Collegiate Aviation Review
International

Volume 39 | Issue 2 Peer Reviewed Article #8

11-04-2021

Usability of the Virtual Reality Aviation Trainer for Runway-Width Illusions

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The Virtual Reality Aviation Illusion Trainer (VRAIT) is a simulator that targets the topic of in-flight visual and vestibular illusions affecting pilots, specifically focusing on the runway width illusion. Effective training using state-of-the-art Virtual Reality (VR) technology is a new instructional method that can be leveraged to train pilots in recognition and awareness of aviation illusions, thus fostering a safer environment in the aviation industry. The VRAIT is designed to demonstrate simulated situations that can lead to illusions by providing examples of what the illusions look and/or feel like. A runway illusion scenario was designed, and pilots were recruited to provide feedback on their experience in the VRAIT. During the experience, pilots were reminded of what to do if illusions were experienced in flight through an active learning experience that aimed to better prepare the pilot to identify and take corrective action when and if future in-flight illusions occur. Data was collected on pilot experience during the scenarios, pilot enjoyment, realism, simulator sickness, the effect of the illusion, and knowledge gained in the scenario. Although knowledge on VR as a training tool is widely available, the research aimed to address the gap in whether VR is a useful and effective tool for training pilots for in-flight illusions.

Recommended Citation:
Thomas, R. L., Dubena, R., Camacho, G. L. J., Nieves, N. A., Barcza, T. D., Green, S., & Perera D. (2021). Usability of the virtual reality aviation trainer for runway-width illusions. *Collegiate Aviation Review International*, 39(2), 163-179. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/8356/7658

Introduction

One of the leading causes of worldwide fatal aircraft crashes is loss of control in flight (IATA, n.d.). In-flight illusions can be a major causal factor to loss of control in flight (Patterson, 2013). The human body receives orientation and movement information from three main physiological sources when flying: vestibular, somatosensory, and visual systems (FAA, 2011). Although most accidents happen during the maneuvering phases of takeoff and landing, in-flight illusions severely degrade the pilot's situational awareness, which is a major factor in the chain of events that lead to a crash (Meeks et al., 2021). Pilots generally have a clear idea of body and aircraft movement based on information received from these three systems; however, under certain flying conditions, pilots can become disoriented when one or more of these systems provide conflicting information to the brain. The vestibular system, for example, becomes unreliable when the pilot loses visual contact with the horizon (FAA, 2016). Disorientation can then lead the pilot to misinterpret airplane attitude and unintentionally put the aircraft in an unfavorable/dangerous flight profile. One example is the crash of Flash Airlines Flight 604. The first major contributing factor to this accident was Spatial Disorientation experienced by the flight crew, as cited on the Egyptian Ministry of Civil Aviation's (EMCA) Final Report of the accident (EMCA, 2005).

Two remedies for overcoming spatial disorientation are prevention and awareness (FAA, 2011). Virtual Reality (VR) training can be a great resource to help develop an awareness and possibly prevent pilots from getting into a disoriented scenario by allowing them to experience the illusion from a safe training setting. By simulating the flight scenario using VR, pilots can visualize what the illusion looks like so they can be better prepared to take corrective action should they encounter such a situation in flight. The training aims to expose pilots to a runway width illusion scenario through VR and analyze various aspects of the usability and perceived fidelity of the system. The goal of the experiment is to analyze the effectiveness of VR as a learning/training tool, and to examine the reaction of student and instructor pilots to a VR software that simulates a changing runway width in-flight illusion.

Review of Relevant Literature

Vision is one of the most important senses for the safety of flight (FAA, 2016). The use of visual cues through hours of training gives the pilot an idea of the aircraft's orientation relative to the ground. Though heavily relied upon, there are key pitfalls to the visual system of which pilots need to be cognizant to prevent falling into unfavorable flight attitudes. A visual illusion occurs when a pilot becomes disoriented due to conflicting visual cues (FAA, 2016).

Runway Width Illusion

One type of visual illusion is the runway width illusion, which occurs when a pilot is approaching a runway that is narrower or wider than they are accustomed to. When the runway is narrower than what they are used to, the pilot's visual system gives them the feeling that they are higher on their approach path than normal (FAA, 2016). The pilot's response would then be to pitch down to increase the descent rate, to achieve what the pilot feels to be a normal approach path. In doing so, the pilot will then fly a lower-than-normal approach, causing the pilot to touch down before the start of the runway (FAA, 2011).

On the other hand, if the pilot was to approach a runway that is wider than normal, visual cues would give the pilot the impression that they are on a lower approach path than normal (FAA, 2011). To correct the illusion of being low, the pilot's response would be to increase the pitch attitude to arrest the descent rate and establish an approach path that the pilot feels to be normal. In doing so, the aircraft would actually be flying a higher approach path than normal, which may result in a low-altitude stall or a missed approach (FAA, 2011).

Although there is no single direct remedy to overcome spatial disorientation or counteract the perception of being high/low during an approach to a wide or narrow runway, there are measures that can be taken to lessen the risk associated with entering an undesired flightpath. Hazard awareness and assessment are two key strategies that can help pilots avoid the effects of a visual illusion (Airbus, 2005). Knowing the airport environment and assessing the terrain information relevant to the operation are ways of mitigating the risk of a visual illusion. Furthermore, if flying in a multi-crew environment, Crew Resource Management is a key resource to be used, as task sharing and effective cross-check of items inside and outside the cockpit are fundamental for ensuring the safety of the flight and checking to ensure the crew is not susceptible to illusions (Flight Safety, 2009).

