The Effects of Feedback on the Accuracy of Completing Flight Checklists

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THE EFFECTS OF FEEDBACK ON THE ACCURACY OF COMPLETING FLIGHT CHECKLISTS

by

William G. Rantz

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William G. Rantz
This study examined whether pilots completed airplane checklists more accurately when they received post-flight graphic and verbal feedback. Participants were 8 college student pilots with instrument rating. The task consisted of flying flight patterns using a Personal Computer Aviation Training Device. The main dependent variable was the number of checklist items completed correctly per flight. A multiple baseline design across pairs with reversal was used. During baseline, the average number of correctly completed items per flight varied considerably across participants, ranging from 21 to 39 out of 40. It increased to near perfect levels for all participants after they were given feedback and praise, and remained high after the feedback and praise were removed. The results suggest that graphic feedback and praise can be used to increase the extent to which pilots use checklists accurately.
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INTRODUCTION

Flight operations consist of various tasks which flight crews perform to manage risks within an ever-changing, dynamic environment. Even with today's high technology flight decks, managing these tasks efficiently and effectively continues to challenge flight crews. The airplane checklist is a job aid used to accomplish these important flight tasks. The checklist is used during different segments of flight to sequence specific, critical tasks and aircraft configuration adjustments that correspond to specific environmental demands (Degani & Wiener, 1990). It is divided into sub-sections with task checklists that correspond to all flight segments and, in particular, critical segments such as take off, approach, and landing (Degani & Wiener). For example, checklists are used by flight crews (a) before take-off to insure the aircraft is airworthy, (b) during take-off to insure correct airspeed, flap configuration, and ascent angle, (c) during cruise to insure proper power settings, pressurization, and fuel burn, (d) during the landing approach to correct for approach briefings, landing configurations, and cabin preparations, and (e) before and after landing to insure system status from flight operations to ground operations. Special checklists are also used during abnormal and emergency conditions. These special checklists contain the essential tasks for a particular abnormal situation that requires timely action and deliberate execution of sequential tasks.

Airplane checklists are usually developed by the manufacturer of the aircraft and are aircraft specific. "The major function of the checklist is to ensure the crew will properly configure the plane for flight, and maintain this level of quality throughout the flight, and in every flight" (Degani & Wiener, 1990, p. 7). The complexity of these task checklists cannot be overstated. Standard procedures common to some cockpits are not
compatible with other cockpits or with newer generation cockpits. Additionally, the task lists can be very long. For example, on some checklists, the "before engine start" subsection has 76 items for the first flight of the day, and 37 items for subsequent flight segments (Degani & Wiener).

Degani (2002) addressed the importance of pilot checklists, stating, "You see, there is a certain limit on how much a human, even the most conscientious one, can recall. We ask pilots to remember, flawlessly, many sets of procedure items, numbers, and sequences. At some point we hit a limitation of our memory abilities. And this is where an aid, like a checklist, comes in handy" (p. 6). In an historical account that traced the development and use of flight checklists, Turner (2001) emphasized their importance by recounting a 1935 crash by a military test pilot. The military test pilot was flying a Boeing YB-17 model 299 (the prototype of the famous Boeing B-17 bomber of World War II) and crashed shortly after take-off. An investigation revealed that the pilot had failed to perform a standard, yet critical, pre-flight task.

If a professional military-aircraft test pilot could forget such a critical step in their takeoff preparations, correctly reasoned Boeing and Army crash investigators, then any 'line' aviator could too. The best solution was to make a list of all the things a pilot needed to do to prepare for takeoff and train the pilot to use the list to avoid missing anything. From there it was a quick leap to creating checklists for all phases of flight, not just for takeoff, and to require pilots to use the checklists. (Turner, 2001, p. 7)

Since that time, checklists have become the main strategy to standardize pilot performance and increase flight deck safety. Thus, it is not surprising that many aviation
experts have addressed their importance and design, as well as the practices and policies that surround their use (Adamski & Stahl, 1997; Degani, 1992, 2002; Degani & Wiener 1990; Federal Aviation Administration [FAA], 1995, 2000; Gross 1995; Turner, 2001).

Even so, the incorrect use of flight checklists is still often cited as the probable cause or a contributing factor to a large number of crashes (Degani; Degani & Wiener; Diez, Boehm-Davis, & Holt, 2003; Turner). Similarly, many investigations by the National Transportation Safety Board (NTSB) have revealed that the aircraft were not properly configured for flight, which usually results from improper checklist use (NTSB, 1969, 1975, 1982, 1988a, 1988b, 1989, 1990, 1997).

Studies by Lautmann and Gallimore (1987) and Helmreich, Wilhelm, Klinect, and Merritt (2001) provide more direct evidence of improper checklist use by flight crews. In a study funded by the Boeing aircraft manufacturer, Lautmann and Gallimore surveyed twelve airlines and concluded that procedural errors involving use of the checklist contributed to a substantial number of aircraft crashes and incidents.

In an effort to identify what particular errors flight crews commit, the National Aeronautics and Space Administration (NASA) sponsored a series of studies in which crews were observed while flying. Crew errors were recorded using the Line Oriented Safety Audit (LOSA) developed by Helmreich and his colleagues (Helmreich, Klinect, Wilhelm, & Jones, 1999; Helmreich et al., 2001; Klinect, Murray, Merritt, & Helmreich, 2003). Between 1997 and 1998, LOSAs were conducted at three airlines with 184 flight crews on 314 flight segments (Helmreich et al. 2001; Klinect et al.). Errors were classified into five categories: (1) intentional noncompliance errors, (2) procedural errors, (3) communication errors, (4) proficiency errors, and (5) operational decision errors.
Failure to properly complete the checklist was recorded as a rule compliance error. Seventy-three percent of the flight crews committed errors (Klinect et al.). The number of errors ranged from zero to fourteen per flight, with an average of two. Rule-compliance errors were the most frequently occurring errors, accounting for fifty-four percent of all errors (Helmreich et al., 2001; Klinect et al.). Checklist errors constituted the highest number of errors in this category.

Despite widespread recognition that checklist errors occurred relatively frequently and were major contributing factors to many crashes, the design of checklists “escaped the scrutiny of the human factors profession” until the 1990s (Degani & Wiener, 1993, p. 28). In 1988, when testifying at a NTSB investigative hearing for a fatal crash, Wiener stated that he knew of no research on how a checklist should be designed, a fact that he and Degani confirmed by an extensive literature search of U.S. and European databases (Degani & Wiener, 1990). Degani and Wiener began their work on checklist design shortly thereafter. While recognizing that various types of checklist devices existed (i.e., paper, scroll, mechanical and electromechanical, vocal, and computer-aided), Degani and Wiener focused on paper checklists because they were the most common form of checklists used in commercial operations.

