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Effectiveness of a Flight Simulation Training Visual Aid for Normal and Crosswind Approach and Landing

Shlok Misra
Embry-Riddle Aeronautical University, Daytona Beach, misras@my.erau.edu
Victor Fraticelli Rivera
Embry-Riddle Aeronautical University, Daytona Beach, fraticev@erau.edu
Nikhil Khale
Embry-Riddle Aeronautical University, Daytona Beach, khalen@my.erau.edu
Jorge L. D. Albelo Ph.D.
Embry-Riddle Aeronautical University, Daytona Beach, diazalbj@erau.edu

The early stages of flight simulation development date back to the early 1900s (Page, 2000). For decades, flight simulator facilities have been an integral part of flight training, contributing to the safety and future of pilot training and flight control research (Allerton, 2010; Hess & Siwakosit, 2001). The use of flight simulators contributes to the safety of civilian and military aviation and the reductions in environmental impact by reducing the pilot's training time in the actual airplane. Practical flight training is possible due to the advances in technological systems that could realistically represent an aircraft and its flight characteristics. Even traditional flight simulators (not primarily developed for flight training), such as Microsoft Flight Simulator, have been found to have a positive transfer of learning and, to some extent, influence the knowledge and performance of aspiring pilots if it is supported by instructional programs (Korteling et al., 2017). Certainly, technology has been an integral part of the development and advances in flight simulation, including the development of different systems enhancing user experience (Allerton, 2010). Throughout the past three decades, advances in flight simulation technology have facilitated the development of tools and aids that replicate different scenarios without the risks involved if the scenario is conducted in real life. In this study, researchers aimed to evaluate the effectiveness of the student's learning process with the use of a flight simulator visual aid. Specifically, the researchers assessed a visual aid designed to introduced proper flight control inputs during the approach and landing phase of flight.

Aviation accident reports statistically reflect that the approach and landing phase of flight accounts for most aviation accidents in modern history. For example, between 2011 and 2020, over half of the fatal accidents of commercial jet fleets worldwide (54%) occurred during the approach and landing segment of the flight (Boeing, 2021). The final approach phase accounts for 28% of fatal accidents, while the landing accounts for 26%. Since 2011, there have been 21 fatal accidents during the final approach and landing phase of flight and 18 fatal accidents in all other phases of flight (Boeing Commercial Airplanes, 2021). The Aircraft Owner and Pilots Association's (AOPA) most recent Air Safety Institute Nall report concluded that in 2019 there were 308 landing accidents, five of which were fatal. In 2019, loss of control was the leading cause of 163 landing accidents (AOPA Air Safety Institute, 2019). Given the uprise in the accidents recorded during the final approach and landing phases of flight, it becomes evident that the aviation industry must evaluate different strategies to mitigate future final approach and landing accidents in the commercial and general aviation sectors.

The Federal Aviation Administration (FAA, 2022) states that it is critical to focus on establishing and maintaining a stabilized approach and landing to prevent experiencing a loss of control leading to a runway excursion. According to the FAA Aviation Safety (2022), a stabilized approach is attained when the pilot approaches a predetermined point on the landing runway at a constant glide-path angle.

Establishing a stabilized approach translates to the pilot's ability to identify different visual cues that will support their decision-making in adjusting airspeed, vertical speed, runway centerline alignment, and proper flight control inputs. In flight training, unstabilized approaches pose a significant risk for pilots that, if not corrected in time, can lead to a major accident or incident (Blajev & Curtis, 2017). Misra et al. (2022) found that mental and environmental factors impair flight students' judgment when assessing their approach to landing. Internal perceptions, such as insights and observations, affect the pilot's risk and safety discernment during the approach to landing phase of flight. New pilots' exposure to proper techniques will support aviation safety by providing a visual tool to transfer an appropriate final approach and landing techniques during the early stage of their flight training. Therefore, assessing the effectiveness of the student's learning process with the use of a flight simulator visual aid could reinforce the spatial attention and object-based attention necessary to maintain a stabilized approach and landing.

Visual aids are used in advanced training to reinforce or reintroduce essential concepts required to improve flight techniques. The tool assessed in this study is intended primarily to assist student pilot's learning process in interpreting the airplane's current state to establish a stabilized final approach and landing. Perceptions plays a key factor in the learning process of student pilots. According to the FAA Aviation Instructor Handbook (2020), learning occurs through the use of perceptions that are directed to the brain by one or more of the five senses. A person could use one or more senses, such as sight, hearing, touch, smell, and taste, to learn new experiences. Hearing and sight account for 88% of all perceptions (Aviation Instructor Handbook, 2020). Sight alone accounts for 75% of the total perception. Considering the human learning process and how perceptions impact learning, a visual tool was developed and assessed to support students' learning process using a visual tool as a potential learning tool.