Illusion training and education are two methods that can also prepare pilots ahead of time on what to expect, should they find themselves flying into a wider/narrower runway than they are accustomed to. Topics such as depth, perception of height, and assessment of glide path are important for pilots to understand for them to know beforehand what to expect when flying an unfamiliar approach (Airbus, 2005). Furthermore, making use of all available resources, such as approach lights, runway lights, and instrument approaches, can help the pilot accurately judge the airplane's height over the terrain and thus reduce the chance of being deceived by a visual illusion (Flight Safety, 2009). Following the indications of the instruments is the safest action a pilot can take if found in an undesirable situation. A pilot should seek to avoid following body sensations and reference the flight instruments whenever possible before changing the aircraft's flight path (Wynbrandt, 2004).

Another method pilots use to help develop an awareness of disorientation in flight is by undergoing a simulation training scenario. The Barany Chair and Vertigon are two devices that induce a spatial disorientation sensation by various rotating parts and gimbals. The GAT Trainer is also a simulator that is placed on a rotating base that allows the pilot to fly a scenario while the base of the simulator spins, thus allowing the pilot to experience various vestibular illusions (Wynbrandt, 2004). With the continual development of new technologies, VR has also become a major innovative solution for the prevention of in-flight illusions.

To adequately adapt aviators to flight illusions, training programs can effectively utilize VR, which has progressively proven to produce better performance in memory tasks than traditional book methods of learning and video conditions (Allcoat, D., & von Muhlenen, A., 2010). VR adapts all three learning styles of visual, auditory, and kinesthetic to aid the user in the proficiency of learning a new concept. Learning through multiple modalities ensures the effectiveness of retaining information and allows the user to test concepts that enable active learning. When a user is placed in an immersive system, their learning complexity is simplified to Mayes and Fowler's three fundamental stages of "conceptualization, construction and dialogue" (Fowler, 2015). The user conceptualizes information by gathering facts, then constructs these facts through presenting and explaining what was learned through a final dialogue, whether that be through an application or some form of discussion.

Counteracting disorientation through flight is best attempted using adaptation. To effectively adapt an individual to any new circumstance, adaptation should be consistent, incremental in exposure and introduced over a distributed period to counteract aversive effects. Options considered as stimuli have been medication, adaptation programs, behavioral strategies and sensory cueing. Medication treats the symptoms but does not prevent the symptoms from occurring (Lawson, Rupert, & McGrath, 2016). Behavioral strategies are not always readily available in up-tempo situations in which individuals experience task overload or emergency situations. What is left becomes adaptation training programs and sensory cueing where somatosensory inputs are enhanced.

To effectively target participants to respond realistically in VR, realistic simulations are imperative. For a user to become engaged in realistic responses with the immersive system, there are two necessary components called place illusion and plausibility illusion (Slater, 2009). Place illusion contributes to the user having a sensation that they are present within the simulation even though they are not there. The sense of immersion within the illusion is codified through sensorimotor contingencies, which are the actions carried out to perceive the environment such as moving the head up and down, or bending down and seeing something from a different point of view (Slater, 2009). The further the user probes the system, the more likely the place illusion is to break once the virtual boundaries are surpassed. Each user comes out of the experience with a different opinion that will dictate the place illusion's effectiveness.

The plausibility illusion keeps the user engaged in the scenario that is occurring. To maintain the user's attention, events that are not in direct user control in the virtual environment must always refer to the user. The user's realistic response to items in the virtual world is thereby referred to as "response-as-if-real" (Slater, 2009). Overall, the place illusion can be treated as binary because the illusion is either there or not, in different modalities. Individuals are capable of maneuvering through a cockpit tutorial while still asking their instructor questions that are not within the tutorial. In contrast, the plausibility illusion does not reform again if broken (Slater, 2009). The ability to maintain both place and plausibility illusions is dependent upon an event lining up with the expectations of what the user deems is likely to occur in each scenario. Perhaps the point of presence in the illusion is to target the user on a perceptual level, not as in a cognitive illusion. The user's perceptual system recognizes a threat and rapidly responds much before the cognitive system can catch up and remind the user that the illusion is not real; however, the reaction has already occurred. Although users are aware that the VR scenario is a fictitious environment, that does not change their attitude or perception of the training (Slater, 2018).

Simulator Sickness in VR

Disorientation is a major symptom of cyber-sickness, also called VR sickness. Causes of cyber-sickness can be separated into three main categories: hardware, content, and human factors, all of which contribute to overall user discomfort. Hardware factors include features of the device itself, such as display, where content factors reference the function and use within the program/experience itself, thus referring to differences related to individual personal characteristics that affect discomfort during VR use. A literature review by Chang, Kim, and Yoo (2020) found that existing research on hardware factors have focused primarily on display, with sub-factors including latency, flicker, field of view (FOV), and display type and mode. Most of these studies have collected data via subjective measures, namely, the simulator sickness questionnaire (SSQ) as opposed to objective features. With advances in hardware, however, updates to the software must also occur. Chang, Kim, and Yoo (2020) identified five categories of VR content factors: optical flow, graphic realism, reference frame, content FOV, and task. Again, measurements were primarily subjective. The use of objective measurements has been limited. The field of VR research should diversify the forms of measurement used, particularly by collecting more physiological data or otherwise objective measurements (Chang, Kim, and Yoo, 2020.).

