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Effect of Integrated Method of Flight Instruction on Student Pilot Performance

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With the prevailing use of integrated cockpit displays in flight training, flight students have shown to have difficulty controlling the aircraft and maintaining situational awareness. The integrated method of flight instruction is a proven tool to help transfer the skills necessary from visual to instrument flying, but it may also distract the student and lead to the formation of dangerous habits. This research study looked at whether the integrated method of flight instruction helps or hinders a student at the beginning of flight training. A quantitative experimental research design was used to measure situational awareness, reaction time to a traffic conflict, and ability to maintain the altitude and heading of participants instructed with visual and instrumental cues. Participant scores were analyzed using independent samples t-tests to measure the expected results that students exposed to visual and instrumental cues have significantly different scores. The results showed that participants instructed with visual cues had a significantly higher level of situational awareness in the subcategory of orientation, an overall higher level of situational awareness, and a quicker reaction time to a potential mid-air collision. The results showed that the very onset of training may not be the appropriate time to introduce instrumental cues.

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Introduction

Flight training instruction is a relatively new field that has garnered significant attention in modern research. Government agencies, commercial organizations, and individual researchers have dedicated substantial hours and fiscal resources to ensure the routine and safe operation of aircraft. In pursuit of this goal, government transportation regulators have prioritized perfecting the training procedures and processes involved in learning to fly an aircraft. Much of the research into learning theories used in modern flight instruction techniques stems from foundational work by psychologists since the 19th century, who studied how people learn. These theories are thoroughly outlined in the Federal Aviation Administration's (FAA) *Aviation Instructor's Handbook* (FAA, 2020).

The integrated method of flight instruction has been subject to study since the development of instrument flight rules (IFR) flying. The FAA has sponsored several research studies on the integrated method of flight instruction to identify the optimal minimum hour requirements for a pilot to obtain an instrument rating (Childs, 1986). Additionally, Situational Awareness (SA) has been a focus for human factors researchers, the FAA, and major airlines (Wright & O'Hare, 2015). With the increasing complexity of aircraft displays and automation systems, concerns over pilots' SA have grown steadily.

Methods of Flight Instruction

For the purpose of this study, flight instruction methods refer to the techniques Certified Flight Instructors (CFI) use to communicate information about the aircraft's attitude in relation to the external environment, particularly the ground. These methods include the use of visual cues, instrumental cues such as Basic Attitude Instrument (BAI), the integrated method of flight instruction, and, more recently, Integrated Sensory Flying (ISF).

Visual Cues Based Flight Training

Visual, or "contact" cues are the first method used in teaching a student how to manipulate flight controls and manage an aircraft's attitude. CFI uses visual cues by guiding students to reference a "sight picture" or an "out-the-window" view to control the aircraft.

Instrument Based Flight Training

In contrast, Basic Attitude Instrument (BAI) training teaches students to manage an aircraft's attitude by solely relying on flight instruments, extracting information from various displays to understand the aircraft's conditions during flight. CFIs teach the BAI technique by guiding students to interpret and cross-reference flight instruments, enabling them to visualize the aircraft's orientation in space and apply the necessary flight controls based on this information. Research suggests that early integration of instrument training benefits students in attaining an instrument rating. However, other studies also suggest that early integration of instrument training can be difficult and potentially hazardous to student learning and overall flight safety.

Integrated Flight Instruction Method

The combination of visual cues and BAI training is known as the integrated method of flight instruction. The integrated method of flight instruction has been used to facilitate the learning and transference of piloting skills from visual to instrument flying. The integrated method of flight instruction was first shown to be an effective technique in flight training by the Boeing School of Aeronautics in 1935 (Childs, 1986). A later study conducted by Ritchie and Michael (1955) demonstrated that transferring skills from instrument flying to visual flying was easier than teaching visual skills from scratch. Further research by Ritchie and Hanes (1964) found that delaying the introduction of instrumental cues can hinder student pilots when pursuing an instrument rating later in their careers.

As the aviation industry evolved, the necessity of instrument flying increased due to growing air traffic and weather-related challenges, which demanded greater consistency from pilots regardless of external conditions. As a result of increased instrument flying, many studies looked to assess the performance of instrument-rated pilots based on when instrument training was introduced in their flight training curriculum. The results of these studies demonstrated that the early introduction of instrument cues benefits the student tremendously in achieving an instrument rating in the least amount of training time (Childs, 1986). Childs (1986) indicated that there are benefits of applying the integrated method of flight instruction early on during flight training. According to Childs, early instrument training can also improve overall pilot skills in the face of sensory illusions (1986).