In aviation, many scientific studies have evaluated different tools designed to support pilot situation awareness and reduce workload in different environments and conditions. For example, heads-up displays (HUD) have become integrated into flight simulators and aircraft in civil and military aviation in recent years. Empirical findings support the conclusion that these visual aids or tools significantly affect the pilot perception and situation awareness of helicopter pilots in visual or low visibility conditions (Stanton et al., 2018; Stanton et al., 2019; Walko & Schuchardt, 2020). Participants reported experiencing a reduction in the pilot's workload and an increase in perceived situation awareness (Stanton et al., 2018; Stanton et al., 2019). The HUD contributed to reducing periodic visual redirections from outside the cockpit to the instrument panel inside the cockpit. As a result, pilots reported having benefited from valuable information (airspeed, heading, etc.) while preserving the visual cues facilitating and promoting situation awareness (Stanton et al., 2018). Even though Stanton et al., 2018, and Stanton et al., 2019 scientific studies were focused on the aspects of HUDs in a degraded visibility meteorological condition, findings suggest that pilots reported having little to no impact on flight performance during visual meteorological conditions. In other words, had no impact on the ability to fly the airplane safely by looking outside. On the other hand, Walko and Schuchardt (2020) experimented with the potential benefits of a helmet-mounted display in low visibility meteorological conditions. The participants concluded that the use of helmet-mounted visual aid directly contributed to workload reduction and an increase in situation awareness. Consequently, visual aids have been effective in providing crucial information during critical phases of flight while at the same reducing pilots' workload.

Furthermore, considering that perceptions are an integral part of learning and situation awareness, Malik et al. (2020) findings concluded that using haptics on uncrewed aerial vehicle (UAV) simulators proved to have a significant effect on the pilot performance and their overall situation awareness. Similarly, virtual reality has also been evaluated as a potential supplement to flight simulation and has proven to be a valuable addition to the existing flight deck design processes (Oberhauser & Dreyer, 2017). Other tools, such as the Smart Icing System, have also provided a realistic approach to flight crews experiencing icing conditions (Deters et al., 2006). The Smart Icing System enhances the pilot's experience and safety by providing additional tools to aid the pilot in sensing ice accretion and using multiple aircraft systems (de-icing and anti-icing systems) to assess the pilot's response to the icing threat. Even though many studies have investigated the use of different learning tools, there is a lack of empirical findings evaluating flight simulator's visual aids. In particular, there is a lack of empirical evidence on visual aids primarily designed to assist the pilots' learning process in developing proper flight control techniques during the approach and landing phases of flight.

The Flight Simulator Visual Aid

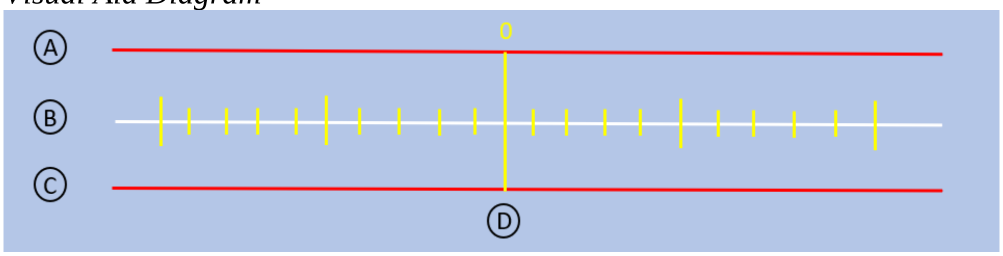
The flight simulator visual aid aims to support students' learning process by focusing the student's perceptions on visual cues during the approach and landing phase of flight. In other words, the visual aid is intended to direct the student's attention towards the elements that, when interpreted correctly, could result in a stabilized approach. The flight simulator visual aid assessed in this study is part of a fleet of FAA-certified advanced Frasca Level 6 Flight Training Devices (FTDs). The Frasca FTDs' 220-degree visual display system can reproduce realistic scenery and graphic depiction of different weather phenomena, such as precipitation, low visibility conditions, clouds, traffic, cities, and airports. In addition, the FTDs can display visual aids suitable for multiple training purposes.

The visual aid tested in this study consists of three fixed horizontal lines (two lines depicted in red and one depicted in white) and a series of fixed vertical lines depicted in yellow (see Figure 1). The lines are illustrated with letters *A*, *B*, *C*, and *D*. Line *A* represents the top red line. The top red line is used to set the proper descent pitch attitude during the initial approach towards the runway. Students are instructed to smoothly pitch the airplane down and place line *A* on the natural horizon. Line *B* is depicted in white and not only represents wings' level attitude for straight and level flight but also enables students to focus on the aiming point during the final approach phase. The aiming point is a subjective point on the runway, determined by the pilot, in which the airplane is progressing during the approach to the runway.