The Motion Sickness Questionnaire (original version by Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G., 1993) was used to quantify any motion sickness participants might have felt during the scenario. The benefit of the Simulator Sickness Questionnaire (SSQ) over a general Motion Sickness survey is that the SSQ focuses more on symptoms that can be experienced under exposure to a simulator, which is a reliable method of measuring various symptoms that can be felt by participants specifically in a simulator environment. The questions addressed in the SSQ asked the user to rate symptom intensity ranging from none, slight, moderate, or severe in the following:

- General Discomfort
- Fatigue
- Headache
- Eye Strain
- Difficulty Focusing
- Salivation
- Sweating
- Nausea
- Difficulty Concentrating
- Fullness of the Head
- Blurred Vision
- Dizziness with Eyes Open
- Dizziness with Eyes Closed
- Vertigo
- Stomach Awareness
- Burping

Results from the survey questions and how different groups of participants' answers differed from each other will be further analyzed in the Results section of the report.

Usability of VR in Training

Virtual illusions are utilized in VR to keep the user engaged and counteract the user's rigid perception of reality. The human brain quickly adapts to unchanging stimuli in a process called adaptation (Huckins, 2020). Manipulation of environments within the virtual world exceeds that of the physical world in false visual feedback, which can be utilized as a direct benefit in training (Cuperus, 2019). To create human-machine interfaces to support such models of training, eye-hand controls and head motion tracking devices have been under continuous revision. Visual mechanisms focus on the lower, middle, and higher levels of vision. The lower level concentrates on where the user's attention is focused at the time on the high visual acuity of the fovea. The middle level of vision focuses on the peripheral sense of motion perception. The higher level of vision is the eye movements that generate the "representation" or "cognitive model" of a scene (Stark, 1995).

With these separate processes occurring in the eye, there is a top-down model created where vision completes the perceived visual information of the visual world where humans foveate approximately 30 times in 10 seconds throughout varied scan paths (Stark, 1995), which can at times lead to the illusion of seeing without looking when there are dual displays on augmented reality. Particularly in simulated airplane landings onto runways, there are documented cases where individuals are looking at dual controls and the runway simultaneously and overlook a vehicle at the end of the runway (Stark, 1995). Training to counteract these occurrences has proved beneficial when presented with these situations in VR.

Engaging users through VR beyond the perceptual level to the cognitive level requires effective processes to be applied. Bottom-up multisensory processing, sensor motor self–awareness frameworks, and top-down prediction manipulations can be utilized in combination to generate brain mechanisms of a user to "believe" that a computer-generated world can be real (Gonzalez, 2017). In bottom-up processing the brain combines bodily signals to adapt feedback that will enable the user to respond effectively to the environment, which serves as a key component of self-body consciousness (Gonzalez, 2017).

Problems with simulators tend to divulge themselves when the visual and vestibular systems do not match. The brain then is made to believe that the body is both static and moving (Gonzalez, 2017). To overcome the differences in information the brain is receiving, systems can be manipulated to outweigh the information that is being relayed to the brain. Sensory information can then be changed by keeping moving individuals stationary or seated. When seated, an individual has more proprioceptive sensors relaying to the brain that the body is static, which can overcome the visual information being relayed to the brain. To overcome visual information relayed to the brain, headset hardware must be specially designed to maximize peripheral vision to the user. Enhancing cognitive level effects in VR illusions can benefit the "conversion moment" described by users since the 1980s; the conversion from stepping out of the real world into one of VR is now cognitively possible (Gonzalez, 2017), thanks to the advances in hardware and software technology currently available.

Summary

VR makes it possible for users to feel that they are part of an altered situation and identity. Participants have responded to these situations as if they were their reality. To be able to create these illusions, there is basic equipment and stimulations of the sensory inputs that are necessary. VR instrumentation includes sensors to track and measure a set of the participants' body motions, physiological states, and displays (Gonzalez-Franco et al., 2017).

When the sensor-coupled stimuli match what participants' brains expect of what will come next, the brain tends to treat that simulated reality as real, then engages more neural mechanisms to continue the perceived truth of the illusion. Research shows that VR can stimulate coordinated perceptual modalities so that the brain mechanisms which collect and process afferent sensory input will interpret the information coherently (Kilteni et al., 2015). For participants to be able to interact with their environment without breaking the illusion, there must be minimum VR instrumentation with a continuously updated (head-tracked) display. (Gonzalez-Franco et al., 2017).

Therefore, VR training for in-flight illusions can be an effective training solution for illusion prevention and awareness. By engaging in active learning through the VR environment, participants can experience the illusion from a safe setting (simulation), which aims to better prepare them for maintaining constant awareness in-flight. Specifically tailored to the runway-width illusion, the experiment aims to better prepare pilots to detect and take corrective action during the final approach to a runway that might seem wider or narrower than what the pilot is accustomed to.

Methodology

The runway width illusion experiment aimed to investigate the usability of VR training software and supporting devices to determine whether VR is an appropriate system that can accurately simulate real-world aviation illusion scenarios. Embry-Riddle Aeronautical University's (ERAU) Institutional Review Board approved the research project.