The integrated method of flight instruction is a proven technique in accelerating the time required for training students who intend to continue to an instrument rating (Childs et al., 1981; Holmes & Childs, 1982). However, there remains limited research on the optimal timing for safely introducing and implementing this method during flight training. Introducing instrument training too early may pose risks related to Visual Situational Awareness (VSA), as pilots must still look outside beyond their instruments while flying (Childs, 1986; Lane, 2009). Due to the limitations of the integrated flight instruction method, the Integrated Sensory Flying (ISF) technique was developed to address visual and instrument flying in today's complex training environments. ISF encourages students to use sensory information—such as sight, sound, and feel—to analyze their flying environment, with instruments providing a secondary confirmation to visual cues. By keeping the student's focus outside the cockpit, ISF enhances VSA, ensuring that the early introduction of instrumental cues does not diminish their ability to maintain situational awareness.

Challenges of the Technologically Advanced Flight Deck

Advanced systems concepts adapted from military and airline operations are increasingly finding their way into General Aviation (GA) aircraft. The rapid development of new equipment and technologies has resulted in more complex GA flight decks (Lane, 2009). A new term has been developed to describe aircraft fitted with modern equipment: Technically Advanced Aircraft (TAA). TAAs are aircraft equipped with an IFR approved GPS, autopilot, and moving map displays (Lane, 2009). While these systems can greatly enhance safety and efficiency when used correctly, they have also been shown to negatively affect less experienced pilots, leading to distraction and proficiency gaps due to inadequate training standards (Lane, 2009).

Integrated cockpit displays, or glass cockpits, first emerged in the aviation industry at the end of the twentieth century. Glass cockpit technology quickly became the standard avionics package on newly built aircraft of all designs and purposes (National Transportation Safety Board [NTSB] 2010, as cited in Wright & O'Hare, 2015). Traditional flight instruments consisted of six electro-mechanical individual units: the airspeed indicator, altimeter, vertical speed indicator, attitude indicator, heading indicator, and rate-of-turn indicator. Unlike traditional flight instruments, the glass cockpit consolidates all of this information onto a single LCD screen, called the Primary Flight Display (PFD). The PFD is typically accompanied by a Multifunction Display (MFD), which can be used to display navigation maps and other information. However, studies have shown that operating an aircraft configured with a glass cockpit can be significantly more challenging and result in less situational awareness (SA) than a conventional round dial aircraft due to the increasing amount of information required to be interpreted by the pilot (Wright & O'Hare, 2015). While experienced pilots may find these glass cockpit advancements beneficial, they can pose greater challenges for novices and student pilots (Lane, 2009). One solution is to ensure pilots receive thorough ground training on the equipment before operating a TAA.

Situational Awareness (SA) in Glass Cockpit Based Flight Training

SA involves gathering information about the surrounding environment, combining it with knowledge and experience, and making complex decisions based on the pilot's objectives (Endsley, 1995). Endsley (1995) categorized SA into three levels: the perception of environmental elements, the comprehension of the current situation, and the projection of future status. Though SA measurement is most commonly applied in aviation, it is relevant to any field requiring dynamic decision-making.

Measuring SA performance in dynamic environments has the advantage of being both objective and nonintrusive. Simulations, combined with computer software, allow for data collection without disturbing the participant's situational awareness. External tasks, embedded tasks, and global measures can help create a comprehensive understanding of SA through measurement devices such as the Situational Awareness Global Assessment Technique (SAGAT) (Endsley, 1995). SAGAT measures SA by pausing a simulated flight, asking a series of questions, and scoring the participant's responses.

Although glass cockpits are generally perceived to enhance SA, research suggests that they may actually reduce situational awareness for GA pilots. (Adams et al., 2001, as cited in Wright & O'Hare, 2015). Wright and O'Hare (2015) found that participants trained in traditional round dial instrument aircraft achieved higher scores on the SAGAT test than those who trained in glass cockpit setups. Although there was no statistically significant difference in the groups' performance on the SAGAT test, the study highlights that integrated cockpit may can impact the situational awareness of novice student pilots.