Line *C* represents the *flare* pitch attitude required for an appropriate touchdown on the runway. As the student transitions from their final approach to their touchdown, they must move line *C* to the natural horizon. Lastly, line *D* represents the longitudinal axis of the aircraft. A series of smaller vertical yellow lines represent deviations (left or right) from the airplane's longitudinal axis and the runway centerline. For a safe touchdown, the student must ensure that line *D* parallels the runway center line.

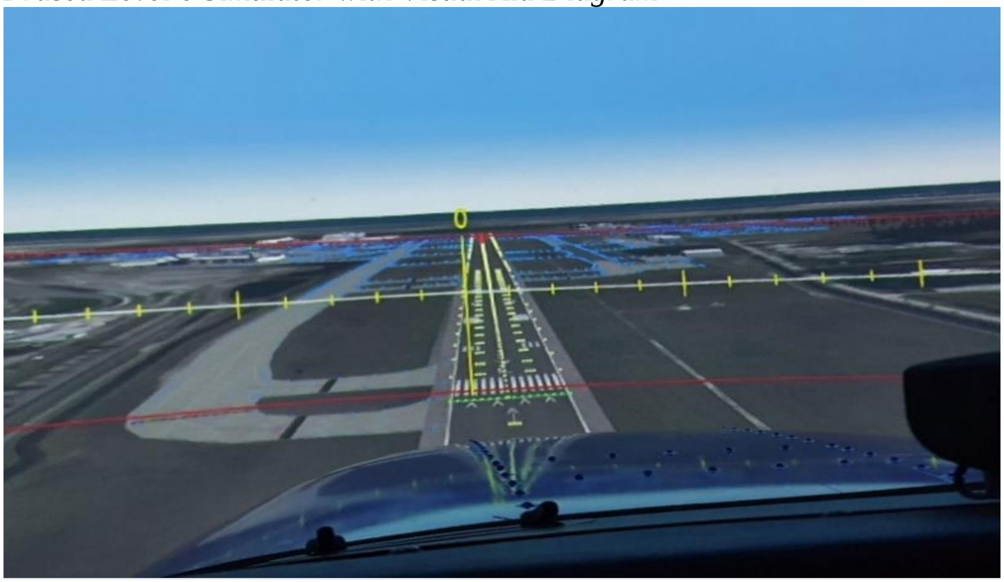
Figure 1

Visual Aid Diagram



Whenever the flight instructor activates the visual aid in the flight simulator, the lines in the visual aid assist the student's learning process by showing the appropriate sight pictures required during initial and final approach phase of flight (See Figure 2).

Figure 2
Frasca Level 6 Simulator with Visual Aid Diagram



The instructor may remove the visual aid once they have determined that the student has demonstrated the skills necessary to identify the visual sight pictures required for a stabilized approach. An instructor may consider that the student has mastered the criteria for a stabilized approach once a full landing is accomplished successfully without the visual aid. Essentially, the flight simulator visual aid could assist students' learning process by focusing the student's attention to important visual cues and perceptions while conducting stabilized approaches.

Theoretical Background

The impact of perceptions in an aviation student's learning process represents an important element during flight training. The theory of visual attention in pictorial perception (VAPP) captures the stable approach criteria. As mentioned earlier, perceptions are a key element of the learning process for aviation students. The VAPP theory states that when perceiving an object with a visual aid, individuals can perceive both the surface and the depicted object; however, the surface is only unconsciously represented (Ferretti & Marchi, 2020). Since unconscious representations do not require attention, research has shown that a student pilot's realistic proportion of visual attention on the flight deck can hardly constitute a visual representation (Sulzer & Skelton, 1976).

During the assessment of the visual aid diagram depicted in Figure 1, the researchers considered the limited processing resources of the human brain (Carrasco, 2011). Spatial and object-based attention were the primary objectives while assessing the visual aid. According to the VAPP theory, cognitive process improves when attention is directed at various visual elements (Ferretti & Marchi, 2020). As a result, visual attention is critical for visual perception. According to Carrasco (2018), spatial attention enables individuals to grant priority in processing information from a single source. By targeting the students' visual field towards the center of the simulation screen (Figure 1), the researchers then ensured that students processed the information within this region. Carrasco (2018) suggests that when spatial attention is evoked, individuals can process information faster and improve attentional guidance.

Furthermore, object-based attention is fundamental in binding features in the conscious and unconscious mind (Chou & Yeh, 2012). Chou and Yeh proved the relationship between an object representation (visual aid for stabilized approach) and an individual’s selective attention, meaning that individuals can select an object even when they are not conscious of it. Even though there are many unconscious objects in the pilot’s visual range (e.g., birds, airport environment, airplanes, etc.), they do modulate the pilot’s attention in both a location and an object-based manner facilitating mental/visual processing (Chou & Yeh, 2012). Consequently, unconscious objects enable student pilots to determine whether their current airplane state meets the criteria of a stabilized approach.