Recruitment

Participants were recruited through the use of flyers, emails, and word-of-mouth. The participants were required to be ERAU students, possess or currently be undergoing training for a Federal Aviation Administration (FAA) pilot certificate, and be at least 18 years of age. A total of 30 participants were recruited, each with varying levels of flying experience.

Process and Procedures

All participants met one-on-one with the researcher for the entire duration of the study and were scheduled for a one-hour time block. The illusion scenario was conducted in the Extended Reality (XR) Lab in the ERAU College of Aviation in Daytona Beach, FL. The procedure began with the participant filling out the Informed Consent Form, followed by the completion of the Demographic Survey. The participant was briefed on how the equipment worked and how to operate the controllers for the VR scenario. The participants then completed the illusion training scenario under the supervision of the researcher and simulator technician. Following the scenario, the participants completed the SSQ and the Post-Training Survey.

Equipment

The VR equipment used was the Valve Index Headset. Participants were instructed to sit in a normal rotating office chair located in the center of the XR Lab. Two hand controllers were available for participants to navigate through menus, but the illusion scenario required no physical input from the participants during the flight scenarios.

Results

The experiment recruited a total of 30 participants (*n*=30). Of the 30 participants, 13 held or were undergoing training for their Private Pilot certificate, six were Commercial Pilots, and 11 were CFIs. Furthermore, out of the 30 participants, 18 of them were aged 19-21, and 12 were 22 years old and over. For statistical analysis purposes, participants were divided into two groups: Those with a CFI certificate and those without. Age was considered as a factor to separate participants into two groups, but flight experience was chosen as a better method of making groups more unique. In this case, those holding a CFI certificate were deemed the group that has more flight experience due to the training time required to possess the additional certificate. Between participants who held a CFI certificate and those who did not, there was significant difference ($p < .001$) in the average amount of flight time; for CFIs ($M = 392.455$, $SD = 124.1542$) and Non-CFIs ($M = 184.789$, $SD = 110.9537$). Therefore, based on flight experience, “CFI vs. Non-CFI” was used as a category to separate participants into two groups. There were a total of 11 CFIs and 19 Non-CFIs in the study.

Pilots with less flight experience (and less exposure to aeronautical knowledge) may benefit more from a VR training experience. For this reason, multiple usability and reaction questions were compared between more experienced and less experienced pilots, to examine if there were any changes in pilot perception of the training software due to flight experience. Results collected and analyzed comprised the usability of the VR equipment (aspects such as how participants enjoyed the illusion, how confident they felt in their abilities to identify a runway illusion, how likely they were to recommend the illusion scenario to a fellow pilot, as well as data regarding the SSQ (which simulator symptoms participants felt, and the strength of each symptom felt).

Post-Training Survey

The Post-Training Survey aimed to investigate the usability of the VRAIT as an appropriate and accurate aviation illusion simulator. The following questions were addressed in the survey:

1. The scenario made me feel as if I was on a real approach to landing.
2. The controls in the scenario were easy to understand and use.
3. The scenario made me feel as if my altitude was changing when the aircraft was paused.
4. The scenario gave me a greater awareness of runway width illusions.

5. I feel more confident in my ability to perceive runway width illusions.
6. The narration during the scenario helped me understand this runway illusion lesson.

The Likert Scale was used as a means to quantify user opinion with scores ranging from 1-5, where 1 was Strongly Disagree, and 5 corresponded to Strongly Agree. Results were recorded along with some basic demographic data from each participant, so answers could be analyzed as a whole, as well as compared between different groups of participants. For the Post-Training Survey, a mean closest to five would indicate better/more favorable simulator usability.

Table 1
Usability of the VRAIT among CFIs and Non-CFIs: Means & SD

	CFI or Non-CFI	N	Mean	Std. Deviation
The scenario made me feel as if I was on a real approach to landing.	Non-CFI	19	4.37	0.60
	CFI	11	4.36	0.92
The controls in the scenario were easy to understand and use.	Non-CFI	19	4.63	0.50
	CFI	11	4.73	0.47
The scenario made me feel as if my altitude was changing when the aircraft was paused.	Non-CFI	19	4.05	1.03
	CFI	11	4.00	1.18
The scenario gave me a greater awareness of runway width illusions.	Non-CFI	19	4.68	0.48
	CFI	11	4.64	0.92
I feel more confident in my ability to perceive runway width illusions.	Non-CFI	19	4.42	0.61
	CFI	11	4.36	1.03
The narration during the scenario helped me understand this runway illusion lesson.	Non-CFI	19	4.63	0.50
	CFI	11	4.73	0.47
I would recommend this training scenario to fellow pilots.	Non-CFI	19	4.74	0.45
	CFI	11	4.73	0.65

The objective of the experiment was to analyze how well VR software can reliably represent the runway width illusion scenario in a training environment, and if there were any differences in response among two different groups of pilots. The null hypothesis that there was no difference in how well participants reacted to the VR training scenario between CFIs and Non-CFIs was tested. The assumption of the equality of variance was tested. Levene's test of equality of variance was not significant for any case ($p > .05$).

All of the questions received a mean score of 4 or above on the Likert Scale. Most of the questions were close to a value of 5, which indicates the participants Strongly Agree. These high scores indicate a positive reaction by both low and highly-experienced pilots towards the VRAIT as a learning and training tool.

