Effects of Conceptual Training and Procedural Training for Teaching Aviation Instrument Holding Patterns

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ABSTRACT

Twenty private pilots without instrument ratings trained how to fly instrument holding patterns. Holding patterns are advanced aviation maneuvers learned during instrument training where pilots maintain a particular "race-track" figure that keeps the airplane essentially stationary. Participants were randomly assigned to a procedural training group or a conceptual training group. The step-by-step sequence of actions to fly instrument holds was emphasized in the procedural training group. The reasons for flying instruments holds and the interrelationship of elements in a dynamic environment were emphasized in the conceptual training group. Training stimuli included reading text and watching videos. Participants who were conceptually trained showed no difference in situation awareness when flying a typical instrument hold in a flight simulator compared to when flying a more difficult, atypical instrument hold in a flight simulator. However, the procedurally trained participants showed significantly less situation awareness when flying the atypical instrument hold compared to when flying the typical instrument hold. It was found that participants who required more attempts to answer questions correctly during training showed better situation awareness when flying atypical holding patterns. Finally it was found that participants required more attempts to answer questions correctly during the training delivered via video than they did during the training delivered via text.

Flying an airplane is a complex task. Dozens of hours of flight training and ground training are required to earn a private pilot's license. Dozens of hours of flight training and ground training beyond earning a private pilot's license are required for advanced maneuvers (e.g., instrument rating, commercial license, etc.). It is critical that the appropriate training paradigms are implemented to assure that pilots will have developed the necessary skills and awareness in typical and routine situations as well as in atypical and non-routine situations. Atypical situations involve maneuvers a pilot would not frequently encounter, such as landing in a tailwind. Non-routine conditions are situations that a pilot would not expect, such as receiving from air traffic control that goes counter to the normal flow of traffic.

Two important approaches for flight training are conceptual training and procedural training. Conceptual training emphasizes the interrelationship of elements in a dynamic environment and procedural training emphasizes the step-by-step actions necessary to complete an action or maneuver (Bibby & Payne, 1993). Thus, knowing how to work a system is synonymous with procedural training. Knowing how a system works is synonymous with conceptual training. Both types of training are important in learning advanced flight maneuvers (Dattel, Durso, & Bédard, 2009). One may initially learn a task sooner when procedural training is emphasized, especially if the task is not complex. However, conceptual training is important for learning complex tasks and improving situation awareness (SA), especially in atypical or non-routine situations (Hockey, Sauer, & Wastell, 2007). SA is the understanding of relevant information in a dynamic environment (Durso, Rawson, & Girotto, 2007). Endsley (1995) emphasizes the importance of predicting future status, as noted in her 3rd level of how she defines SA. Because conceptual training focuses on the interrelationship of elements, higher levels of SA should develop during conceptual training than during procedural training.

Dattel, et al. (2009) found that private pilots who received a conceptual review of landings and traffic patterns (maneuvers learned in private pilot training) showed better performance during atypical landings and typical traffic pattern situations than participants who received procedural reviews of traffic patterns and landings. Thus, a review of the conceptual elements of traffic patterns, which are more mentally complex maneuvers than landings, was more beneficial than

procedural training for traffic pattern performance. Although conceptual review showed no improved performance for typical landings when compared to participants who received the procedural review, conceptual review was better than procedural review for performance for atypical landings.

One complex advanced maneuver that instruments pilots learn is instrument holding patterns. Holding patterns are an advanced maneuver learned in instrument training where pilots maintain a particular "race-track" pattern that keeps the airplane essentially stationary. That is, when airplanes must wait while traveling, they fly in circles until conditions permit them to continue to their destinations. Air traffic controllers assign instrument holding patterns to pilots when air traffic becomes heavy and backed up. These back-ups in air traffic usually result from weather issues, but can sometimes be the result of malfunctioning radar systems. Instrument holding patterns are very complex maneuvers (both physically and mentally) and require a high level of working memory (WM) to execute. WM is the ability to store information in short-term memory while simultaneously processing other information (Baddeley & Hitch, 1974). When executing instrument holding pattern, one must quickly calculate algebraic and geometric functions, remember assigned headings, routes and altitudes, and be keenly aware of the appropriate amount of time to remain in the various "legs" of the hold. An instrument rated pilot flying on an instrument flight plan must be prepared to execute holds at any time, frequently in complex, and sometimes atypical, conditions.