Methodology

This study aimed to assess the effectiveness of a normal and crosswind landing visual aid for student pilots. The present study used a quantitative experimental research design and utilized surveys and quantitative performance assessments. The surveys targeted descriptive data from the student pilots regarding the purpose of the visual aid. The quantitative performance assessment used for the hypothesis testing was aimed at the effectiveness of the visual aid for normal and crosswind landing performance. Utilizing both the survey and performance assessments allowed the researchers to gather comprehensive data on participants’ feedback and objective measurement of the student pilots’ landing performance.

Data Collection

A total of 63 participants from a world leading aviation higher education institution, located in the southeast region of the United States, were recruited for the study. The requirement to participate in the study was to hold at least a Private Pilot certificate but less than an Airline Transport Pilot Certificate or a Flight Instructor certificate. The purpose of the sampling method was to capture data from a broad spectrum of student pilots enrolled at the research site. The experience criteria (i.e., private pilot certificate) prevented data outliers from participants with excessive or scant flight experience. The data from each participant were collected separately, and the participant confidentiality was safeguarded per IRB approval #21-138. Once the participant had arrived at the data collection site and had read and signed the Informed Consent Form, the researcher asked the participant to complete a pre-survey. The purpose of the pre-survey was to gather demographic data and data on previous experience and training the participant had received on normal and crosswind landings.

After the pre-survey was completed, each participant was escorted by an Instructor Pilot (IP) from the university to a simulator for the performance evaluation. The participant was introduced to the simulator to be used for the study and was allowed to familiarize themselves with the operations of the simulator by flying a few traffic patterns. Once the participant informed the IP that they were ready to begin the assessment, the participant was asked to fly a Cessna 172 Skyhawk airplane in a traffic pattern and land at a pre-determined point on the runway with a 15 knots crosswind. The participant was informed that the performance would be evaluated per the objective performance assessment criteria. After the landing, the IP introduced the visual aid (see Figure 2) utilizing a pre-written script and teaching plan. Once more, the participant was allowed to familiarize themselves with the visual aid by flying the aircraft in the traffic pattern. The participant was asked to fly the aircraft in a traffic pattern and land the aircraft with opposite crosswind conditions. The second landing was assessed with the same objective performance assessment criteria; however, the visual aid was disabled by the IP. Once the performance assessment was completed, the participants were asked to complete a post-survey that was used to gather data on the feedback and effectiveness of the visual aid.

Objective Performance Assessment Criteria

A quantitative performance assessment criterion was needed to assess the landing performance of the participants and to collect data to complement the pre-survey and post-survey. The researcher used the same 5-point scale Competency-based grading model utilized by the university to assess the effectiveness of the visual aid. One advantage of the Competency-based grading model is to its objectivity and minimization of bias. Additionally, error was further reduced given the familiarity of the IP with the grading model. The 5-point grading criteria was adapted from guidance provided by the FAA in the Aviation Instructor's Handbook (2020) and the Airmen Certification Standards (2018) and assessed risk management, knowledge, and aircraft trajectory. The IP graded the participants in seven components of normal and crosswind landings which were used to test the seven null hypotheses.

Research Design

The study consisted of a pre-survey, post-survey, and performance assessments. The pre-survey and post-survey were used to gather descriptive data on the experience and feedback of participants on the visual aid proposed and tested in this study. The performance assessments of the participants with and without using the visual aid were used for the hypothesis testing in the study. The performance assessment was developed by Embry-Riddle Aeronautical University based on a competency-based grading framework adapted on guidance from the

FAA in the Aviation Instructor's Handbook (2020) and Airmen Certification Standards (2018). The assessment standards were independently validated by subject matter experts and tested by the university. Thus, the researchers did not need to independently test the reliability and validity of the performance assessment. The IP was also standardized on the performance assessment by the university before the data collection phase of this study. To assess the effectiveness of the research design and data collection tools the researchers conducted a pilot study with five participants. After the pilot study, there were no design changes required.

Hypotheses Testing

To complement the data collected from the pre-survey and post-survey, seven null hypotheses were tested. The researchers utilized paired sample *t*-tests at a significance of 0.05 to test the hypotheses.

$H_0 1$: There is no significant difference in the mean performance score of maintaining appropriate airspeed on the final leg of a traffic pattern with using the visual aid and the mean performance score of maintaining appropriate airspeed on the final leg of a traffic pattern without using the visual aid.

$H_0 2$: There is no significant difference in the mean performance score of maintaining appropriate vertical speed on the final leg of a traffic pattern with using the visual aid and the mean performance score of maintaining appropriate vertical speed on the final leg of a traffic pattern without using the visual aid.

$H_0 3$: There is no significant difference in the mean performance score of maintaining the extended runway centerline on the final leg of the traffic pattern with using the visual aid and the mean performance score of maintaining the extended runway centerline on the final leg of the traffic pattern without using the visual aid.

