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THE ROLE OF SIMULATOR SCENARIOS IN LEARNING LOW VISIBILITY PROCEDURES IN FLIGHT

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Abstract

The continuation of visual flight in meteorological conditions with inadequate visibility accounted for the majority of fatal weather-related general aviation accidents. During practical flight training in the aircraft, the standardization of low visibility procedures training is very limited due to weather variability and regulations restraining from flying below visibility minima. This study describes and evaluates a theoretical briefing and simulator scenarios for low visibility procedures that are practiced by ab initio student pilots and can be used to extend the current syllabus. The simulator scenarios included flying traffic patterns in conditions of degrading visibility (80 km, 8 km, 5 km and 1.5 km), returning or flying through a mountain pass in marginal conditions, and 180° turns out of clouds. The simulator training program was evaluated in a pretest-training-posttest design with ab initio student pilots assigned to a training and a control group. The results show a significant effect of simulator training to improve the performance of student pilots. The research presented in this study addresses improvements of the training methods for low visibility procedures, supporting pilots' management of weather-related threats and errors and the standardization of the syllabus.

Keywords: Ab initio pilot training, flight skills, flight simulation, low visibility procedures, threat and error management

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1. Introduction

A significant rate of fatal weather-related general aviation accidents occurred when pilots continued a visual flight rules (VFR) flight in instrument meteorological conditions (IMC) with inadequate visibility (Aircraft Owners and Pilots Association; Kalagher et al., 2021). Whereas flying in IMC can be safely and legally done with the appropriate license and aircraft instruments, this study focuses on pilots that are only VFR-rated. The minimum visibility requirements for a VFR flight are specified by international regulations and depend on the type of airspace and the flight altitude. In addition to visibility requirements (e.g., 5 or 8 kilometers), the pilots are required to maintain vertical and horizontal distances from clouds that vary depending on the type of airspace.

Research has addressed the issue of VFR flight into IMC from the perspective of decision making (Johnson & Wiegmann, 2015), compliance (Stanton et al., 2021) and over-reliance on automation (Johnson & Wiegmann, 2011). Pilot's estimation of their ability and of the visibility were found to predict whether a pilot would continue a VFR flight in IMC or divert the flight (Goh & Wiegmann, 2002). Pilots' gender seems to play a role as observed by Sitler (2004), who noted that female pilots are less prone to fly into dangerous weather, or to take risks. The most common threats related to VFR flight into IMC are disorientation, loss of control of the aircraft, flying at lower altitudes and collision risk (Johnson & Wiegmann, 2011). Pilots can manage these threats by diverting, cancelling or postponing the flight, flying through valleys and passes in the mountains. They can use the aircraft's instruments to check their altitude, attitude, heading and escape from IMC, if they inadvertently flew into clouds. The anticipation and management of these threats should be addressed during the practical flight training. Although it has been emphasized that training needs to be improved, there is a lack of methods, scenarios and evidence for the effectiveness of training on pilots' management of marginal visibility procedures (Johnson & Wiegmann, 2011; Seidl, 2019).

The development of skills goes beyond the theoretical, cognitive knowledge of a procedure and requires practice (Anderson, 1982). Practice also influences the storage of a procedure in the memory (Schacter, 1994). Research on anticipative processes shows that people can develop the skills to anticipate and manage threats by developing a mental model and predicting the effects of their actions (Kallus, 2012; Koglbauer, 2015a; Koglbauer & Braunstingl, 2021). These skills are developed through practice in the relevant context, using feedback to compare expected and real effects and adjusting their actions according to specific goals (Koglbauer & Braunstingl, 2021). This study proposes the use of simulator scenarios as didactic means to create a consistent and standardized environment for training low visibility procedures in the basic, ab initio flight training syllabus. Didactic means with informative, illustrative and formative functions (Baciu et al., 2022) have been developed in order to create a stimulating learning environment.

Simulator training has been shown to have a positive effect on the flight performance in both simulator (Hays et al., 1992; Koglbauer, 2016; Koglbauer & Braunstingl, 2018) and real flight (Koglbauer et al., 2016). For these scenarios the simulator needs to have task-relevant fidelity features (Farmer et al., 2003; Koglbauer et al., 2016). Thus, in addition to the aircraft cockpit, various visibility margins, clouds, mountain scenery need to be implemented into the visual system of the simulator. During practical flight training in the aircraft the standardization of low visibility procedures training is

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very limited due to weather variability and regulations restraining from flying below visibility minima. This study describes and evaluates a theoretical briefing and simulator scenarios for low visibility procedures that are practiced by ab initio student pilots and can be used to extend the current syllabus.