Degani and Wiener (1990, 1993) observed flight crews while flying, interviewed flights crews from seven major U.S. airlines, and analyzed how the design of checklists contributed to aircraft crashes and incidents that were reported in three aviation databases. Their analytic guidelines became the industry standard. In 1995, all FAA inspectors that certified checklists were mandated to follow their recommendations (Patterson, Render, & Ebright, 2002).
Although Degani and Wiener (1990) did not pursue the behavioral factors that influence checklist use, they recognized their importance, indicating that “social issues” were a core problem that led some pilots to misuse the checklist or not use it at all. They also noted that the promotion of a positive attitude toward the use of the checklist procedure was an important element that was often overlooked. Regardless, an extensive search of the aviation checklist literature did not reveal any studies that have examined whether behavioral interventions could increase the appropriate use of flight checklists.

As in aviation, checklists have been used in a number of Organizational Behavior Management (OBM) studies as antecedents to document and prompt the completion of specific behavior chains. Based on information obtained from a detailed task analysis, a checklist can be constructed in a manner that clarifies tasks for workers and maximizes their sequence of performance (Anderson, Crowell, Hantula, & Siroky, 1988). By doing so, checklists can reduce time and effort, particularly for tasks that require multiple responses and long chains of behavior (Anderson, Crowell, Sponsel, Clarke, & Brence, 1982). Checklists can also be combined with self-monitoring to increase sequential task reliability and accuracy (Bacon, Fulton, & Malott, 1982).

Checklists have been used in a variety of settings (i.e., manufacturing, hotels, banks, offices, retail establishments, and restaurants) to improve a diverse array of performances, including cleaning and housekeeping tasks (Altus, Welsh, & Miller, 1991; Anderson et al., 1988; Anderson et al., 1982), office tasks (Bacon et al., 1982), banquet set-up times (LaFleur & Hyten, 1995), machine set-up time, (Wittkopp, Rowan, & Poling, 1990), metal yield (Moses, Stahelski, & Knapp, 2000), end-of-shift closing tasks (Austin, Weatherly, & Gravina, 2005), staff-client contact time (Porterfield, Evans, &
Blunden, 1985), and customer service behaviors (Crowell, Anderson, Abel, & Sergio, 1988). In most studies, checklists have been used as part of a package intervention, combined with verbal feedback, graphic feedback, goal setting and/or tangible rewards.

LaFleur and Hyten (1995) combined checklists with training, job aids, daily feedback, goal setting, and monetary incentives to increase the accuracy and timeliness of banquet set-ups by hotel staff. Checklists were used for each banquet set-up. Participants checked off completed tasks and then initialed the form. The supervisor collected the checklists, reviewed the banquet set-ups, and initialed each completed task to verify its completion. The treatment package was evaluated using an ABAB reversal design. The percentage of tasks completed correctly increased from an average of 68.8% to 99.7% when the treatment package was implemented, dropped to 82.3% when the treatment package was removed, and increased to 99.3% when the treatment package was reintroduced. These results clearly demonstrate the effectiveness of the treatment package; however, the independent effects of the intervention components, including the checklists, were not assessed.

Other studies that have successfully combined checklists with feedback and tangible rewards include Anderson et al. (1982) who delivered tokens contingent upon performance, Pampino, Heering, Wilder, Barton, and Burson (2003) who used a monetary lottery as a reward, and Pampino, MacDonald, Mullin, and Wilder (2003) who used access to preferred items as a reward. Performance improved in each study, demonstrating the effectiveness of these types of package interventions. However, once again, it is not possible to tease out the impact of the individual components.
Two studies by Austin and his colleagues (Austin et al., 2005; Shier, Rae, & Austin, 2003) demonstrated that checklists, when combined only with feedback, could effectively alter performance. Shier et al. used checklists and posted feedback to improve the appearance of five departments in a grocery store. A multiple-baseline design across departments was used to evaluate the results. Checklists were placed on clipboards and put in a specific location in each department. At the end of each shift, employees recorded the status of each task, signed, and dated the checklist. Feedback graphs were updated weekly and attached to the clipboard. The average percentage of tasks completed across all five departments during baseline was 27%. Following implementation, task completion increased by an average of over 45% across all departments.

Austin et al. (2005) examined the effects of posted checklists, verbal feedback and graphic feedback on closing tasks performed by servers and dishwashers in a restaurant. After a baseline period, checklists were posted in the relevant areas. Managers provided verbal feedback at two regularly scheduled times as well as sporadically during the week. For servers, task completion rose from an average of 75% to an average of 87%. For dishwashers, it rose from an average of 49% to 87%. Graphic feedback was then provided to servers. Graphs were updated weekly and posted next to the checklists. Server task completion increased further, from an average of 87% to 90%. As noted by the authors, the small increase might have been the result of a ceiling effect, as servers were already performing at high levels when the graphic feedback was added.

The preceding two studies are important for several reasons. First, they demonstrated that a package intervention consisting of only checklists and feedback could improve task performance. They are also important because, as noted by Shier et
al. (2003), feedback interventions are (a) more cost-effective than interventions using tangible rewards, and (b) easier for management to maintain.

Three studies examined the effects of a checklist alone as an independent variable (Anderson et al., 1988; Bacon et al., 1982; Crowell et al., 1988). Bacon et al. implemented checklists for student workers engaged in office and teaching activities at a university. The design was a multiple baseline design across three groups, with a reversal for two of the groups. During baseline, task completion averaged from 45% to 60% across the three groups. Checklists increased performance by an average of 28.8%, with task completion ranging from 80% to 100%. When checklists were withdrawn for two of the groups, their performance decreased by about 10%. Performance was measured for only two weeks following withdrawal eliminating the possibility of observing any further decreases.

The results of Bacon et al. (1982) seem to demonstrate that the checklist alone increased the percentage of completed tasks. It should be noted, however, that the checklist system incorporated some features that could have contributed to the results. The checklist procedure was modeled from a study conducted by Brethower (1970). The results of that study suggested that three components might be important for checklists to affect behavior: (a) clear task definition, (b) daily recording of behavior, and (c) supervisor review of checklist completion. Hence, Bacon et al. added these features to their checklist procedure. Checklists were designed so participants could check off tasks as they completed them. When the checklists were implemented, the supervisor explained how to record responses on the checklist. He also indicated that he would examine their checklists weekly, but that nothing good or bad would happen based on checklist
completion. Consistent with this explanation, the supervisor gave participants new checklists each week, but did not mention the checklists that participants had turned in the week before. Therefore, no feedback was given to the participants about checklist completion, nor was it consequated.