$H_0 4$: There is no significant difference in the mean performance score of maintaining appropriate height above the runway threshold with using the visual aid and the mean performance score of maintaining appropriate height above the runway threshold without using the visual aid.

$H_0 5$: There is no significant difference in the mean performance score of maintaining appropriate runway touchdown airspeed with using the visual aid and the mean performance score of maintaining appropriate runway touchdown airspeed without using the visual aid.

$H_0 6$: There is no significant difference in the mean performance score of touching down on the runway centerline with using the visual aid and the mean performance score of touching down on the runway centerline without using the visual aid.

$H_0 7$: There is no significant difference in the mean performance score of maintaining appropriate sideslip angle during touchdown with using the visual aid and the mean performance score of maintaining appropriate sideslip angle during touchdown without using the visual aid.

Results

The purpose of the study was to assess the effectiveness of a normal and crosswind landing visual aid for student pilots. The data was collected through a pre-survey, post-survey, and performance assessments of participants landing with and without the visual aid. The different surveys and data collection techniques allowed the researchers to gather data for a comprehensive data analysis to assess the effectiveness of the visual aid. Table 1 depicts the demographic information of the 63 participants in the study.

Table 1

Participants Demographics

Characteristics	Subgroup Categories	Frequency	Percentage
Age	17-20	21	33.3%
	21-24	39	61.9%
	25-29	1	1.6%
	30 and over	2	3.2%
		63	100%
Certification	Private	16	25.4%
	Instrument	20	31.8%
	Commercial-Single	14	22.2%
	Commercial-Multi	13	20.6%
		63	100%
Gender	Male	41	65.1%
	Female	22	34.9%
		63	100%

Pre-Survey Results

Figure 3 depicts the pre-survey results that aimed to assess the experiences and background of participants in relation to normal and crosswind landings training. Based on the results, a significant number of participants (43%) were confident and comfortable with their ability to land an aircraft in strong crosswind conditions on a solo flight. Eighty percent (80%) of the participants agreed that visual guidance would further enhance their performance on crosswind landings and that they utilized visual cues and perceptions to land the aircraft in crosswind conditions. Pre-survey findings suggest that a significant number of participants (63%) did not find previous flight training instruction to contribute to the development of the necessary skills to conduct a proper normal and crosswind landing. Furthermore, prior flight instruction did not enable the identification of visual cues during a stabilized approach and landing.

Figure 3

Pre-Survey Results

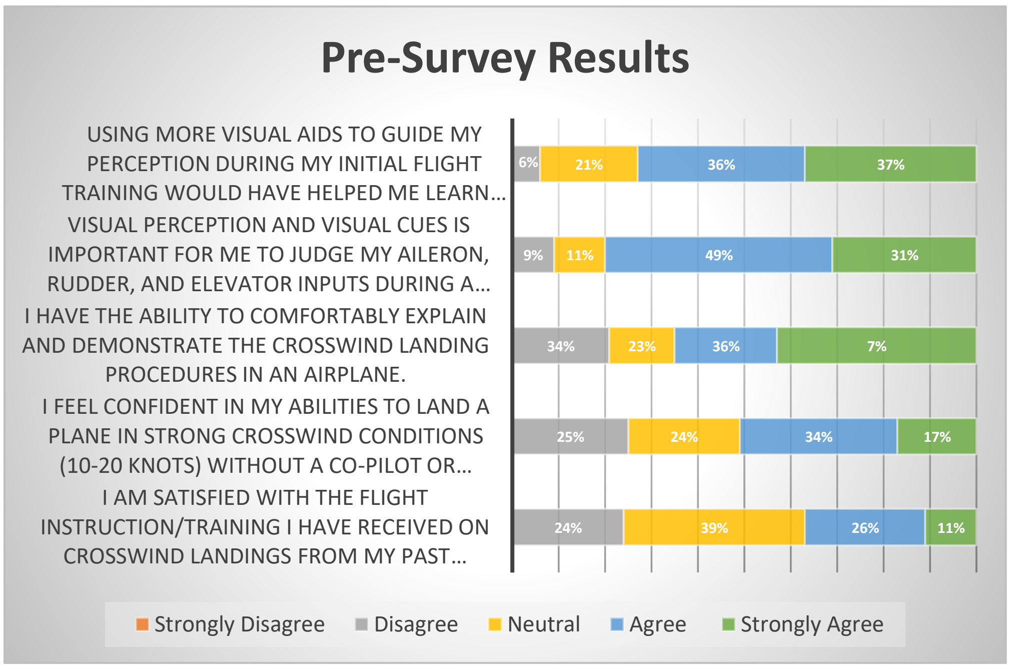


Figure 4 depicts the post-survey results that aimed to assess the experiences and perceptions of the participants in regard to the visual aid. Results of the survey indicate that a large percentage of participants (94%) found that the visual aid assisted in developing a better understanding of the required crosswind technique for different phases of the approach and landing. Additionally, the participants found the aid supplemented the concepts explained to them by the instructor. A large number of participants (34%) had negative sentiments regarding the effectiveness of the visual aid in identifying the appropriate sight picture during the flare and touchdown segment of landing.