Comparison of Visual and Instrumental Cues Based Flight Training

Flight instruction often occurs in complex training environments, requiring a multifaceted approach to effectively convey information to students. CFIs must choose whether to emphasize visual or instrumental cues during the initial stages of training. As seen in Figure 1, visual cues present the student feedback on the attitude of the aircraft using sight pictures in relation to the horizon, while instrumental cues (seen in Figure 2) provide the same information in the form of an artificial horizon or attitude indicator.

Figure 1
Visual Cue Based Flight Training

Figure 2
Instrumental Cue Based Flight Training

During the onset of flight training, CFIs typically choose between teaching students using visual cues or the integrated method of flight instruction. Initially, students must first become familiar with flying the airplane safely while looking outside of the cockpit to navigate and avoid traffic. However, as newer aircraft are often equipped with integrated cockpit displays, students can become overwhelmed by the complexity of these systems. The task saturation and demands of flying a glass cockpit aircraft led to students spending a lot of time looking inside the cockpit at the screens instead of outside for visual cues. This may impact students' situational awareness and overall safety of flight. One of the most significant problems is that novice student pilots who fly airplanes with complex flight displays spend too much time looking inside the cockpit and have a reduced amount of situational awareness as opposed to student pilots who fly airplanes with less complicated flight displays. Introducing the integrated method of flight instruction too early may inadvertently lead to negative flying habits.

Summary

Research supports the integrated method as a valuable tool, particularly for students pursuing an instrument rating, showing that skills learned in instrument flying transfer positively to visual flying. However, the complexity of integrated displays can hinder situational awareness, increasing the tendency for students to focus inside the cockpit. While experience is necessary to master instrument flying, visual techniques like Integrated Sensory Flying (ISF) are considered safer for beginners. Although research suggests that the integrated method and BAI should be introduced early in training, the optimal timing remains unclear.

This research study examined the effects of visual versus instrumental cues on beginner student pilots learning to fly aircraft with integrated cockpit displays. The purpose of this study is to identify whether the integrated method of flight instruction helps or hinders students' situational awareness and performance when flying aircraft with complex flight displays and highlight the advantages and disadvantages of each technique.

Methodology

This research study was conducted at Embry-Riddle Aeronautical University (ERAU) in the Advanced Flight Simulation Center. This study utilized an experimental research design by measuring the effects of instructional techniques on situational awareness. The experiment incorporated surveys, reaction time assessments in response to potential Near Mid-Air Collisions (NMAC), and evaluations of participants' ability to maintain aircraft orientation. The independent variable, instructional technique, had two levels: visual cues and instrumental cues. The dependent variables of this study were participant scores on a situational awareness test, reaction time to an NMAC, and scores on the ability to maintain altitude and heading.

Population/Sample

Participants were selected using convenience sampling from the population of graduate and undergraduate students at ERAU. In order to participate in the study, participants were required to have no prior flight training experience. The sample size of the study was 30 participants, with 15 randomly assigned to each group.

Procedures

At the start of the session, each participant was briefed on potential hazards, including possible discomfort from motion sickness and being in a confined cockpit. The informed consent form was then reviewed and signed by participants who agreed to proceed.

Before the simulated flight commenced, the participant was shown a pre-recorded PowerPoint presentation lecture covering the basic information necessary for operating an aircraft. The presentations for the two groups (Visual and Instrument) were identical except for the cues referenced to control the aircraft. The visual group was only shown external visual cues, and the instrument group was only shown in-cockpit instrumental cues necessary for flying an aircraft. A sample presentation slide is illustrated in Figure 3. After the ground training, the participant and researcher entered the flight simulator.

Figure 3
Sample Training Slide

Note. To perform a turn, turn the control wheel in the direction desired

Each participant was instructed to maintain situational awareness, scan for traffic during the simulated flight, and notify the researcher if any traffic was observed. Once the participants had learned to maintain level flight, execute turns in both directions and perform 90-degree turns to cardinal headings, they were tasked with maintaining a specific altitude and heading. They were then asked to perform 90-degree level turns to a cardinal direction and back again to ensure they were actively controlling the aircraft. Altitude and heading management data were collected for five minutes as the participant got situated with flying the aircraft. The simulation was then paused, and the screens were blanked to administer the first situational awareness test using the Task 1 SAGAT questionnaire (refer to Appendix A).