One of the questions, "The scenario made me feel as if my altitude was changing when the aircraft was paused," had a slightly higher SD of 1.18 among the CFI group's mean of 4.0. Reasons for this could include that some CFIs have already been exposed to other illusion training aids, are already knowledgeable about the illusion, or possibly have experienced the runway width illusion in real life, which would lead to a wider distribution of scores. Pilots with less experience, including those still undergoing training, were believed to benefit more from a training device such as the VRAIT. This idea is supported by means of questions 2, 3, and 4. Pilots with lower experience ranked these questions slightly higher and with a smaller SD compared to CFIs. Nonetheless, the overall scores of all questions, for both groups support good usability, high fidelity and effectiveness of the VRAIT as a training and learning tool for pilots, as shown in Figure 1.

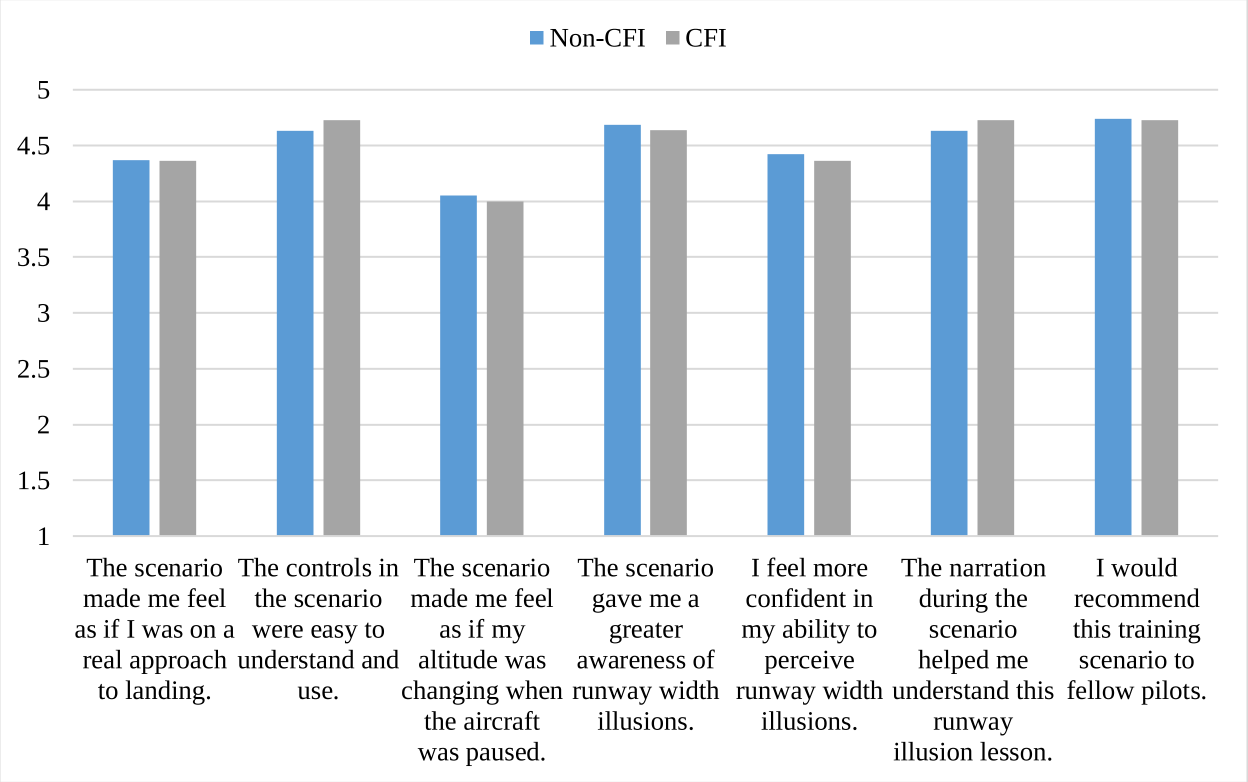

Figure 1. Usability of the VRAIT among CFIs and Non-CFIs: Means (Illustrated)

None of the *t*-tests presented a statistically significant difference in how CFIs and Non-CFIs ranked their answers related to the Usability of the VRAIT. “The controls in the scenario were easy to understand and use,” for CFIs (*M* = 4.727, *SD* = .4671) scored a slightly larger mean than for Non-CFIs (*M* = 4.632, *SD* = .4956). Nonetheless, an independent samples *t*-test was not significant at the alpha level of .05, *t*(28) = -.520 , *p* = .607. The null hypothesis was retained for all cases.