Figure 4
Post-Survey Results

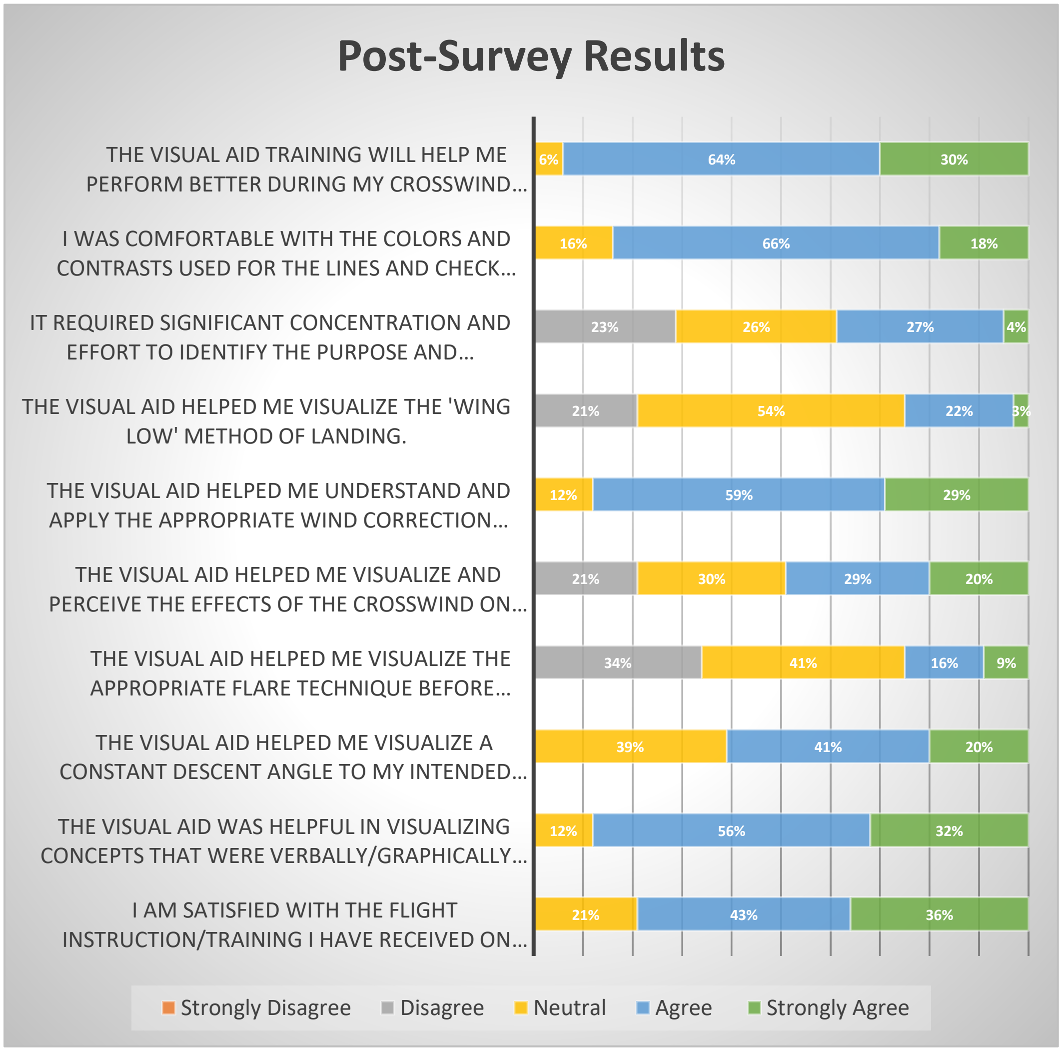
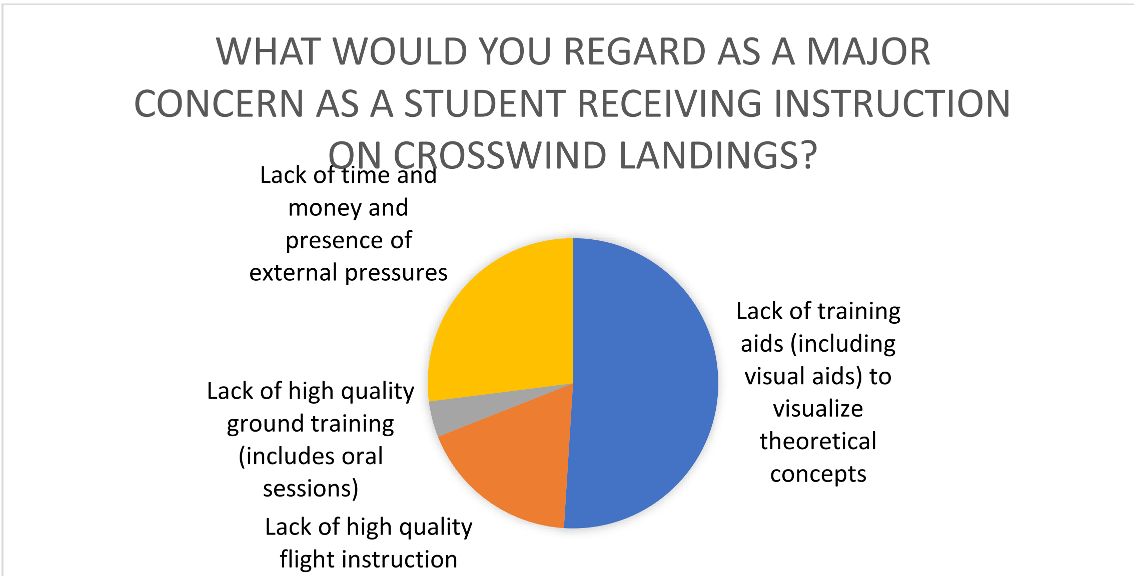