Bacon et al. (1982) referred to their procedure as a package intervention, identifying a number of factors that could have been responsible for the effectiveness of the checklist. First, the checklists might have clarified the criteria for task completion and improved discrimination of the required tasks. Second, the checklists were paired with successful task completion, which supported their use. Third, the checkmarks on the checklists may have acquired reinforcing properties because checklist use provided a visual record of accomplishment. Fourth, the potential punishing or reinforcing consequences of the supervisor’s review of checklist completion might have maintained its use. Unfortunately, for the purposes of this review, the authors did not report data on the extent to which the participants actually used the checklists.

Anderson et al. (1988) assessed the effects of task checklists with and without posted feedback on the cleaning behaviors of students in a student-operated university bar. They used a multiple baseline across groups design. Eleven checklists were developed and posted in the relevant work areas. Checklist implementation resulted in an abrupt improvement over baseline. The overall average increase over baseline during the checklist phase was 13%. Feedback was then provided in the form of publicly displayed individual line graphs, coded by numbers assigned to the workers. Task completion increased by an average of approximately 26% over the checklist alone phase. At the
conclusion of the feedback phase, task completion had increased an average of approximately 62% over baseline.

Anderson et al. (1988) showed that antecedent task clarification via posted checklists can immediately change desired behaviors. However, the change was modest until feedback was added. One unknown factor is the extent to which participants came into contact with the posted checklists. Although the checklists were posted in prominent locations in the relevant work areas and could be continuously viewed by participants, it is not clear whether participants actually looked at them or, if they did, how often they looked at them. Nonetheless, the data suggest that the posted checklists resulted in a desirable, if modest, increase in performance.

Crowell et al. (1988) examined the independent effects of a different task clarification procedure (a memo from management) on the customer service behaviors of bank tellers. Eleven categories of behaviors were defined and each was assigned quality points that summed to 100. For example, greeting the customer was assigned a value of 10 points, offering additional assistance was assigned a value of 6 points, and voice tone was assigned a value of 15 points. Eighty-five points was deemed to be minimal acceptable performance. The mean point score per customer transaction, averaged across tellers, was the dependent variable. Task clarification, feedback, and social praise were implemented sequentially. Then, after a 20-day suspension, baseline, feedback and social praise were once again introduced sequentially. Task clarification alone was not repeated because the researchers believed that it was not subject to withdrawal.

At the beginning of the task clarification phase, management distributed a memo that defined the customer service behaviors and indicated the point values attached to
each category. The memo was given to tellers at a meeting, discussed, and explained. Teller performance was then observed for 35 days. Performance increased from an average of 61.4 points during baseline to an average of 72 points during the task clarification phase. Daily feedback was then added. Feedback consisted of publicly posted line graphs, coded by numbers assigned to the workers. Additionally, managers gave verbal feedback to each teller individually at the start of each workday. Managers were instructed not to interpret or evaluate performance during these feedback sessions. The transaction score averaged 78 points for the entire phase and 81.4 points for the last six sessions of the phase. In the social praise phase, verbal praise was added to the verbal feedback. Performance increased and remained above the 85-point minimum. Performance declined during the second baseline phase, but only to an average of 76 points, suggesting carry-over effects from the prior phases. Performance trends during the second feedback and social praise phases were similar to those in the first, with performance reaching the highest levels during the final social praise phase.

As in Anderson et al. (1988), task clarification resulted in an immediate, but modest increase in performance. Crowell et al. (1988) described the performance change as follows, “The performance change produced by clarification emerged quickly and remained relatively consistent throughout the phase” (p. 69). Once again, the reason clarification affected performance is not clear. It is not known whether the knowledge obtained from explicit task definition was responsible for the increase or whether the memo prompted better performance through continued use (or both). Although the authors did not address this issue, they appear to support the former interpretation stating, “The present effects of task clarification are noteworthy because they are consistent with
prior evidence showing that knowledge [italics added] of task relevant behaviors can facilitate work performance, even in the absence of explicit feedback” (p. 70).

The preceding three studies demonstrate that performance can be improved through task clarification, whether the clarification is provided via hand-held check sheets (Bacon et al., 1982), posted checklists (Anderson et al., 1988) or memos (Crowell et al., 1988). In Anderson et al. and Crowell et al., improvements were modest, 13% and 17% over baseline, respectively. In both studies, performance improved further when feedback was added and, in Crowell et al., performance improved even more when social praise was added. Performance gains were higher in Bacon et al., with performance averaging about 30% higher during the checklist phase than during baseline.

The relatively large performance gains in Bacon et al. (1982) may be due to two factors. First, participants were asked to check tasks as they completed them on a daily basis. Second, the supervisor reviewed the completed checklists at the end of the week. Although the behavioral effects of these design features need to be empirically verified, the results of Bacon et al. suggest that checklists will be more effective if they are interactive (require some type of active response by the performer) and if completion is subject to supervisor review.

In most studies, checklist use was not monitored as part of the study, thus it is not known whether participants actually used the checklists or referred to them. Checklist use was required in only one study, LaFleur and Hyten (1995). As indicated earlier, in that study, workers initialed completed tasks on the checklist and the supervisor later verified the completion of tasks by initializing each completed task. In Bacon et al. (1982), workers were asked to record daily task completion on checklists and turn the checklists in
weekly, however, they were not required to do so. Checklist completion rates were not reported in the study. Similarly, in Shier et al. (2003), participants were asked to self-monitor task completion using checklists that were collected by the researchers at the end of each day. There were a number of days, however, when participants did not complete the checklists. Shier et al. suggested that the failure to complete the checklists was probably due to the fact that there were no programmed consequences for doing so. Thus, they indicated that, "Future research would benefit from offering non-monetary incentives for completing and submitting self-monitoring reports" (p. 38).

It should be noted that all of the studies examined the effects of checklists, alone or in combination with other variables, as independent variables. None has examined checklist use as a dependent variable. And, as indicated above, few studies have monitored whether the checklists were actually used. Data from Shier et al. (2003) suggest that unless checklist completion is consequated, individuals may use them inconsistently. On the other hand, when consequences are provided for task completion (as opposed to checklist completion), as they were in several studies (Altus et al., 1991; Anderson et al., 1982; Crowell et al., 1988; LaFleur & Hyten, 1995; Pampino, Heering, et al., 2003; Pampino, MacDonald, et al., 2003), those consequences may maintain use of the checklist.