The current study tested whether conceptual training creates better SA than procedural training for an advanced aviation maneuver, specifically instrument holding patterns. WM was also explored as a factor affecting SA. It was predicted that pilots who received procedural and conceptual training would show better SA during holding patterns than pilots who received only procedural training for the same amount of time.

METHOD

Participants

Twenty participants who were private rated pilots, but who were not instrument rated took part in this study. Mean age of participants was 45.7 (*SD*=15.44) years. There was no significant difference in total flight time between training groups. The conceptual group had an average of 180.43 (SD=172.74) total flight hours and the procedural group had an average of 238.32 (SD=199.33) total flight hours. Four participants' data were loss due to technical difficulties. Half of the participants were randomly assigned to the conceptual training group and half of the participants were randomly assigned to the procedural training group. It took each participant approximately 2 hours to complete the study, and each participant was paid $15 per hour for their time.

Materials

Operations span (OSPAN) was used to test working memory (Turner & Engle, 1989). One conceptual instrument hold video was created and one procedural instrument hold video was created. The conceptual hold video was the same flight as the procedural hold video. However, the procedural hold video was viewed from the pilot's perspective and showed the step-by-step actions necessary to fly an instrument hold. The conceptual hold video was shot from a bird's eye view, showing the plane from an external view as the plane flew an instrument holding pattern. The videos were recorded in Microsoft Flight Simulator 2004.

A text describing the conceptual explanations for conducting instrument holds was developed that emphasized the reasons of flying instrument holds using metaphors and diagrams. The procedural text that was developed described the step-by-step sequence of actions necessary to fly an instrument holding pattern. A total of 18 training questions (multiple choice and short answer) accompanied the four training materials (2 training videos and 2 two training texts). Two test scenarios for holding patterns were developed in Elite PI-135. The Elite PI-135 is a personal computer flight training device (flight simulator) that the Federal Aviation Administration (FAA) has approved flight students to log training time when flying the device. Three situation awareness questions were developed for each test scenario. All training stimuli and testing scenarios were developed by commercial pilots and flight instructors.

Procedure

After signing a consent form, participants completed OSPAN to test their working memory capacity. The OSPAN consists of 15 trials of two to six operations each. Participants were shown a simple mathematical operation (e.g., "Is 6/2 = 2?" or "Is 2 + 5 = 7?"), followed by a one syllable word (e.g., fern). Participants read the operations and words aloud and determined if the mathematical operations were true or false by verbally saying their answers (i.e., "Yes" or "No"). At the end of each trial, participants were asked to write down as many words as they could recall and to write them in the correct order they were presented.

All training text, videos, and questions were accessed and presented through Microsoft PowerPoint. After each training trial (i.e., reading the assigned text or watching the assigned video), participants answered three questions relevant to the respective training text or training video. The participants were permitted to refer back to the text or video for the specific trial at anytime while they were answering the questions. Participants had three chances to answer each question correctly. If participants answered a question incorrectly, they were prompted to try again, with the training materials available to refer to. Once the participants answered a question correctly, the next question appeared. After three incorrect answers, participants were given the correct answer and were then allowed to continue with the training.

The procedural trained participants read and watched the procedural stimuli twice. Because the participants had not learned how to conduct instrument holds before participating in this study, it was necessary to provide all participants with procedural training. Thus, the conceptual group received equal amounts of procedural training and conceptual training. The procedural group received twice as much procedural training as the conceptual group, but did not receive any conceptual training.