Figure 5 highlights the responses to the question regarding the participants' biggest concerns surrounding crosswind landing instruction. The results indicated that the biggest concern was the lack of training aid that supplemented theoretical concepts taught by flight instructors surrounding crosswind landings.

Figure 5
Major Concerns Regarding Crosswind Landing Flight Instruction



Hypothesis Testing

Seven null hypotheses were tested to complement the data collected from the pre-survey and post-survey. The researchers utilized paired sample *t*-tests at a significance of 0.05 to test the hypotheses.

The null hypothesis ($H_0$1) that there is no significant difference in the mean performance score of maintaining appropriate airspeed on the final leg of a traffic pattern with using the visual aid and the mean performance score of maintaining appropriate airspeed on the final leg of a traffic pattern without using the visual aid was tested. The mean of performance scores with the visual aid (M = 3.77, SD = 1.095) was larger than the mean of performance scores without the visual aid (M = 2.80, SD = 1.117). A dependent samples *t*-test was significant at the alpha level of .05, $t(62) = 6.065$, $p < 0.001$. Therefore, the null hypothesis was rejected—Cohen's d = 0.88, which is a large effect.

The null hypothesis ($H_0$2) that there is no significant difference in the mean performance score of maintaining appropriate vertical speed on the final leg of a traffic pattern with using the visual aid and the mean performance score of maintaining appropriate vertical speed on the final leg of a traffic pattern without using the visual aid was tested. The mean of performance scores with the visual aid (M = 4.21, SD = 0.932) was larger than the mean of performance scores without the visual aid (M = 3.52, SD = 1.314). A dependent samples *t*-test was significant at the alpha level of .05, $t(62) = 4.316$, $p < 0.001$. Therefore, the null hypothesis was rejected. Cohen's $d = 0.61$, which is a medium effect.

The null hypothesis ($H_0 3$) that there no significant difference in the mean performance score of maintaining the extended runway centerline on the final leg of the traffic pattern with using the visual aid and the mean performance score of maintaining the extended runway centerline on the final leg of the traffic pattern without using the visual aid was tested. The mean of performance scores with the visual aid ($M = 4.30$, $SD = 0.944$) was larger than the mean of performance scores without the visual aid ($M = 4.00$, $SD = 1.135$). A dependent samples *t*-test was not significant at the alpha level of .05, $t(62) = 1.625$, $p = 0.109$. Therefore, the null hypothesis was retained.

The null hypothesis ($H_0 4$) that there is no significant difference in the mean performance score of maintaining appropriate height above the runway threshold with using the visual aid and the mean performance score of maintaining appropriate height above the runway threshold without using the visual aid was tested. The mean of performance scores with the visual aid ($M = 4.63$, $SD = 0.758$) was larger than the mean of performance scores without the visual aid ($M = 4.17$, $SD = 1.107$). A dependent samples *t*-test was significant at the alpha level of .05, $t(62) = 2.912$, $p = 0.004$. Therefore, the null hypothesis was rejected. Cohen's $d = 0.48$, which is a medium effect.

The null hypothesis ($H_0 5$) that there is no significant difference in the mean performance score of maintaining appropriate runway touchdown airspeed with using the visual aid and the mean performance score of maintaining appropriate runway touchdown airspeed without using the visual aid was tested. The mean of performance scores with the visual aid ($M = 3.30$, $SD = 1.013$) was larger than the mean of performance scores without the visual aid ($M = 3.20$, $SD = 1.312$). A dependent samples *t*-test was not significant at the alpha level of .05, $t(62) = 0.629$, $p = 0.532$. Therefore, the null hypothesis was retained.