Simulator Sickness Questionnaire

A *t*-test was conducted to identify any differences in simulator sickness symptoms:

Table 2
Motion Sickness Symptoms among CFIs and Non-CFIs: Means & SD

	CFI or Non-CFI	N	Mean	Std. Deviation
General Discomfort	Non-CFI	19	1.16	0.37
	CFI	11	1.36	0.67
Fatigue	Non-CFI	19	1.00	0.00
	CFI	11	1.27	0.47
Headache	Non-CFI	19	1.00	0.00
	CFI	11	1.27	0.65
Eye Strain	Non-CFI	19	1.21	0.42
	CFI	11	1.36	0.67
Difficulty Focusing	Non-CFI	19	1.21	0.42
	CFI	11	2.09	1.14
Salivation Increase	Non-CFI	19	1.11	0.32
	CFI	11	1.36	0.81
Sweating	Non-CFI	19	1.37	0.68
	CFI	11	1.18	0.40
Nausea	Non-CFI	19	1.00	0.00
	CFI	11	1.18	0.40
Difficulty Concentrating	Non-CFI	19	1.00	0.00
	CFI	11	1.55	1.04
Fullness of the Head	Non-CFI	19	1.26	0.56
	CFI	11	1.46	0.69
Blurred Vision	Non-CFI	19	1.37	0.60
	CFI	11	1.82	0.87
Dizziness (Eyes Open)	Non-CFI	19	1.00	0.00
	CFI	11	1.27	0.65
Dizziness (Eyes Closed)	Non-CFI	19	1.00	0.00
	CFI	11	1.18	0.60
Vertigo	Non-CFI	19	1.05	0.23
	CFI	11	1.09	0.30
Stomach Awareness	Non-CFI	19	1.05	0.23
	CFI	11	1.00	0.00
Burping	Non-CFI	19	1.00	0.00
	CFI	11	1.00	0.00

The null hypothesis that there was no difference in motion sickness symptoms felt among CFIs and Non-CFIs was tested. None of the *t*-tests presented a statistically significant difference in how CFIs and Non-CFIs felt the symptoms of motion sickness, except “Difficulty Focusing.” “Difficulty Focusing” was the only symptom that demonstrated a statistical difference among participants. Levene’s test of equality of variance was significant (p = .005).

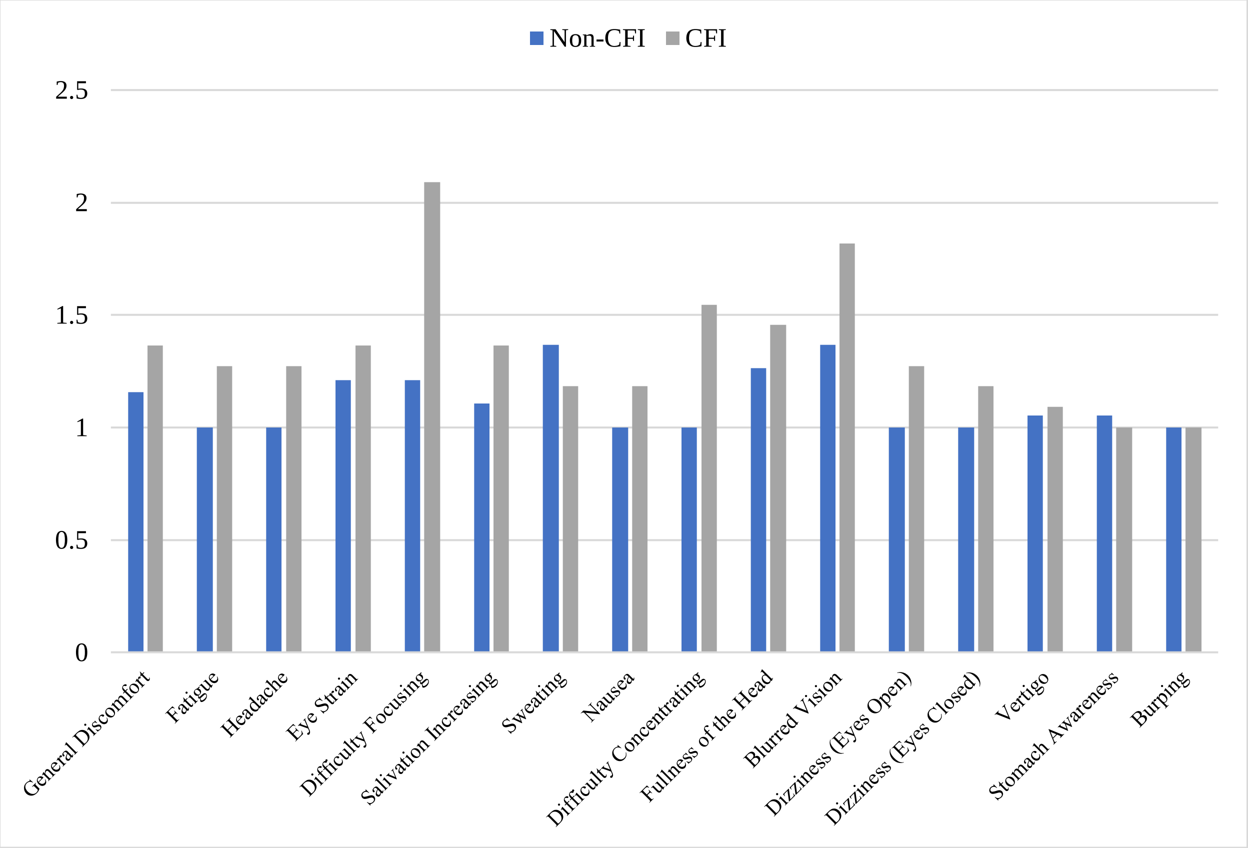

Figure 2. Motion Sickness Symptoms among CFIs and Non-CFIs: Means (Illustrated)

CFIs ranked difficulty focusing (*M* = 2.091, *SD* = 1.1362), higher than Non-CFIs (*M* = 1.211, *SD* = .4189). A one-independent sample *t*-test was significant at the alpha level of .05, *t*(11.596) = -2.474, *p* = .030, therefore, the null hypothesis was rejected. Cohen’s *d* = 1.03, which is a large effect. Apart from Difficulty Focusing, all other motion sickness symptoms were not significantly different among the two groups of participants. Most means were considerably low, which on the Likert Scale, closest to one would indicate none/very low motion sickness symptoms.

