angle > -8.00 deg*

Yaw

Start Time	*152.00 s*	Command Type	*Velocity*
Position	*0.00 deg/s*	Velocity	*1.00 deg/s*
Acceleration	*60.00 s*		

Voice Message

Start Time	*214.00 s*	Message Name	*DF_2CAST_1_06.wav*
Duration	*4.33 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn right direct Hotel November Lima V O R* "			

Condition

Start Time	*215.00 s*	Condition	*Roll Angle < 5.00 deg*

Condition

Start Time	*216.00 s*	Condition	*Distance < 2.00 mile(s)* *from Lat : 21° 18' 29.91*

Voice Message

Start Time	*217.00 s*	Message Name	*DF_2CAST_1_08.wav*
Duration	*5.83 s*	Volume	*50*
Message: *„Oscar Alpha Lima, after passing Hotel November Lima V O R turn left heading 2 5 0* "			

Condition

Start Time	*218.00 s*	Condition	*Heading < 262.00 deg*

Voice Message

Start Time	*238.00 s*	Message Name	*DF_2CAST_1_07.wav*
Duration	*4.03 s*	Volume	*50*
Message: "*Oscar Alpha Lima, descend altitude 1 thousand 5 hundred feet*"			

Condition

Start Time	*239.00 s*	Condition	*Longitude < -158° 1' 48.00"*

Voice Message

Start Time	*240.00 s*	Message Name	*DF_2CAST_1_10.wav*
Duration	*3.47 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn left heading 0 4 5* "			

Condition

Start Time	*241.00 s*	Condition	*Heading < 260.00 deg*

Condition

Start Time	*242.00 s*	Condition	*Roll Angle < -5.00 deg*

Yaw

Start Time	*243.00 s*	Command Type	*Velocity*
Position	*-60.00 deg/s*	Velocity	*1.50 deg/s˛*
Acceleration	*40.00 s*		

Condition

Start Time	*284.00 s*	Condition	*Heading < 65.00 deg*

Condition

Start Time	*285.00 s*	Condition	*Roll Angle > -15.00 deg*

Yaw

Start Time	*286.00 s*	Command Type	*Velocity*
Position	*0.00 deg/s*	Velocity	*12.00 deg/s˛*
Acceleration	*5.01 s*		

Condition

Start Time	*292.00 s*	Condition	*Heading < 60.00 deg*

Voice Message

Start Time	*312.00 s*	Message Name	*DF_2CAST_1_11.wav*
Duration	*3.58 s*	Volume	*50*
Message: "*Oscar Alpha Lima, descend altitude 8 hundred feet* "			

Condition

Start Time	*313.00 s*	Condition	*Latitude > 21° 17' 57.00"*

Voice Message

Start Time	*314.00 s*	Message Name	*DF_2CAST_1_12.wav*
Duration	*6.28 s*	Volume	*50*
Message: "*Oscar Alpha Lima, turn right heading 0 8 0 and runway 0 8 right cleared to land*"			

4.2.4 Additional remarks

Outcomes from flights on an simulator that induces illusions should cover several key aspects that help the trainee better understand and manage situations in a real aircraft in the future. Among the most beneficial outcomes of the entire exercise is the ability to recognize individual illusions.

Other important aspects include:

- Trainees should be able to identify different types of illusions that may occur during flight, including Somatogravic, Coriolis, and Somatogyral illusions. Beyond recognizing these illusions, trainees will become aware of the real situations that induce these illusions, enabling them to anticipate and avoid them in the future.
- Trainees should be capable of appropriately responding to illusions encountered during flight, with reference to instruments. This may involve correcting misperceptions of the aircraft's attitude, direction, or speed.
- The trainee pilot should correctly interpret information from cockpit instruments and navigation devices despite the presence of illusions. This includes distinguishing between the aircraft's actual attitude and illusory attitudes caused by vestibular illusions.
- Trainees should evaluate the risks associated with illusions and make appropriate decisions based on this assessment. This might involve, for example, deciding to correct the flight path or altitude in response to an illusory perception of the situation.
- Throughout the flight, the trainee should effectively communicate with the instructor/ATC. This could involve sharing information about perceived illusions and decisions made.
- Outcomes should reflect the trainee's ability to handle illusions and successfully manage them during a simulated flight. These skills are essential for the safety of aviation and the success of pilots under real conditions, since this type of training directly supports pilot competencies based on Threat and Error Management.

Given the physical and mental demands of vestibular illusion training, and considering the time allocation is at least 60 minutes, it is not recommended to assess the trainee's performance and results on a pass or fail scale.

Evaluating parameters against standards for successfully passing an instrument qualification exam is not considered for training flights on a vestibular illusions simulator. Simulator flights are part of the training with a clear goal to educate the pilot, not to serve as an exam or to be compared with one. In final flights with an examiner, the trainee demonstrates competence from learned and drilled scenarios. Flights on the vestibular illusions simulator do not replace these exams. During training, the potential for pilot failure is also accounted for. This fact was also demonstrated during research, showing that pilots could significantly deviate from the flight path or even crash due to illusions. The pilot can undertake multiple flights on the simulator to improve resilience and response to vestibular illusions, not being limited to just the initial, often unsuccessful, experience.

The example given pertains BIR training, designed as an introductory course for flying under IFR. Nevertheless, this type of training can also be integrated into various other training formats as well.

5

Concluding Remarks

The methodology outlined in the document establishes a structure for incorporating vestibular illusion training into pilot training programs, emphasizing the essential role of such training in enabling pilots to navigate and counteract spatial disorientation within simulated settings. This well-founded strategy, supported by thorough research and compliant with regulatory norms, equips pilots with crucial skills to enhance their resilience during IFR flights, directly contributing to the improvement of overall aviation safety. It delves into the mechanics and procedures for inducing specific illusions like somatogravic, Coriolis, and somatogyral through simulators, also highlighting ways these exercises can be integrated into the existing curricula of flight schools, thereby widening pilots' comprehension of spatial disorientation and readying them for real-world scenarios to elevate their preparedness and competency in flight operations.

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