The null hypothesis ($H_0 6$) that there is no significant difference in the mean performance score of touching down on the runway centerline with using the visual aid and the mean performance score of touching down on the runway centerline without using the visual aid was tested. The mean of performance scores with the visual aid ($M = 4.30$, $SD = 0.788$) was larger than the mean of performance scores without the visual aid ($M = 4.07$, $SD = 1.006$). A dependent samples *t*-test was not significant at the alpha level of .05, $t(62) = 1.397$, $p = 0.168$. Therefore, the null hypothesis was retained.

The null hypothesis ($H_0 7$) that there no significant difference in the mean performance score of maintaining appropriate sideslip angle during touchdown with using the visual aid and the mean performance score of maintaining appropriate sideslip angle during touchdown without using the visual aid was tested. The mean of performance scores with the visual aid ($M = 4.67$, $SD = 0.655$)

was larger than the mean of performance scores without the visual aid (M = 4.50, SD =0.930). A dependent samples t-test was not significant at the alpha level of .05, $t(62) = 1.321$, $p = 0.192$. Therefore, the null hypothesis was retained.

Discussion

Based on the data collected from the pre- and post-results survey, 80% of the participants expressed that they had a high level of understanding of visual cues and perceptions required to perform a crosswind landing. Additionally, 43% of the participants expressed high levels of confidence with regard to knowledge and performance of landings in strong crosswind conditions. However, 63% of participants expressed a lack of readiness in their previous flight training and instruction regarding preparation for crosswind landings.

Despite the confidence expressed in the pre-results survey, the post-results survey highlighted that 90% of the participants found that the visual aid assisted with identifying visual cues and perceptions that aided the participants during the crosswind landings in the FTD. Additionally, 80% of the participants found the visual aid relatively simple to understand and utilize, with all the corresponding lines and marks being easily understood. Additionally, a large number of the participants (34%) expressed a lack of utility in the visual aid when it came to assisting with developing better performance methods (e.g., wing-low method, flare, and touchdown technique) to complete a crosswind landing.

The statistical analysis of the null hypotheses identified that the visual aid allowed the participants to successfully maintain the required airspeed, vertical speed, and height above the runway threshold on the traffic pattern's final leg. The data from the performance assessment suggest that the horizontal lines on the visual aid were successful in assisting participants in the identification of the appropriate visual cues and perceptions utilized for appropriate flight control inputs during crosswind landings.

While there was a significant difference observed with certain factors associated with utilizing the visual aid for crosswind landings, the analysis identified areas where the visual aid was not as effective. The ability of the applicant to maintain an extended centerline on the final approach or touchdown on the runway centerline was not improved through utilizing the visual aid, even though the mean values for performance were higher for applicants while using the visual aid. Similarly, the performance regarding appropriate touchdown speed as well as maintaining the appropriate sideslip angle for the approach and landing were not improved using the visual aid. The findings suggest that the lines, representing degrees of variation between the longitudinal axis of the airplane, did not help participants in the development of necessary visual cues and perceptions needed to perform the proper corrective actions (sideslip angle) during the approach and landing phases of the crosswind landing during this study.

Conclusion

After collecting the results from a pre-survey and a post-survey, several conclusions, limitations, and areas for further research were identified. Based on the pre-survey and post-survey, the usefulness, need, and acceptance of visual aids for crosswind landings were identified. The participants expressed positive sentiments regarding the effectiveness of the visual aid in identifying and visualizing theoretical concepts taught by flight instructors regarding crosswind landings. In regard to the performance assessments, the visual aid was only successful in demonstrating a significant difference in four out of the seven areas assessed. The conclusion of the study highlights the need for such visual aids, further potential improvements in such a visual aid, and the scope of utilizing visual aids for improving flight education. While the post-survey and performance assessment highlighted the deficiency in the visual aid in fulfilling some of the objectives of the development of the aid, the results should be used as a foundation for further development of visual aids for flight education.

Limitations and Areas for Further Research

As discussed already, due to certain segments of the study not yielding significant differences in performance with and without the visual aid, the horizontal line with increments of variation along the longitudinal axis could utilize design changes to allow students to better understand and perform successful techniques to maintain the appropriate sideslip angle to correct for the wind conditions during crosswind landings. Utilizing a larger sample will also allow for a more in-depth understanding of whether the success of the visual aid was influenced by a higher pilot skill level as a larger percentage held additional ratings or licenses beyond the Private Pilot License. Exploring the effectiveness of this visual aid with new pilots or student pilots will allow the researchers to better understand the effectiveness of the training aid at the beginning of training.

Due to limited literature surrounding this topic in the industry currently, this study can serve as a theoretical foundation for continued research in the industry. Future developments of more advanced and improved visual aids for simulated flight training can aid the development of crucial visual cues and perceptions early in the training stage, which can contribute to the greater goal of improved aviation safety and situational awareness of General Aviation pilots.

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