After the first SA test, the simulation then resumed, and the screens were restored. The participants were then presented with a traffic conflict to avoid, and their reaction time to identifying the traffic was measured. The traffic was another Cessna 172 aircraft programmed to fly directly towards the participant's aircraft and collide in 20 seconds if no intervention was made. Participants were asked to verbally identify if they saw the aircraft traffic or if they needed to manipulate the controls to avoid a collision. After the NMAC reaction time was measured, the simulation was paused, and the screens blanked. The researcher then administered the second situational awareness test using the Task 2 SAGAT questionnaire (refer to Appendix A). The study session was then concluded with a debriefing explaining the purpose of the study, and incentives were given to the participants.

Apparatus and Materials

The ground portion of this study was conducted in a small classroom with a computer to present the PowerPoint presentation. The simulation was conducted in a Frasca G1000 Cessna 172 flight simulator. The flight simulator used was a high-fidelity FAA approved level six Flight Training Device (FTD) that provides a realistic flight experience with a dome projection screen and fully enclosed and functional cockpit via the Garmin G1000 integrated cockpit display avionics package. The simulated flight was controlled by an iPad, which the researcher used to set conditions and prompt traffic conflicts and other scenarios.

SA data was collected using SAGAT questionnaires (refer to Appendix A; Endsley & Garland, 2000). All the SA tasks were totaled up to get a total SA score for each participant. Data on reaction time to an NMAC was collected during the simulated flight using a stopwatch to measure reaction time and an iPad to prompt the simulation to create a traffic condition. The simulated traffic appeared on the horizon and was set to collide with the participant's airplane in 20 seconds in each scenario. The researcher simultaneously created the traffic and started a stopwatch to measure reaction time. The researcher stopped the stopwatch if the participant verbally announced the sight of the airplane or clearly moved the flight controls to avoid collision. Data on participant performance on the ability to maintain altitude and heading were recorded, measured, and collected by the flight simulation software.

Data collection on reaction time was made reliable by prompting the participant to tell the researcher when there was traffic in sight at the beginning of the flight and measuring the time carefully.

Independent between groups *t*-tests were performed to test the following null hypotheses:

$H_0 1$: There is no significant difference in overall situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0 2$: There is no significant difference in aircraft attitude situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0 3$: There is no significant difference in traffic avoidance situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0 4$: There is no significant difference in orientational situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0$5: There is no significant difference in the reaction time to a potential mid-air collision on the first flight of students exposed to visual and instrumental cues.

$H_0$6: There is no significant difference in the altitude deviation scores on the first flight of students exposed to visual and instrumental cues.

$H_0$7: There is no significant difference in the heading deviation scores on the first flight of students exposed to visual and instrumental cues.

Results

Descriptive Statistics

The following data in Table 1 illustrates the descriptive statistics for the SA and performance metrics.

Table 1
Descriptive Statistics

Statistic Type	Group	Mean	Standard Deviation	Score Range
Aircraft Attitude Situational Awareness				
	Visual	10.27	4.30	0.00 - 15.00
	Instrumental	10.40	3.94	0.00 - 15.00
Traffic Avoidance Situational Awareness				
	Visual	5.33	1.63	0.00 - 6.00
	Instrumental	4.20	2.37	0.00 - 6.00
Orientational Situational Awareness				
	Visual	5.33	1.45	0.00 - 6.00
	Instrumental	3.00	1.85	0.00 - 6.00
NMAC Reaction Time				
	Visual	8.54 s	6.38 s	1.50 - 20.00 s
	Instrumental	10.69 s	6.50 s	2.00 - 20.00 s
Altitude Deviation Before Turns				
	Visual	54.99 ft	32.03 ft	13.99 - 105.49 ft
	Instrumental	38.16 ft	32.98 ft	3.29 - 106.92 ft
Altitude Deviation After Turns				
	Visual	149.51 ft	138.28 ft	9.26 - 479.22 ft
	Instrumental	122.79 ft	119.28 ft	10.70 - 426.00 ft
Heading Deviation Before Turns				
	Visual	11.91°	21.01°	2.11 - 84.11°
	Instrumental	6.91°	6.32°	0.99 - 21.56°
Heading Deviation After Turns				
	Visual	7.04°	8.63°	1.26 - 35.34°
	Instrumental	10.64°	25.57°	1.01 - 102.61°

Hypothesis Testing

$H_0$1: There is no significant difference in overall situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was applied to test the null hypothesis that there is no significant difference in situational awareness on the first flight of students exposed to visual and instrumental cues. The assumption of equality of variance was tested. Levene's test of equality of variance was not significant ($p > .05$), which implies that variance across the different groups is equal.