In aviation, incorrect task checklist completion has been identified as the probable cause or a contributing factor to many aircraft crashes. Incorrect use can lead to consequences that are literally fatal. In addition, the completion of checklists during flight is more behaviorally challenging than in the settings in which OBM studies have been conducted due to constantly changing environmental demands, distractions, and schedule
pressures. For example, in one fatal crash, the taxi checklist was not completed because of several interruptions (new weather information, checking aircraft and runway data) (Degani & Wiener, 1990). Yet, to date, no study has examined whether behavioral interventions can improve checklist use. Nor have any OBM studies examined how to increase checklist use. The current study filled that void by examining whether post-flight graphic feedback and verbal praise would increase the accuracy and quality of checklist use by pilots during simulated flights.

As illustrated in the studies discussed herein, feedback, alone or in combination with other independent variables, has been used to improve a variety of organizational performances. In a review of studies published in the *Journal of Organizational Behavior Management* during the first ten years of its publication (1977-1986), Balcazar, Shupert, Daniels, Mawhinney, and Hopkins (1989) reported that feedback was used as an independent variable in approximately 65% of the studies. In a review that analyzed the *Journal*’s second decade of publications, Nolan, Jarema, and Austin (1999) found that percentage to be 71%.

Graphic feedback was used in the current study because it has been shown to be more effective than other types of feedback. In their classic review of feedback, Balcazar, Hopkins, and Suarez (1985-86) reported that graphic feedback produced more consistent improvements in performance than other types of feedback. Additionally, Austin et al. (2005) found that graphic feedback enhanced the effectiveness of verbal feedback, and Wilk and Redmon (1998) found that it enhanced the effectiveness of both verbal feedback and goal setting. In the current study, graphic feedback was combined with verbal praise because in another comprehensive review, Alvero, Bucklin, and Austin
(2001) reported that the combination of graphic and verbal feedback was more effective than either alone, a finding that was experimentally verified by Crowell et al. (1988).
METHOD

Participants

Participants were 8 undergraduate students enrolled in commercial flight courses in the aviation flight science program at Western Michigan University (WMU). Criteria for inclusion included a Private Pilot Certificate, instrument rating, and personal computer (PC) flight simulation experience.

A Private Pilot Certificate and instrument rating were prerequisites for performing the simulated instrument flight patterns used as the experimental task. Instrument flight refers to the use of flight instruments to maintain straight and level flight, turn, climb and descend while vision is obscured by clouds, precipitation, or other weather and environmental conditions. The FAA requires that pilots have a minimum of 125 flight hours before they can obtain instrument rating, thus all participants had these minimum flight hours. The possession of a Private Pilot Certificate and instrument rating was assessed by self-report. A copy of the participant qualification questionnaire can be found in Appendix A.

Another criterion for inclusion was past experience with PC flight simulators. Participants were required to have a minimum of two hours of experience with a PC aircraft training device (PC-ATD) with at least rudder and yoke controls, flying some type of instrument approach at least once. This insured that participants had some understanding of how the flight software program functioned and what responses were required to perform technical flight skills on the PC-ATD. This previous exposure enabled participants to perform technical flight skills more fluently sooner than those
who would not have had such exposure. Participants self-reported this experience on the qualification questionnaire in Appendix A.

Recruitment flyers and in-class announcements were used to notify potential participants of the opportunity to volunteer for the study. A copy of the flyer can be found in Appendix B. A copy of the in-class announcement script can be found in Appendix C. Potential participants were asked to read a consent form (Appendix D). Only those who signed the consent document participated. The approval letter from Western Michigan University's (WMU) Human Subjects Institutional Review Board (HSIRB) is in Appendix E.

Setting

The experimental setting was a 12 by 16 foot room that was used as the PC-ATD flight laboratory. The laboratory was located in a building adjacent to WMU’s Aviation Education Center in Battle Creek, MI. Within the room, dividers restricted the vision of the participant to the PC-ATD flight simulation testing equipment.

Apparatus

**PC-ATD equipment.** The PC-ATD equipment consisted of a Pentium II® 300 megahertz processor, 4 megabytes of SRAM video memory, and 64 megabytes of SDRAM memory. Other PC equipment included a Dell QuietKey® keyboard, a mouse, a 10 X 14 inch monitor and two JUSTer™ SP-660 3D speakers. Operating software was Microsoft Windows 95™ and the simulation software was On-Top version 8. Flight support equipment for the PC-ATD included a Cirrus yoke, a throttle quadrant, an avionics panel, and rudder pedals. The On-Top software permitted the simulation of several different aircraft. The aircraft that was simulated in the current study was the
Cessna C-172. The Cessna was chosen due to its vast popularity in the flight training field as well as the fact that it was the primary aircraft used in the WMU training fleet. Technical flight parameters, which depicted how well participants flew the designated flight patterns, vertically and horizontally, were recorded for each flight. The On-Top simulation software automatically recorded these technical parameters and enabled them to be printed.

*Flight patterns.* There were six different flight patterns. Each flight pattern was divided into six segments: (a) pre take-off, (b) after take-off, (c) cruise, (d) arrival, (e) pre landing, and (f) after landing. Each pattern took approximately 15-20 minutes to complete. To realistically simulate actual flight patterns and insure that the patterns were flown in a consistent way across trials and participants, the experimenter provided typical air traffic control instructions throughout each flight pattern. These instructions were transmitted using an intercom. The specific flight parameters for the flight patterns and scripts for both the experimenter (i.e., the air traffic control instructions) and pilot responses are listed in narrative form in Appendix F.

*The flight checklist.* The flight checklist contained 40 checklist items divided into sections that corresponded to each of the six flight segments (see Appendix G). This checklist, which was based on the checklist for the Cessna 172 R (Cessna Aircraft Company, 1985), was similar to the one used in WMU's flight training curriculum. Items that could not be performed on the PC-ATD, however, were deleted. The checklist was mounted in plain sight 10 inches from the flight instrument display monitor. A paper checklist (rather than an electronic checklist) was used because paper checklists are the
most common type of checklist used in aviation and in other industries for complex processes (Boorman, 2001).