Table 3
Motion Sickness Symptoms among CFIs and Non-CFIs: t-tests

	t	df	Sig. (2-tail)
General Discomfort	-.932	13.652	.367
Fatigue	-1.936	10.000	.082
Headache	-1.399	10.000	.192
Eye Strain	-.770	28	.447
Difficulty Focusing**	-2.474	11.596	.030
Salivation Increasing	-1.015	11.785	.330
Sweating	.822	28	.418
Nausea	-1.491	10.000	.167
Difficulty Concentrating	-1.747	10.000	.111
Fullness of the Head	-.828	28	.414
Blurred Vision	-1.675	28	.105
Dizziness (Eyes Open)	-1.399	10.000	.192
Dizziness (Eyes Closed)	-1.000	10.000	.341
Vertigo	-.392	28	.698
Stomach Awareness	.755	28	.456

*** indicates p < .05*

Scenario Description

Participants were seated in a Cessna 172 on final approach to a runway on a clear day. As the aircraft approached the runway, the simulation froze at 100 feet above the ground (AGL), and the runway width increased/decreased at certain intervals. A verbal narration provided participants context and knowledge on the illusion during the course of the simulation. The approach then continued until the aircraft was about to flare, and the simulation froze one more time. The runway width again transitioned multiple times from narrow, to normal, to wide, while the narration described ways to identify and mitigate the illusion.

Figure 3. Demonstration of changes in runway width: Wide, Normal, Narrow

Limitations

There were three limitations encountered throughout the study. First, the sample size was somewhat small (*n*=30), as the study was designed as a proof of concept for further training material development. Conclusions and statistical comparisons could be more robust if the sample size was larger and included pilots with various experience levels. Second, the participants were only recruited from students enrolled at ERAU's Daytona Beach campus. Therefore, the results obtained may not be generalizable to the entire general aviation population but instead focused more on the collegiate aviation training program population. Lastly, some of the questions posed were opinion-type inquiries and were reliant on truthful answers and subjective opinions of participants.

Discussion, Conclusions, and Recommendations

There are various factors that contribute to the safety of the aviation industry in the United States. Mechanical equipment, infrastructure, facilities, and personnel training in aviation are structured and maintained at very high standards to lessen the chances of an unexpected event and mitigate risks. Pilots are trained and evaluated by rigorous FAA standards constantly, ensuring the safety of individuals as well as of the general flying public. Human factors, however, play a large role in the safety of the aviation system. (Patterson, 2013).

Disorientation can lead a pilot to put the aircraft in an undesired state, compromising the safety of flight if not properly corrected. Therefore, pilots must understand possible in-flight illusions and their effects, as well as ways to overcome them when encountered. There is no single solution to overcoming in-flight illusions, but two main remedies for detecting and overcoming in-flight illusions are awareness and prevention (FAA, 2011). Awareness could be accomplished by a pilot effectively planning for unexpected pitfalls before the flight and knowing what to expect for that specific operation. Prevention, on the other hand, could be accomplished by practice and simulation training.

The Virtual Reality Aviation Illusion Trainer was a resource used to simulate the Runway Width in-flight illusion. Participants from different age groups and different flight backgrounds ran through the scenario and were asked to evaluate their experiences and opinions about usability, faithfulness, general reactions, and physiological symptoms they might have felt in the scenario. Participants were separated into two groups based on flight experience (split between CFIs and Non-CFIs), and results to multiple post-session questions were analyzed and compared among the two groups.

Both groups had a generally positive reaction to the simulation scenario. Seven questions were asked regarding the usability of the VRAIT, based on a scale of 1-5 (where 5 would be very good). The means of all the questions were 4 or above for all questions among both groups of participants, indicating the participants enjoyed the scenario and viewed the VRAIT as a useful training tool. When comparing the symptoms of motion sickness, 16 different symptoms were analyzed per participant. Fifteen of those did not present a statistically significant difference between groups. Most means were considerably low (on a scale of 1-4, where 1 would indicate no symptom felt). When analyzing these results, flight experience had no significant effect on participant perception/reaction towards the VR training, as well as among symptoms of motion sickness. Based on these results, the VRAIT could be an effective tool for training pilots of different age groups and different flight experience backgrounds.

Some recommendations for future studies include gathering a larger sample size for better accuracy of data collected. Although the study counted with a total of 30 subjects, if more participants were available, subjects could be placed into more diverse categories for comparison purposes. Another recommendation for further research could include different questions aimed at addressing other factors of equipment usability, such as biometrics or ergonomic factors. More questions could be tailored toward objective parts of the illusion, such as testing if subjects were able to identify a purposefully integrated flaw or detail into the illusion scenario. Furthermore, the development of different illusions appears to be the most relevant recommendation following the completion of the study, according to the overall positive feedback received from participants.