The mean of the visual group ($M = 20.93$, $SD = 5.87$) was larger than the mean of the instrumental group ($M = 17.60$, $SD = 7.04$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 1.41$, $p = 0.17$; thus, the null hypothesis was retained.

$H_0$2: There is no significant difference in aircraft attitude situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in aircraft attitude situational awareness on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 10.27$, $SD = 4.30$) was smaller than the mean of the instrumental group ($M = 10.40$, $SD = 3.94$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = -0.09$, $p = 0.93$; thus, the null hypothesis was retained.

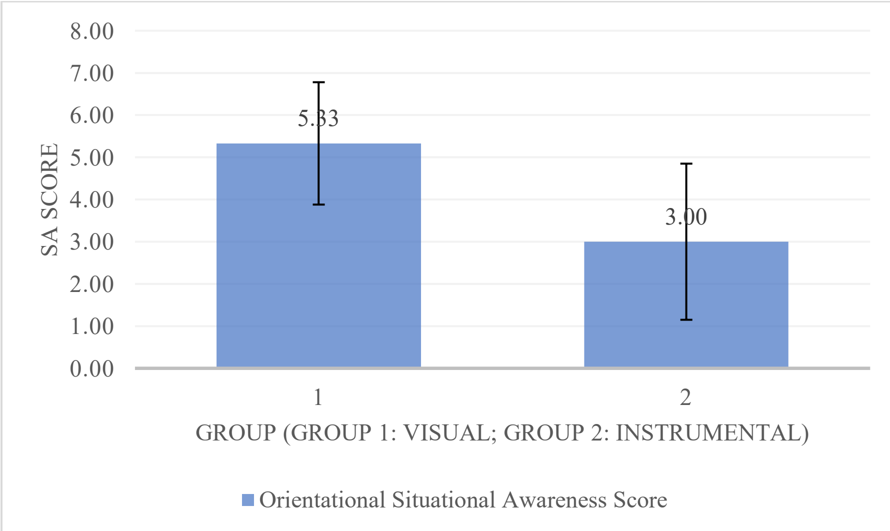
$H_0$3: There is no significant difference in traffic avoidance situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in traffic avoidance situational awareness on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 5.33$, $SD = 1.63$) was larger than the mean of the instrumental group ($M = 4.20$, $SD = 2.37$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 1.53$, $p = 0.14$; thus, the null hypothesis was retained.

$H_0$4: There is no significant difference in orientational situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in orientational situational awareness on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group (Group 1; $M = 5.33$, $SD = 1.45$) was larger than the mean of the instrumental group (Group 2; $M = 3.00$, $SD = 1.85$). An independent samples *t*-test was significant at the alpha level of .05, $t(28) = 3.85$, $p = 0.001$; thus, the null hypothesis was rejected. Cohen's $d = 1.41$, which indicated a large effect. Figure 3 shows the difference between these two groups.

Figure 3
Orientational Situational Awareness Comparison



$H_0$5: There is no significant difference in the reaction time to a potential mid-air collision on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in the reaction time to a potential mid-air collision on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 8.54$, $SD = 6.38$) was smaller than the mean of the instrumental group ($M = 10.69$, $SD = 6.66$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = -0.90$, $p = 0.37$; thus, the null hypothesis was retained.

$H_0$6: There is no significant difference in the altitude deviation scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in the altitude deviation scores on the first flight of students exposed to visual and instrumental cues. The data measured for this hypothesis test came from the first 30 seconds of in-flight measurement before the participant completed two 90 degree turns. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 54.99$, $SD = 32.03$) was larger than the mean of the instrumental group ($M = 38.16$, $SD = 32.98$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 1.42$, $p = 0.17$; thus, the null hypothesis was retained.

An independent samples *t*-test was run to evaluate the hypothesis during one minute of in-flight measurement after the participant completed two 90 degree turns. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 149.51$, $SD = 138.28$) was larger than the mean of the instrumental group ($M = 122.79$, $SD = 119.28$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 0.57$, $p = 0.58$; thus, the null hypothesis was retained.