**Observation equipment.** Observers observed participants remotely via web cameras and, using a dual computer monitor arrangement, were also able to see the same computer screen as the participants. The observation system is described in detail in the *Dependent Variables* section below. The observing equipment consisted of two Logitec® QuickCam® Fusion™ web cameras with built-in microphones. The observer recording computer used a Dell Latitude D510® with a 5.7 gigabyte hard drive, a Pentium M® 1866 megahertz processor, and a plug and play monitor with 128 megabytes of memory. Other PC equipment included a Dell Microsoft Natural® PS/2 keyboard and a Sigma Tel C-Major® audio adapter.

**Dependent Variables**

The main dependent variable consisted of the number of checklist items completed correctly per flight. Two secondary dependent variables were the percentage of total errors for each of the six flight segments during each experimental phase (baseline, feedback, and reversal) per participant and the percentage of baseline trials participants performed each of the checklist items incorrectly.

For an item to be scored “correct,” participants had to (a) respond to the correct flight equipment, (b) respond appropriately with respect to that equipment, and (c) at the appropriate time in the flight segment. For example, if the checklist item required turning the heading indicator to the direction corresponding to the compass reading and the participant turned the heading indicator (the correct equipment) to the "corresponding compass heading" position (the correct response), the item was scored “correct.”
However, if the participant turned the heading indicator (the correct equipment) to the wrong heading (an incorrect response), the item was scored "incorrect." If the participant turned the heading indicator (the correct equipment) to the corresponding compass heading position (the correct response) at the incorrect time in the flight or checklist sequence, the item was also scored "incorrect." All observed behaviors were compared to the criteria outlined in the checklist behavior protocol in Appendix H.

The checklist behaviors were scored by trained observers using the checklist observation form included in Appendix I. The observers occupied a room that was adjacent to the participant’s room. The two web cameras used by the observers had built in microphones which allowed the observers to see and hear both the nonverbal and verbal responses that were required to complete the checklist. One camera was mounted on the computer monitor approximately 20 inches in front of the participant to capture hand and arm movements. The other was positioned 35 inches behind the participant to observe the participant’s interaction with the flight panel. To insure the accuracy of frequencies entered into the communication and navigation radios, which could not be seen clearly via the web cameras, observers viewed a dual computer monitor that mimicked the computer screen of participants. All flights were recorded and stored digitally for the purposes of conducting interobserver agreement checks.

**Independent Variable**

The independent variable was the presence or absence of post-flight (a) graphic feedback on the total number of checklist items completed correctly per flight, (b) graphic feedback on the number of items completed correctly, completed incorrectly, and omitted for each of the six flight segments per flight, and (c) praise for improvement in
the number of checklist items completed correctly. Procedural details are described below in the *Procedures* section.

**Experimental Design**

A multiple baseline design with reversal across pairs of participants was used. Sessions lasted approximately one hour and participants flew three different flight patterns per session. Each flight was considered a trial, and checklist performance was scored and graphed separately for each trial. Each flight lasted approximately 15-20 minutes. There were six different flight patterns. The order of exposure to the flight patterns was randomized in blocks of six for each participant.

A reversal phase was included to assess whether checklist performance would maintain after the post-flight feedback was withdrawn.

**Procedures**

*Recruitment.* As indicated in the *Participants* section, potential participants were recruited from commercial flight courses at WMU and through the use of posted flyers on WMU’s campus. When recruiting from classes, the experimenter asked individuals who were interested in learning more about the study to print their name, telephone number or email address on a sheet of paper and give it to the experimenter. Each individual wrote this information on a separate sheet of paper in order to maintain the confidentiality of the information provided. In addition, the experimenter handed out a sheet of paper with his name, telephone number and email address, and told individuals that they could contact him by telephone or email if they preferred. The experimenter contacted individuals in the following two to three days to arrange a meeting to discuss the details of the study. If individuals contacted the experimenter based on the flyer, the
experimenter repeated the information contained in the flyer and arranged a meeting to discuss the details of the study.

**Informed consent process and screening.** The experimenter met individually with potential participants and obtained their consent using the consent document approved by the HSIRB. If consent was obtained, the experimenter asked them to complete the self-report inclusionary questionnaire. They were told that the experimenter would contact them within a few days to inform them if they had been selected for the study. If selected, the experimenter scheduled their first experimental session. The experimenter screened participants for possession of a Private Pilot Certificate, instrument rating, and PC-ATD experience by examining responses on the inclusionary questionnaire. The experimenter selected the first 8 participants who qualified.

**Baseline.** Participants were told that the PC-ATD aircraft was not programmed for any system failures and that each flight pattern was a radar-vectored instrument flight, with an instrument landing system approach to a full stop landing. They were also told that their behavior during the flight would be observed and recorded using web cameras. They were then shown the flight checklist and asked to use it as they did during regular flights. Additionally, they were told that the experimenter would provide them with some post-flight information after each flight and that it would take him about 3-5 minutes to prepare that material. They would, thus, have a short break after each flight. Although this break was not necessary to provide the post-flight technical information during this phase, this break was necessary to permit the observer to summarize the participant’s checklist performance during the intervention phase. Thus, the same post-flight break was scheduled during this phase as well. After instructing participants, the experimenter
left the room. See Appendix J for the instructional scripts that were read before the first flight and subsequent flights.

After the participant completed a flight, the experimenter printed out a technical diagram of the flight pattern flown by the participant. This diagram was automatically created by the On-Top simulator software, and displayed the lateral and vertical flight paths. A sample print out is contained in Appendix K. The experimenter then entered the experimental room, gave the diagram to the participant, and discussed the technical merits of the flight, praising adequate performance. The post-flight technical briefing is contained in Appendix L. No feedback was given to the participant about the use of the flight checklist. This protocol was repeated for each flight during the baseline phase.

One participant completed 37 or more of the 40 checklist items correctly during one of his three flights in the first baseline session. The participant was eliminated from the study and another participant was selected from the pre-screened pool.

Post-flight checklist feedback. In addition to giving participants the technical diagram that depicted critical flight parameters after each flight, the experimenter provided feedback on the use of the flight checklist. After each flight, the experimenter immediately calculated the number of checklist items completed correctly, entered it into the computer, and printed a line graph that displayed the number of correctly completed items for each trial, including baseline. The experimenter also entered the number of items completed correctly, completed incorrectly, and omitted for each of the six flight segments for that particular flight, and printed a bar graph that displayed those data. As in the baseline phase, the experimenter printed out a technical flight diagram as well. It took the experimenter approximately 3-5 minutes to complete these activities. The
experimenter then entered the experimental room. He first showed the technical flight
diagram to the participant and discussed the technical merits of the flight. He then
showed the two checklist feedback graphs to the participants and praised any
improvements. This protocol was repeated for each flight. The feedback script and
sample feedback graphs are provided in Appendix M.