The research question is if flight training with simulator scenarios significantly improves the performance of student pilots when carrying out low visibility procedures. The simulator training program is evaluated in a pretest-training-posttest design with ab initio student pilots assigned to a training and a control group. In the following sections the method of the study, including simulator scenarios are described, as well as the criteria used for performance evaluation. The results are discussed in relation to the research in the field.

2. Research Methods

2.1. Training Means

Three training means have been used in this study: a technical theoretical briefing, simulator scenarios and a sighting device. These will be described in the following.

2.1.1. Theoretical Briefing

The theoretical Briefing consisted of written information about rules and legal requirements for visibility and separation from clouds when conducting VFR flights in conditions of low visibility in various types of airspace. A special section was dedicated to common threats and errors related to VFR flight in low visibility conditions such as disorientation, illusions, collision with terrain, obstacles or other aircraft. In addition, procedures for managing such threats and errors (e.g., avoiding to fly in low visibility, returning when inadvertently flying into a cloud, approaching a mountain pass with the possibility to turn around, and turning around before a “closed” mountain pass) were explained.

2.2. Simulator Scenarios

The first simulator scenario was flying a traffic circuit at a familiar airport with visibility degrading from 80 km, to various legal VFR flight minima specified by regulations such as 8 km, 5 km and 1.5 km (special VFR). In this first scenario the student pilots could experience and compare the flight situations and challenges posed by various visibility margins. The first simulator scenario was followed by three test and training scenarios described below.

2.2.1. Return before a mountain pass

This scenario simulated a flight in the mountains in conditions of 5 km visibility and the sky overcast with clouds, that was in conformance with legal requirements for that airspace. Only at a close distance from the pass it is possible to determine if the visibility through the pass is sufficient.

i. The required technique is approaching the ridge from the right side at an approximate 45° angle because of the narrow space at the pass, and preparedness to turn around if the pass is obscured by clouds or fog

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ii. When approaching the pass, the trainee observes that the pass is obscured by clouds and turns around before reaching the pass
iii. Due to the limited space before the pass the students need to turn with steep bank angles of 30 to 45 degrees
iv. During the whole exercise the trainee must fly at a constant altitude.

2.2.1.1. Flying through a mountain pass

This scenario simulated a flight in the mountains in conditions of 5 km visibility and the sky overcast with clouds. Only at a close distance from the pass it is possible to determine if the visibility through the pass is sufficient.

i. The required technique is approaching the ridge from the right side at an approximate 45° angle because of the narrow space at the pass, and preparedness to turn around if the pass is obscured by clouds or fog
ii. When approaching the pass, the trainee observes that the pass is clear and flies through the pass
iii. During the whole exercise the trainee must fly at a constant altitude.

2.2.1.2. Turn out of clouds

This scenario simulated a cruise flight in conditions of 5 km visibility and the sky overcast with clouds. The instructor changes the visibility to simulate an "inadvertent flight into clouds". As soon as the visibility is lost the trainee has to:

i. Monitor the artificial horizon and maintain the pitch attitude
ii. Monitor the directional gyro and read the reverse heading at the bottom of the directional gyro. Thus, the direction of the 180 degrees turn is identified. The trainee is encouraged to call out loudly the new heading and memorize it. In the simulator they could also set this new heading using the heading bug
iii. The trainee performs a "standard turn" to the reverse heading. The rule of thumb for calculating the bank angle for the "standard turn" was the airspeed divided by 10, and adding 7. For example for 100 knots airspeed, the bank angle was 17 degrees
iv. After reaching the opposite heading the trainee continues for 2 minutes until re-entering visual meteorological conditions (VMC)
v. The trainee monitors the instrument indications for avoiding potential spatial disorientation.

2.2.2. Sighting Device

A sighting device in form of a point on the visual system screen that marked where the longitudinal axis of the aircraft intersected the visual scenery of the simulator was used during training by the training group. The purpose of this device was to facilitate students' orientation by visual reference to the natural horizon. The device indicated the aircraft's attitude relative to the natural horizon (and roughly the direction of flight).

2.3. Procedure

The procedure of the study for the training and control group is presented in Table 1.