$H_0$7: There is no significant difference in the heading deviation scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in the heading deviation scores on the first flight of students exposed to visual and instrumental cues. The data measured for this hypothesis test came from the first 30 seconds of in-flight measurement. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 11.91$, $SD = 21.01$) was larger than the mean of the instrumental group ($M = 6.91$, $SD = 6.32$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 0.88$, $p = 0.39$. Therefore, the null hypothesis was retained.

An independent samples *t*-test was run to test the hypothesis during one minute of in-flight measurement after the participant completed two 90 degree turns. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 7.04$, $SD = 8.63$) was smaller than the mean of the instrumental group ($M = 10.64$, $SD = 25.57$). An independent samples t-test was not significant at the alpha level of .05, $t(28) = -0.52$, $p = 0.61$. Therefore, the null hypothesis was retained.

In the following section, these results are discussed.

Discussion

The results show a few key differences in the performance of the two groups (Visual and Instrumental). First, the visual group had a higher average score on situational awareness with significantly better SA in orientational awareness. Second, the visual group had a faster reaction time to a near-mid-air collision. However, the instrumental group performed slightly better at maintaining positive control of the aircraft.

Situational Awareness

The visual group scored better overall on the SAGAT test for situational awareness. Although the statistical analysis was not statistically significant, the differences in SAGAT scores still provide insightful information on student pilot situational awareness. The SAGAT test measured SA based on the student pilot's main goals of maintaining positive control of the aircraft, avoiding collisions, and maintaining aircraft orientation. Both groups were taught to maintain positive control of the aircraft based on their respective cues. The instrumental group scored high marks for the SA questions based on the goal of maintaining positive control of the aircraft but low marks on the SA questions based on maintaining orientation. The visual group tended to score high marks on all the SA questions, especially orientation and collision avoidance.

These results suggest that BAI or instrumental cues negatively impact student SA at the onset of training, especially in the subtasks of collision avoidance and orientation. Collision avoidance and orientation are very critical tasks to the safety of flight. Disorientation and loss of visual situational awareness can often result in further issues, such as airspace violations.

Instrumental cues did result in similar SA scores on awareness of the current state of the aircraft in space. This is most likely because of the participant's direct focus on the instruments, but these scores were on par with the visual group and not significant enough to maintain that instrumental cues are beneficial at the onset of training.

SA scores provide evidence that the very onset of training is not the appropriate time to introduce instrumental cues. The CFI needs to focus directly outside of the cockpit to develop the primacy effect of maintaining VSA.

Reaction time to NMAC

The visual group reacted faster on average to the traffic conflict. Although the statistical analysis was not statistically significant, the differences in reaction time measurements can still be analyzed from a qualitative perspective. Both groups were instructed to scan for traffic during the ground lecture, which covered how to scan for traffic and how to avoid colliding with traffic. Only one traffic conflict resulted in a mid-air collision, which occurred with a member of the instrumental group. These results show that initially teaching students instrumental cues, even when telling them to look outside the window, results in focus being shifted inside the cockpit. According to these results, one in 15 students taught by reference to instrumental cues at the onset of training will result in a catastrophic collision if an NMAC situation arises and is not caught by the CFI.

Orientation and Performance

The instrumental group outperformed the visual group in maintaining altitude. There was a significant statistical difference in orientation between the two groups, suggesting that different training methods enhance piloting accuracy. The instrumental group maintained a better heading prior to the turns, and the visual group maintained a better heading after the turns. In terms of task balance, both groups performed equally well in different areas. The visual group had a much higher deviation in altitude. This deviation would cause more safety of flight issues than the other performance factors. Therefore, it was weighted higher for analysis. The instrumental group appeared to have a higher level of control of the aircraft and were much more aware of altitude deviations than the visual group.

These results show that a proper understanding of the instruments will help the student tremendously in controlling the aircraft and maintaining altitude and heading. It is the CFI's responsibility to ensure the student understands that instruments are for verifying a condition exists that is already understood using visuals and ISF. Proper use of the instruments at the onset of training will benefit the student in both SA and performance.

Conclusion

This study investigated the potential outcomes, benefits, and disadvantages of using visual versus instrumental cues at the beginning of flight training. It is important for CFIs to be aware of the resulting effects of their chosen teaching techniques, as they can influence the safety of flight and the future habits of their students. CFIs should think carefully about how to present information to the students in the early phases of flight training to ensure optimal learning and safety.