*Reversal.* Feedback was no longer provided for use of the flight checklist after
each flight. This phase was identical to the baseline phase.

*Debriefing.* Immediately after participants completed their last session they were
debriefed. The experimenter read the debriefing script (see Appendix N), answered any
questions they had, and thanked them for participating in the experiment.

*Interobserver Agreement (IOA)*

A second observer watched randomly selected recordings of the flights and scored
performance using the checklist observation form (Appendix I). After a participant
completed the study, numbers corresponding to each trial were placed in a container and
at least 10% were randomly drawn. This process was repeated for each participant. This
ensured that (a) at least 10% of the sessions were rescored for each participant, and (b)
the trials that were rescored were randomly selected. Interobserver agreement was
determined for the total number of checklist items completed correctly. Interobserver
agreement was calculated as follows: number of agreements divided by the number of
agreements and disagreements, multiplied by 100. Interobserver agreement was 94% with
a range of 83% to 100%.
Independent Variable Integrity

To be sure that the technical flight and checklist feedback was administered correctly, the experimenter read from prepared scripts (Appendices L and M). In addition, participants were asked to initial the technical flight diagrams and the checklist feedback graphs that were used during post-flight briefing sessions and give them back to the experimenter. One-hundred percent of all flight diagrams and feedback graphs were initialed by the participants.
RESULTS

Figure 1 displays the total number of checklist items completed correctly for each participant per trial. All participants increased performance accuracy over baseline when post-flight checklist feedback was provided and improvements remained during intervention withdrawal.

Baseline checklist performance varied considerably across participants with participant 1 showing the highest level of performance and participant 2 showing the lowest level. Baseline trends were very stable over time with the exception of participant 3, who showed a sudden increase in accuracy following the first two trials and participant 4 who showed a downward trend at the end of the phase.

Performance increased for all participants after the intervention was introduced. Five participants showed an abrupt level change following the introduction of the treatment (P1, P5, P6, P7, and P8), two participants showed a level change followed by an increasing trend (P2 and P4), and one participant showed a gradually increasing trend (P3). Overall, the average percentage of checklist items completed correctly increased from 53% during the baseline phase to 98% during the last three sessions of the intervention phase.

Each participant maintained high levels of correct item completion after the feedback intervention was withdrawn. The average percentage of checklist items completed correctly was 99% during the return to baseline condition for participants 1, 2, 3, 4, 5, and 6. Due to time constraints (end of the teaching semester), participants 7 and 8 did not experience the reversal phase.
Figure 1. Total number of checklist items completed correctly by participant.
The percentage of total checklist errors for each flight segment for each participant during each experimental condition is shown in Figure 2. During all flights, 1,973 total errors were observed. The percentage of errors was high and variable across all segments during baseline. The average percentage of segment errors was highest for the after take-off segment (88%, range = 71.43% - 100%) and lowest for the pre take-off segment (32%, range = 5.88% - 68.91%). For all participants, errors decreased or were eliminated during intervention. During reversal, three participants performed perfectly (P1, P5, and P6). Participants 2, 3, and 4 performed nearly perfectly.

Figure 3 shows the percentage of total checklist errors for each participant during each of the six segments for each phase of the experiment. Generally, the percentage of errors by flight segment varied across participants and flight segments. Participant 2 had the highest consistent errors for all segments in baseline.

During baseline, pre take-off checklist errors were relatively low across all participants. All participants had a higher percentage of errors in the second segment, the after take-off segment, than in the pre take-off segment. Errors in the cruise segment were highly variable with three participants showing high levels of error (P2, P4, and P5). Arrival errors were relatively low except for participants 2 and 4. Errors were quite variable across participants for the pre landing and after landing segments. Errors decreased considerably for all participants during intervention. Participants 6 and 8 did not commit any errors in any segment during intervention. As indicated earlier, errors were very low during reversal.
Figure 2. Percentage of checklist errors for each condition per flight segment.
Figure 3. Percentage of checklist errors for each condition per participant.
Table 1 shows the percentage of trials that participants completed each item incorrectly during baseline. Percentages that are 50% or greater are shaded for each participant. Also, the checklist item name is shaded if the percentage of error was 50% or greater for four or more participants. Thus, horizontally shaded patterns indicate problematic checklist items, while vertically shaded patterns indicate particular participants who made a high percentage of errors on several items.

Three checklist segments emerge as having the highest percentage of errors. As indicated earlier, a total of 1,973 errors occurred. The highest frequency of errors occurred for two items in the after take-off segment: Checking flaps and engine instruments, with 99 errors each. These errors occurred on approximately 50% of the total flights across all participants. The pre landing items were the next problematic. Six of the eight participants had high percentages of errors on all five items in this segment (P1, P2, P3, P4, P5, and P7). The after landing segment had the third highest errors, with four participants having high error rates on all four items (P2, P3, P5, and P7).

Table 1
Percentage of Baseline Trials Participants Performed Items Incorrectly

<table>
<thead>
<tr>
<th>Segment / Item</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
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<td></td>
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#### After Take-off

| Flaps                   | 57 | 100| 92 | 92 | 93 | 100| 94 | 78 |
| Engine instruments      | 57 | 100| 100| 100| 93 | 67 | 94 | 78 |

#### Cruise

<p>| Landing light           | 0  | 100| 42 | 67 | 100| 0  | 28 | 17 |</p>
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<tr>
<th>Segment / Item</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
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**Arrival**

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**Pre Landing**

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DISCUSSION

The use of paper checklists in the flight environment remains a vital component to safe operations. As with the airline audits conducted by Helmreich and his colleagues (Helmreich et al., 1999; Helmreich et al., 2001; Klinect et al., 2003), this study found that checklist compliance varied considerably across individuals during baseline. Checklist compliance increased to near perfect levels after pilots were given post-flight feedback and praise for accurate checklist use, and remained high after the feedback and praise was removed. Although this study was conducted in a simulated environment, the results strongly suggest that graphic feedback and praise could be used to increase the extent to which pilots use checklists accurately, potentially preventing crashes and saving lives.

During baseline, the average percent of checklist items completed correctly per trial by participants ranged from 53% to 91%. When the intervention was introduced, accuracy increased rapidly to near perfect levels for each participant. Furthermore, those changes maintained after the intervention was removed, continuing for seven simulated flights.