Table 1. Procedure

Phase	Training Group	Control Group
Theoretical Briefing	VFR rules and procedures	VFR rules and procedures
Simulator Flight with Degrading Visibility	Visibility degrading	Visibility degrading
	from 80 to 8 km	from 80 to 8 km
	from 8 to 5 km	from 8 to 5 km
	from 5 to 1.5 km (special VFR)	from 5 to 1.5 km (special VFR)
Simulator Pretest	1x Return before the pass	1x Return before the pass
	1x Fly through the pass	1x Fly through the pass
	1x 180° turn out of clouds	1x 180° turn out of clouds
Simulator Training	3x Return before the pass	
	3x Fly through the pass	Basic flight exercises in VMC
	3x 180° turn out of clouds	
Simulator Posttest	1x Return before the pass	1x Return before the pass
	1x Fly through the pass	1x Fly through the pass
	1x 180° turn out of clouds	1x 180° turn out of clouds

2.4. Participants

Twenty-six female student pilots with a mean age of 26.46 years, (SD=4.37) and 32 male student pilots with a mean age of 25.19 years (SD=2.56) participated in this experiment. The results are based on data from 26 participants from the training group (12 women, 14 men) and 24 participants from the control group (11 women, 13 men) who completed the study.

The participants were enrolled in the flight training program for obtaining a private pilot license (PPL) to fly a fixed-wing aircraft. As a part of this program the participants received 40 hours of theoretical instruction, 1.5 hours of training in the aircraft and about 4 hours of simulator training before starting this experiment. Each trainee received a written briefing about the experiment and gave informed consent for participation in the study. This research complied with the tenets of the Declaration of Helsinki.

2.5. Independent Variables

There were three independent variables: the test (pretest versus posttetst), the group (training versus control group) and the gender (male versus female students).

2.6. Dependent Variables

Performance was assessed by the instructor on a scale ranging from 0 (low) to 5 (excellent) in accordance with the criteria used by the flight training organisation. The limits relevant for these exercises were height deviations of ± 150 feet, heading deviations of ± 10 degrees and speed deviations of ± 15 knots. Students' ability to fly within these limits was part of the performance assessment. Additional criteria were the procedural errors, the adaption to change, control smoothness, and the necessity for instructor's intervention.

In addition, the students gave a subjective evaluation of the training means (theoretical briefing, simulator exercises and the sighting device) at the end of the module by selecting one of the categories: useful or extremely useful, neutral, not useful, or counterproductive. They were also asked if they would recommend the training means to other student pilots.

2.7. Data Analysis

A repeated measures ANOVA was conducted for the analysis of performance data. The within-subject factor test had two levels (pretest and posttest). There were two between-subjects factors: Group (training versus control group) and gender (male and female). Alpha was set at 0.05. Students' evaluation of the training means is presented descriptively.

3. Findings

The results show a significant effect of training with the simulator scenarios on students' performance as demonstrated by the interaction term Test* Group [$F(1,46)=33.62$, $p < 0.0001$, $\eta^2=0.42$)]. As illustrated in Figure 1, the training group performed significantly better than the control group in posttest, in all simulator scenarios.