Conceptual Training

Participants who were randomly assigned to the conceptual group read the conceptual text first and then watched the conceptual video. After answering questions specific for the respective text or video, participants then read the procedural text, answered the questions specific to the text, and finally watched the procedural video, and answered questions specific to the video.

Procedural Training

Participants who were randomly assigned to the procedural group read the procedural text first, answered questions specific to the text, watched the procedural video, and finally answered the questions specific to the video. Participants then read the procedural text again watched the procedural video again, but answered different sets of questions specific to the video and text. For both procedural and conceptual training, text always preceded videos. The text contained elements that were introductory in nature and the videos showed the maneuvers in action.

Testing

After participants completed the four training trials, they were tested on two scenarios where they were instructed to fly instrument holding patterns on the flight simulator. The first test scenario was a typical holding pattern a pilot would receive. The second test scenario was an atypical holding pattern and more complex. For example, to fly the pattern correctly, the pilot had to make a "parallel" entry (rather than the more frequent "direct" entry) and make a "non-standard" turn while holding in the pattern. Participants were given holding pattern instructions before beginning each test. Radio and navigation instruments were preset, so participants were not required to manipulate any navigation selectors. A timer (to time holds) was provided for the participants. Participants were told to follow the holding pattern instructions given to them, and once entering the holding pattern to remain in the hold. Participants kept a sheet describing the instrument holding pattern instructions during each test scenario. Each test scenario started 7 miles from the point of entry where the participants would enter the hold. Each scenario lasted 9 ½ minutes. At predetermined times (approximately every 2 ½ to 3 minutes) throughout the scenario, participants were asked three pre-recorded SA questions during each test scenario. Each question was relevant to the scenario the participants were flying. SA questions were delivered using the SPAM procedure (see Durso & Dattel, 2004). Specifically, SA questions were delivered in real-time. Also, participants heard a warning tone to let them know a question was imminent. The workload measure of SPAM was not utilized. Accuracy and RT of correctly answered questions were recorded.

RESULTS

A dependent means t-test was conducted for the average number of attempts it took participants to correctly answer questions from the text training stimuli and the average attempts it took participants to correctly answer questions from the video training stimuli (See Figure 1). A significant difference was found between the different training delivery methods $t(15) = 4.406$, $p=.001$, where participants needed more attempts to answer questions for the video training stimuli ($M=1.65$, $SD=.315$) than for the text training stimuli ($M=1.25$, $SD=.258$).

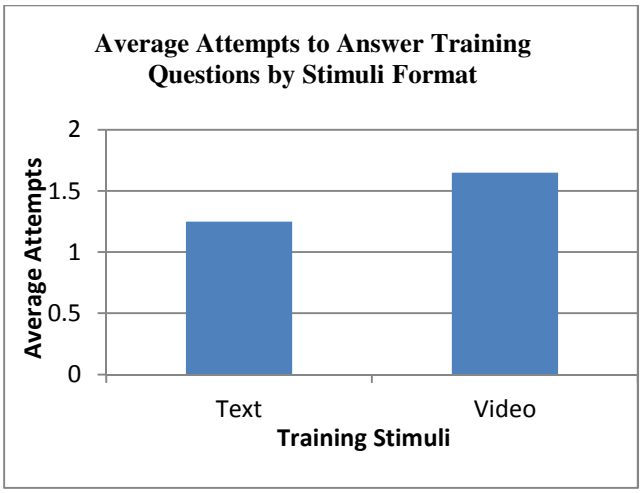

Figure 1. Attempts to correctly answer questions by training stimuli.

A log transformation was made for the SA RT data. Two of the participants' data were excluded in the analyses because of missing data in one of the conditions. Correlations were conducted between WM, attempts to answer training questions for the training stimuli delivery methods, and SA during the two holding pattern tests in the flight simulator (See Table 1). An inverse relationship is shown between attempts to answer video questions and SA where the more attempts it takes to answer questions during the training videos, the shorter the time required to answer SA questions during the atypical holding pattern test. Additionally, a relationship emerged where the more attempts to answer questions for the text training, the shorter time it took to answer SA questions during atypical holding pattern test. An inverse correlation with age r=-638, p=.014 was found for WM.