This study further reinforces recommendations from previous research, suggesting that visual cues and integrated sensory flying techniques should be prioritized in initial flight instruction to help students maintain their focus outside the cockpit. CFIs can prevent students from developing hazardous habits by reinforcing the concept of interpreting the outside flight environment before referencing flight instruments. Beginning flight instruction with visual cues is the safest approach for new students learning to fly under VFR conditions, with instrument cues gradually introduced as their training progresses.

With regard to the BAI training, further research is required to understand the appropriate time in primary flight training for instrumental flying to be introduced. The responsibility of determining the appropriate time to introduce BAI lies with flight program curriculum designers, but it needs to be implemented carefully by the CFI, depending on the unique learning progression of each student. Ultimately, it is up to the CFI to interpret and teach the student based on the student's learning style. The CFI must demonstrate to the student that there are real consequences to mistakes made in flight, and actions must be taken to ensure the safety of the flight.

Limitations

Overall, flight instruction techniques and their impact on student situational awareness (SA), reaction time to Near Mid-Air Collisions (NMACs), and overall performance would benefit from further research. This research study can be improved and can also serve as a foundation for further research.

One of the limitations of this study is its limited sample size. A larger sample size might have yielded more data, potentially revealing statistically significant differences between the two groups. This study could also benefit from being conducted using a within-subjects design, allowing for more direct comparisons across conditions for each participant. The original pilot study for this experiment utilized a within-subjects design. However, the researcher ultimately decided against this approach due to concerns that potential testing bias inherent in within-subjects designs could confound the results of the SAGAT test. To mitigate this issue, a potential solution could be to implement a delay between the two measures, allowing sufficient time for participants' memories of the questions and traffic scenarios to fade.

This study could also be improved by using multiple measures of reaction time to the NMAC scenario. The SAGAT questionnaires could have been evaluated by multiple qualified CFIs, with the average scores taken to provide a less subjective and more reliable measure of situational awareness. Another limitation of this study is that it does not capture the full benefits of an integrated flight instruction method, where pilots utilize both visual and instrument cues. The study overlooks the real-world application of flight training, in which pilots must switch between these cues depending on conditions, and it does not account for holistic skill development. Consequently, it does not reflect how integrated flight instruction may enhance safety by preparing pilots for a broader range of scenarios. This study only focuses on the introductory flying lessons in an ab initio training context. Any observed differences in performance, particularly when comparing performance measures between the visual and instrumental cue groups, may primarily be attributed to students being task-saturated while looking at the instruments rather than true differences in flying skills/learning methods.

Using a *t*-test to compare the two groups also presents limitations, particularly when multiple dependent variables are involved. The *t*-test is designed to compare means between two groups on a single dependent variable and does not account for the potential correlations between multiple dependent variables. This simplification can lead to an increased risk of Type I errors due to multiple comparisons, and it overlooks the complex interactions between variables that might be better addressed with multivariate analysis techniques. Thus, the statistical analysis of this study may not fully capture the nuanced differences between visual and instrument approaches.

Further Study

Further research into this area would be beneficial to the field of flight instruction. Including eye-tracking technology to measure where the participants were looking and for how long could provide useful insights. During the debrief, when the purpose of the study was explained, most participants in the instrumental group acknowledged that they had focused inside the cockpit for much of the simulation. Collecting data on the duration of time participants spent focused inside the cockpit, along with their SA scores and reaction times to an NMAC, could provide valuable insights and enhance the findings of the study.

In future studies, it would be beneficial to include and report demographic information such as age, gender, and experience level. Including this data could help identify underlying demographic influences on the outcomes and ensure that findings are more generalizable. Additionally, understanding how these factors interact with visual and instrument approaches could provide deeper insights and enhance the design of flight training programs, making them more tailored and effective for the different ways students learn. This study could be integrated into a flight training course at a flight school, allowing new student pilots to participate in the research before proceeding with their regular flight training. Subsequent analysis of their performance could reveal whether the primacy effect influenced their progress during training. Future research could extend across multiple lessons and assess students in different phases of flight training to identify the most appropriate timing for introducing specific types of training, thereby optimizing the effectiveness of instructional techniques.