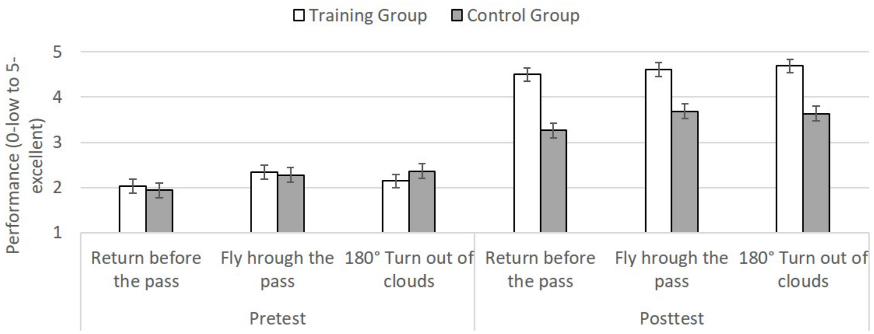

Figure 1. Performance of the training and control groups in pretest and posttest

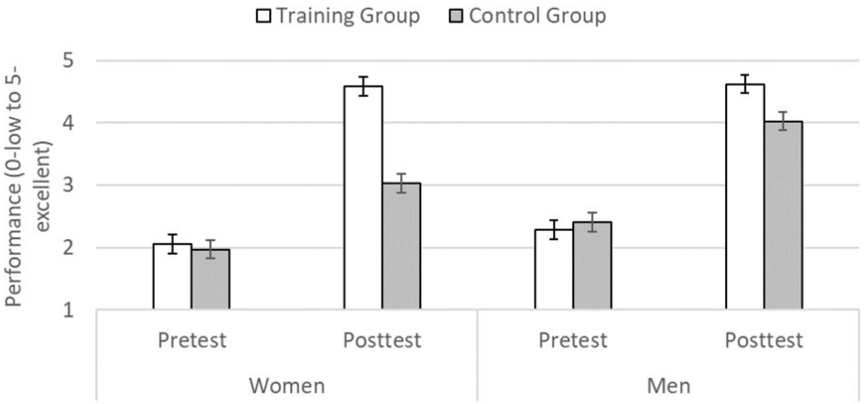

Figure 2. Performance of the gender groups in pretest and posttest

The interaction term Gender*Test*Group just failed to reach statistical significance [$F(1,46)=3.95$, $p < 0.053$, $\eta^2=0.08$)]. However, because of their practical relevance the results are presented in Figure 2. The results show that women and men from the training group reach similar levels of performance after training, but in the control group men performed slightly better than women.

Students' feedback about the training means has shown that 98% rated the simulator scenarios as useful or extremely useful. The theoretical briefing was considered by for 76% as useful or extremely useful. The sighting device was considered by 55% as useful or extremely useful, and 34% rated it as neutral. All student pilots (100%) responded that they would recommend the simulator scenarios to other students. Ninety-two percent of students would recommend the briefing handout and 69% would recommend the sighting device.

4. Discussion and Conclusions

Pilots' mismanagement of marginal visibility procedures in VFR flight was related to a significant rate of weather-related general aviation accidents (Aircraft Owners and Pilots Association; Kalagher et al., 2021). This study addressed simulator scenarios that enable student pilots to experience the challenges related to VFR flight into marginal visibility conditions such as disorientation, tendency to fly at lower altitudes and collision risk (Johnson & Wiegmann, 2011). Most important, the student pilots practiced the procedures required to manage simulated threats and errors in those scenarios.

The training with simulator scenarios was evaluated in a pretest-training-posttest design with ab initio student pilots assigned to a training and a control group. The results show a significant effect of simulator training to improve the performance of student pilots. Student pilots from the training group performed significantly better than those from the control group in posttest consistently, in all simulator scenarios. The acceptance of simulator scenarios was high, as 98% of participants rated the simulator scenarios as useful or extremely useful, and all (100%) stated that they would recommend them to other student pilots. This positive effect of the simulator training on performance is in line with previous findings (Hays et al., 1992; Koglbauer, 2016; Koglbauer & Braunstingl, 2018). A prerequisite is considered the design of simulator scenarios with task-relevant fidelity features (Farmer et al., 2003; Koglbauer et al., 2016) such as the simulated aircraft cockpit, visibility margins, clouds, mountain scenery implemented in the visual system of the simulator. Furthermore, the possibility to practice in addition to receiving theoretical information is essential for the development of skills (Anderson, 1982) and storage in the appropriate memory systems (Schacter, 1994). In this study the gender effect just failed to reach statistical significance. However, it is noticeable that women and men from the training group obtained similar levels of performance after training despite noticeable differences in pretest. Previous findings indicated gender differences in a number of factors related to flight training (Koglbauer, 2015b, 2017; Sitler, 2004). Nevertheless, it appears that initial gender differences disappear after practical training (Koglbauer & Braunstingl, 2018).

Despite the use of informative and illustrative didactic means such as theoretical briefing (Baciu et al., 2022), the results show that a significant effect on the learning outcomes was obtained by adding simulator training which is a formative didactic mean (Baciu et al., 2022). Future research on the formative didactic means for low visibility procedures could include mixed reality (e.g., virtual and augmented reality) applications. Mixed reality applications could potentially improve flight training in terms of visualization, content, augmented didactical features and learning conditions (Brown, 2018; Moesl et al., 2021, 2022; Schaffernak et al., 2021, 2022; Vlasblom et al., 2019).

In conclusion, the research presented in this study shows positive effects of simulator scenarios to significantly improve students' performance of low visibility procedures in simulated VFR flight. The simulator scenarios, the procedure and the performance assessment criteria are described. Thus, this study fills the gap in research on simulator scenarios for low visibility procedures, supporting the standardization of the training syllabus for the Private Pilot License, and pilots' management of weather-related threats and errors in VFR flight.

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