The increases after intervention are similar to increases that have been reported in other studies when graphic feedback and praise have been provided for desired work behaviors (Austin et al., 2005; Crowell et al., 1988; Wilk & Redmon, 1998). The present research is novel, however, in demonstrating such effects for the use of flight checklists by pilots in an extremely challenging and dynamic situation.

Baseline performance varied considerably across participants. Moreover, some participants performed very poorly. The variables contributing to poor baseline
performance are not known but may be due to (a) poor initial flight training, (b) no or infrequent feedback on checklist use during training and/or non-training flights, (c) no aversive consequences for failing to use the checklist accurately in the simulated experimental setting (i.e., no emergencies that could lead to actual danger, no crashes possible, etc.), or (d) a combination of these variables.

Five participants showed an abrupt level change in performance after the first intervention trial (P1, P5, P6, P7, and P8). Additionally, all five maintained high levels of performance during reversal. The abrupt increase in accuracy after one intervention session and the maintenance of high levels of performance following intervention removal suggest that checklist use was being controlled by rules rather than by direct acting contingencies (Michael, 1993; Skinner, 1974), and those participants formed new rules after receiving feedback and praise. The nature of the changes in rules is not known. However, these new rules may have brought checklist behavior under the dual control of the checklist item and the relevant antecedent stimulus in the flight segment, and continued to affect behavior once the experimenter-provided feedback and praise were withdrawn (Galizio, 1979; Shimoff, Catania, & Matthews, 1981).

In contrast to the above five participants, one participant showed a gradual increase in performance over time after successive intervention sessions (P3). This transition may indicate selection by consequence. Two participants showed an abrupt level change in performance after the first intervention trial followed by a gradually increasing trend (P2 and P4), which may indicate that checklist use was being controlled by both rules and direct acting consequences. On the other hand, rule-governed behavior can appear to be contingency-governed behavior (Shimoff, Matthews, & Catania, 1986).
The fact that all of these participants maintained their performance after the removal of feedback suggests that all of them formulated new rules about the importance of checklist use as a function of the treatment contingency.

Although it is likely that all participants developed new rules, the types of rules they developed may have been different. The rules may have been related to safety. For example, participants may have developed a rule like “My checklist use is not good. If I perform this poorly when I actually fly, I might crash.” If this type of rule was developed, accurate checklist use might well generalize to actual flight. Alternatively, the rules may have been related to evaluation by the experimenters; for example, “If I perform poorly, I will look bad to the experimenters who are experienced pilots.” If so, accurate checklist performance would be unlikely to generalize to actual flight. It is also possible that checklist use was multiply controlled by both types of rules.

Future research should investigate the nature of the rule changes and whether accurate checklist use would generalize to actual flight without in-vivo training because of the new rules. If it did, these results would have major implications for simulated flight training, which is less expensive and less risky than in-flight training.

The three measures of error were important measures. They revealed that the frequency of errors differed across flight segments, specific items, and participants. With respect to the flight segments, for example, during baseline participants committed the most errors during the after take-off flight segment and the least errors during the pre take-off segment.

The variability across flight segments might mean that stimuli that evoke (correct) responding are more salient than stimuli that do not. For example, checklist items are
time sensitive and must be completed at a specific point in time during flight. The beginning of a new flight segment is the prompt to complete some checklist items. When this is the case, the passage of time should establish an aversive condition for the pilot that is reduced when the pilot completes the checklist. The immediate reduction of the aversiveness serves as the reinforcer for completing the checklist item. However, the stimuli correlated with the beginning of particular flight segments may not be very salient, and hence not establish time passage as aversive. For example, the beginning of the arrival segment is initiated only by the location of the aircraft in relation to the airport touchdown point and direction of flight (i.e., flying outbound past the touchdown point rather than flying the downwind leg while still along side the runway). On the other hand, some flight segments begin with air traffic control instructions, which are highly salient antecedent stimuli.

Lapses in standardized prompt recognition or lack of feedback for prompt recognition during pilot training may contribute to timing errors and missed items. Thus, prompt recognition should be emphasized in training, particularly for less salient antecedent stimuli.

If the variability in error rates across flight segments in the current study was due, at least in part, to differences in the saliency of the antecedent flight prompts, this type of variability would be expected with other pilots as well. On the other hand, because all of the participants in the study were trained in the same training program, the similar error rates may simply reflect similar training. If so, then the across segment error data would not be expected with pilots trained in other programs.
Finally, the variability in errors across flight segments may also reflect demands of the technical flight, with more errors occurring when flight demands become greater. For example, error rates were generally lower during the pre take-off segment than during the pre landing and after landing segments. And, flight demands are lower in the former segment than in the latter two segments.

While some possible causes of the across flight segment error variability were discussed above, the actual cause or causes are currently unknown. Future research is needed to determine the specific causes of the errors and whether the error data generalize to other pilots. If the error data are replicated, the data could be used to alter current pilot training programs so they emphasize the common errors pilots commit. Similarly, if the individual error data reported in this study were recorded during actual training, they could be used to design efficient individual remedial training.

There are several avenues of future research. The ones most directly related to the current study would include: (a) replicating the current study and ascertaining whether checklist compliance transfers to actual flight; (b) replicating the current study during actual training flights when flight conditions such as weather and airport traffic differ; and (c) determining how long gains in checklist accuracy would continue in the absence of post-flight feedback and praise given that the results of the current study are reproduced.

A very important topic for further study is whether the results would be similar if higher workload demands due to inclement weather, heavy traffic, equipment malfunction, etc. caused higher error rates. In the current study, all simulated flight patterns were flown under “normal operating conditions.” That is, the weather conditions
were good, the air traffic was normal, air traffic control instructions were typical, and all aircraft systems worked normally. In the current study, even under these normal operating conditions, errors were generally higher in flight segments that had higher workload conditions (i.e., after take-off and pre landing). These are also the flight segments where competing contingencies would tend to increase when weather and air traffic control conditions elevate workload. Thus, higher checklist errors might be expected. In the current study, during intervention, checklist errors decreased quickly to zero for most participants regardless of what the initial error rate was. The question becomes whether results would be similar if workload demands were high or extreme during flight.

Although the design and composition of checklists, their position and placement on the flight deck, and standard operating procedures that require their use may encourage accurate checklist completion, they do not ensure it (Degani & Wiener, 1990). In this study, post-flight graphic feedback and praise increased checklist compliance to near perfect levels. This is the first time this type of behavioral intervention has been used to alter checklist use. The intervention was a package and thus it is not possible to partial out the effects of the individual components. Nonetheless, the results of the current study are clear: Graphic feedback and praise can increase the accurate use of flight checklists. Further research is needed to determine whether the results generalize to actual flight and whether the results would be similar when workload demands are elevated due to abnormal flight conditions.
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Appendix A

Participant Eligibility Questionnaire
Participant Eligibility Questionnaire

Please complete the following questions. All information you provide will remain confidential.