Continued research in this field will help make flight instruction safer. Identifying and optimizing instructional techniques that enhance flight safety will enable CFIs to adopt the most effective methods, ultimately producing safer and more aware pilots.

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Appendix A
SAGAT Questionnaires (Task 1 and Task 2)

SAGAT Questionnaire for Student Pilots – Task 1 – Participant:______________________

Desired altitude: **Actual altitude:**

Desired airspeed: **Actual airspeed:**

Desired heading: **Actual heading:**

- *Is the aircraft at the desired altitude? (1)*
  - Yes
  - No
  - I don't know
- *How will you correct to achieve the desired altitude? (2)*
  - Climb
  - Descent
  - The aircraft is at the desired altitude
  - I don't know
- *If the aircraft is off the desired altitude, why? (3)*
  - Low power setting
  - Too much elevator pressure
  - Not enough elevator pressure
  - The aircraft is at the desired altitude
  - I don't know

- *Is the aircraft at the desired airspeed? (1)*
  - Yes
  - No
  - I don't know
- *How will you correct to achieve desired airspeed? (2)*
  - More power
  - Less power
  - The aircraft is at the desired airspeed
  - I don't know
- *If the aircraft if off the desired airspeed, why? (3)*
  - Power setting low
  - Power setting high
  - Inadvertent climb/descent
  - The aircraft is at the desired airspeed
  - I don't know

- *Is the aircraft on the desired heading? (1)*
  - Yes
  - No
  - I don't know

- *How will you correct to achieve the desired heading? (2)*
  - Yes, turn left
  - Yes, turn right
  - The aircraft is on the desired heading
  - I don't know
- *If the aircraft is off the desired heading, why? (3)*
  - Improper rudder usage
  - Inadvertent left turn
  - Inadvertent right turn
  - The aircraft is on the desired heading
  - I don't know

Pitch: up / level / down **Bank: left / level / right**

- *Is the aircraft in a level pitch attitude? (1)*
  - Yes
  - No
  - I don't know
- *Is the aircraft pitched up, down, or level? (2)*
  - Up
  - Down
  - Level
  - I don't know
- *Why is the aircraft at this pitch attitude? (3)*
  - Too much elevator pressure
  - Not enough elevator pressure
  - Improper trim
  - Proper elevator and trim
  - I don't know

- *Are the wings level? (1)*
  - Yes
  - No
  - I don't know
- *Are the wings banked left, right, or level? (2)*
  - Left
  - Right
  - Level
  - I don't know
- *Why are the wings at this attitude? (3)*
  - Right aileron
  - Left aileron
  - Rudder usage
  - Proper aileron usage
  - I don't know

SAGAT Questionnaire for Student Pilots – Task 2 – Participant:______________________

Vertical: above / same / below **Lateral: right / center / left**

Reaction time:

- *Is there traffic in sight? (1)*
  - Yes
  - No
  - I don't know
- *Is the traffic to the left or right of the aircraft? (2)*
  - Left
  - Right
  - Center
  - I don't know
- *Should you turn to avoid a collision, if so, which way? (3)*
  - No
  - Turn left
  - Turn right
  - I don't know

- *Are you aware of an airplane in the general vicinity? (1)*
  - Yes
  - No
  - I don't know
- *Is the airplane above or below the altitude of your aircraft? (2)*
  - Above
  - Below
  - Same altitude
  - I don't know
- *Should a climbing or descending evasive maneuver be performed to avoid a collision, if so, which one? (3)*
  - No
  - Climbing turn
  - Descending turn
  - I don't know

KDAB: left / right / front / behind **Shoreline: left / right / front / behind**

North / South / East / West **North / South / East / West**

- *Is Daytona Beach airport nearby? (1)*
  - Yes
  - No
  - I don't know
- *Which direction is Daytona Beach airport? (2)*
  - Left
  - Right
  - Front
  - Behind
  - I don't know
- *Which direction should we fly to get to get to Daytona Beach airport? (3)*
  - North
  - South
  - East
  - West
  - I don't know

- *Is the shoreline nearby? (1)*
  - Yes
  - No
  - I don't know
- *Which direction is the shoreline? (2)*
  - Left
  - Right
  - Front
  - Behind
  - I don't know
- *Which direction should we fly to get to the shoreline? (3)*
  - North
  - South
  - East
  - West
  - I don't know