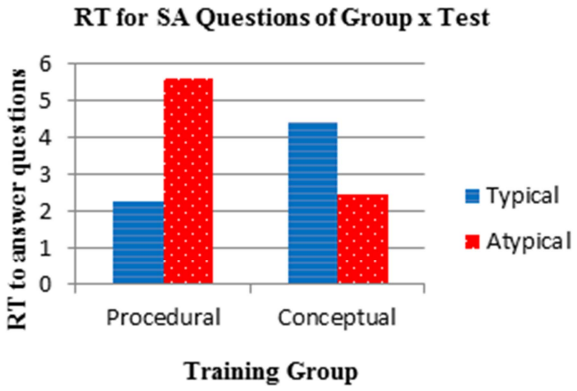

Figure 2. Mean RT to answer SA questions by training group and test.

Table 1. Correlations of Training Material, WM, and SA

Variable	1	2	3	4	5
1.Working Memory	-	-.455 (n=16)	-.372 (n=16)	.173 (n=16)	.141 (n=16)
2. Attempts for Text Training Questions		-	.350 (n=16)	.028 (n=16)	.-540* (n=16)
3. Attempts for Video Training Questions			-	.077 (n=16)	-.648** (n=16)
4. SA in Typical Hold Test				-	.149 (n=16)
5. SA in Atypical Hold Test					-

*p<.05 **p<.01

A 2x2 (Training group: Procedural and Conceptual; Hold (Typical and Atypical) mixed ANOVA for RT of SA questions found an interaction $F(1,14) = 4.792$, p=.007, $\eta p2$ = .415 (See Figure 2). Post hoc analyses showed no differences in SA for conceptually trained participants between typical (M=4.45, SD=2.94) and atypical (M=2.47, SD=2.06) instrument holding patterns. However, procedurally trained participants took longer to answer SA questions (M=5.63, SD=6.40) during atypical holds than to answer SA questions during typical holding patterns (M= during atypical holds (M=2.30, SD=1.86).

DISCUSSION

Participants took more attempts to answer questions correctly during the video training conditions than during the text training conditions. Because participants could go back to the text or video when attempting to answer questions, it is possible that the participants could have just scanned the text till they found the correct word. However, when answering the video questions, more effort was likely required to review the video than just searching for text.

The extra effort it took to answer the training questions correctly seems to have been beneficial because the greater the number of attempts to correctly answer questions during the video training conditions, the better SA was during the atypical instrument holding pattern test. Although to a lesser degree, greater attempts to correctly answer questions during the text conditions

was also related to better SA during the atypical instrument holding pattern test. Thus, it appears that challenging training programs may pay off when pilots find themselves in atypical situations.

Although both procedural training and conceptual training are important training approaches for aviation maneuvers, the results of this study indicate that conceptual training is important for SA during atypical situations. Pilots in this study were learning new aviation maneuvers. The procedurally trained group may have experienced greater cognitive load because they were having a difficult time understanding atypical situations. As a result, the procedurally trained group took almost twice as long to answer SA questions when flying the atypical instrument holding pattern than when flying a typical instrument holding pattern. However, the conceptually trained group's SA did not seem to be negatively affected by the atypical situation. If anything, there may have been a learning curve for the conceptual group just from experiencing the first test, a beneficial byproduct that was apparently absent from the procedurally trained group.

Holding patterns are advanced aviation maneuvers and are very complex. Pilots can learn to fly by procedural training only, but introducing conceptual training at an early stage for more complex maneuvers may improve pilots' SA, especially when the situation is atypical or non-routine. However, an emphasis on procedural training might be as effective as conceptual training for maneuvers that are advanced, but not complex (e.g., Chandelles, Lazy Eights, and other maneuvers that display precision control). Future studies are warranted exploring which training approaches should be emphasized in respect to the complexity and type of aviation maneuver.

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