Technology is in constant growth and development across all sectors of the aviation industry. In the field of training, since the first aircraft simulator was created, new training solutions have been developed and adapted by flight schools, airlines, and governmental agencies for better and more accurate personnel training. The VRAIT aims to use the best of existing VR technology to help pilots become more aware of in-flight illusions and further their knowledge on prevention techniques. Modern, effective training using VRAIT aims to help bring forth a safer environment for pilots and all users of the national airspace system.

References

Airbus, C. (2005, September). *Human Performance Visual Illusions Awareness.* Airbus. https://www.smartcockpit.com/docs/Visual_Illusions_Awareness_and_Avoidance.pdf

Allcoat, D., & von Muhlenen, A. (2010). Learning in virtual reality: Effects on performance, emotion and engagement. *Research in Learning Technology,* 26, 1-13. https://doi.org/10.25304/rlt.v26.2140

Cuperus, A.A., Disco, R.T., Sligte, I. G., van der Kuil, M.N.A., Evers, A. W. M., & van der Ham, I.J.M.(2019). Memory-related perceptual illusions directly affect physical activity in humans. *PloS One*, 14(5), e0216988-e0216988. https://doi.org/10/1371/journal.pone.0216988

Egyptian Ministry of Civil Aviation. (2005). *Final Report of the Accident Investigation – Flash Airlines Flight 604.* Central Administration for Aviation Accidents

Federal Aviation Administration. (2016). *Pilot's Handbook of Aeronautical Knowledge.* U.S. Department of Transportation, Federal Aviation Administration

Federal Aviation Administration. (2011). *Spatial Disorientation Visual Illusions.* U.S. Department of Transportation, Federal Aviation Administration

Flight Safety. (2009). *Visual Illusions.* FSF Alar Briefing Note. https://www.smartcockpit.com/docs/visual-illusions.pdf

Fowler, C. (2015). Virtual reality and learning: Where is the pedagogy? *British Journal of Educational Technology*, 46(2), 412-422. https://doi.org/10/1111/bjet.12135

Gonzalez-Franco, M., & Lanier, J. (2017). Model of illusions and virtual reality. *Frontiers in Psychology,* 8, 1125-1125. https://doi.org/10.3389/fpsyg.2017.01125

Haggard P., Clark S., Kalogeras J. (2002). Voluntary action and conscious awareness. *Nat.Neurosci.* 5, 382–385. https://doi.org/10.1038/nn827

Hancock, P.A., Lawson, B.D., Cholewiak, R.W., Elliott, L.R., van Erp, J.B., Mortimer, B.J., Rupert, A.H., & Redden, E.S. (2015). Tactile cuing to augment multisensory human-machine interaction. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 23, 4 - 9. https://doi.org/10.1177%2F1064804615572623

Huckins, G. (2020, August 08). *What Virtual Reality for Flies Teaches Us About Human Vision.* Wired Conde Nast. https://www.wired.com/story/what-virtual-reality-for-flies-teaches-us-about-human-vision/

International Aviation Transportation Organization. (n.d.). *Loss of Control In-flight (LOC-I).* IATA. https://www.iata.org/en/programs/safety/loss-of-control-inflight/

Kilteni K., Maselli A., Kording K. P., Slater M. (2015). Over my fake body: body ownership illusions for studying the multisensory basis of own-body perception. *Frontiers in Human Neuroscience.* https://doi.org/10.3389/fnhum.2015.00141

Lawson, B. D., Rupert, A. H., & McGrath, B. J. (2016). The Neurovestibular Challenges of Astronauts and Balance Patients: Some Past Countermeasures and Two Alternative Approaches to Elicitation, Assessment and Mitigation. *Frontiers in Systems Neuroscience*, *10*, 96. https://doi.org/10.3389/fnsys.2016.00096

Meeks, R. K., Anderson J., Bell P. M. (2021). *Physiology Of Spatial Orientation.* StatPearls. https://www.ncbi.nlm.nih.gov/books/NBK518976/

Patterson, F. R., Arnold, R. D., & Williams, H. P. (2013). Visual Perspective Illusions as Aviation Mishap Causal Factors. *17th International Symposium on Aviation Psychology*, 512-517. https://corescholar.libraries.wright.edu/isap_2013/29

Slater, M. (2018). Immersion and the illusion of presence in virtual reality. *The British Journal of Psychology*, 109(3), 431-433. https://doi.org/10.1111/bjop.12305

Slater, M. (2009). Place illusion and plausibility can lead to realistic behavior in immersive virtual environments. *Philosophical Transactions. Biological Sciences*, 364(1535), 3549-3557. https://doi.org/10.1098/rstb.2009.0138

Stark, L. W. (1995). How Virtual Reality Works: Illusions of vision in “real” and virtual environments. [Paper presentation]. *IS&T/SPIE's Symposium on Electronic Imaging: Science and Technology*, 1995, San Jose, CA, United States. https://doi.org/10/1117/12/207546

Woods, S. (2016, March). *Preventing Inflight Loss of Control in General Aviation.* FAA Safety Briefing, 55(2), 10-10. https://www.faa.gov/news/safety_briefing/2016/media/marapr2016.pdf

Wynbrandt, J. (2004, August). *Spatial Disorientation.* AOPA. https://www.aopa.org/-/media/Files/AOPA/Home/Membership/AOPA-Debonair-Sweepstakes-Choose-Your-Prizes/Previous-Sweepstakes/New-AOPA-Air-Safety-Foundation-Safety-Advisor-explores-pilot-spatial-disorientation/sa17.pdf