Participant Number __________________________

1. Are you instrument rated? __ Yes __ No

2. How many total actual or simulated instrument hours have you logged? _____ hrs

3. What is your total flight time? _____ hrs

4. How many ILS approaches have you done? _____ hrs

5. Have you used a PC-ATD with a rudder and yoke for flight practice? __ Yes __ No

6. If you answered yes to Question 5; how many hours would you estimate you have used the PC-ATD for flight practice? _____ hrs

7. Have you used a PC flight game such as FlightSim, On-Top, X-Plane, or any such software that emulated aircraft or spacecraft flight? __ Yes __ No

8. If you answered yes to Question 7; how many hours would you estimate you have used the PC for flight gaming? _____ hrs

9. Approximately how many hours have you flown in the past 3 months? _____ hrs

10. How many hours have you flown solo or as PIC after your Private Certificate? _____ hrs

11. Approximately how many total landing have you made since learning to fly? _____

12. Approximately how many hours do you have in a Cessna C-172? _____ hrs

Thank you!
Appendix B

Recruitment Flyer
Participants Sought for an Instrument Flight Research Study

I am looking for Instrument rated pilots to participate in a study designed to determine how pilots perform flying instrument approach procedures using a Personal Computer-Aviation Training Device (PC-ATD) with On-Top flight simulation software.

Participants will receive extra PC simulation instrument flight time to practice local approach procedures in this study. To be eligible to participate, you must have 2 hours of experience with computer flight simulation programs such as FlightSim, X-plane, On-Top, or others with a yoke and rudder pedals. You must also have a valid instrument rating.

Sessions will be conducted in the BCA (Blue Hanger) building in Battle Creek. The study will last 4-5 weeks (8-10 sessions total). Sessions will be about 1 hour and you will be asked to attend two sessions per week. You will be asked to fly 3 instrument approaches during each session.

If you are interested in learning more about the study, please contact Bill Rantz. I am a faculty member in the College of Aviation and am conducting this study as part of my doctoral training in the Department of Psychology at WMU. Your willingness to participate or your later withdrawal from the study will not affect your grade in any class, including my class or any future class you may take with me.

Be sure to provide your name, e-mail address or telephone number, and the times you can be reached.

All information is confidential.
For more information contact Bill Rantz:
E-mail: william.rantz@wmich.edu
or
Phone: (269) 492-2881

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Bill Rantz
william.rantz@wmich.edu
(269) 492-2881
Appendix C

Recruitment Script
Recruitment Script

Hi. My name is Bill Rantz and I am a faculty member in the College of Aviation and a doctoral student in the Psychology Department at Western Michigan University. I am conducting a research study as part of my doctoral training. I am looking for instrument rated pilots to participate in this study which is designed to determine how pilots perform flying instrument approach procedures using a Personal Computer-Aviation Training Device (PC-ATD) with On-Top Simulation software.

Participants will receive extra PC simulation instrument flight time to practice local approach procedures in this study. To be eligible to participate, you must have 2 hours of experience with computer flight simulation programs such as FlightSim, X-plane, On-Top, or others with a yoke and rudder pedals. You must also possess a valid instrument rating.

Sessions will be conducted in the BCA (Blue Hanger) building in Battle Creek. The study will last 4-5 weeks (8-10 sessions total). Sessions will be about 1 hour and you will be asked to attend two sessions per week. You will be asked to fly 3 instrument approaches during each session.

You may withdraw from this research study at any time. Your participation is completely voluntary. Your willingness to participate in the study or your withdrawal from the study at a later time will not affect your grade in this or any other class. If you are enrolled in a class that I am teaching, your grade in that class or any future class you take with me will not be affected by your participation or withdrawal from the study at a later time.

If you are interested in learning more about this study, please print your name, phone number or email address on a sheet of paper and give it to me. I am also handing out a sheet of paper with my name, telephone number and email address, and you can contact me by telephone or email.

I will contact you within the next few days to arrange a time when we can meet to discuss the details of the study.

Thank you for your time!
Appendix D

Informed Consent Form
Western Michigan University
Department of Psychology

Instrument Landing Approaches Using a Personal Computer-Aviation Training Device
with On-Top Flight Simulation Software

Principal Investigator: Alyce M. Dickinson, Ph.D.
Student Investigator: William Rantz

You are being invited to participate in a research study designed to determine how well pilots can fly an instrument landing approach using a Personal Computer-Aviation Training Device (PC-ATD) with On-Top flight simulation software. The study is being conducted by Mr. Bill Rantz who is both a faculty member in the College of Aviation at Western Michigan University and a graduate student in the Department of Psychology at Western Michigan University. Mr. Rantz is conducting this study as part of his doctoral training in the Department of Psychology. Dr. Alyce Dickinson is his advisor.

Eligibility requirements. To be eligible to participate, you must have a private pilot certificate and a valid instrument rating. In addition, you must have a minimum of two hours of experience with computer flight simulation programs such as FlightSim, X-plane, On-Top, or others with a yoke and rudder pedals. Finally, you must be able to attend at least two one-hour sessions a week for 4-5 weeks.

Study procedures and length of participation. During each session, you will fly three standard instrument landing system approaches to an airport using simulation software and a PC-ATD. Each session will last approximately one hour and you will be asked to attend from 7 to 9 experimental sessions over a 4 to 5-week period. The total number of sessions you will attend will depend upon your performance. Your performance on the PC-ATD will be assessed during the first session, however, and there is a possibility that your participation will be terminated after the first session based on that assessment.

Digital Video and Audio Recording. All sessions will be digitally recorded to enable us to accurately assess your flight performance. The recordings will be held in strictest confidence. The digital computer file will be identified only by a number that is assigned to you. The recordings will not be used for public presentations. At the end of the study, these recordings will be destroyed.

Risks. You may experience some physical minor fatigue, or stress when you are performing the instrument landing approaches. To offset this, you will not begin the next flight in the session until you are ready. You may also stop the session at any time by telling the experimenter you do not want to continue.

Benefits. You may improve your flight and instrument landing approach skills by repeatedly flying the simulated flight patterns. You may also learn about research
regarding how post-flight feedback may improve performance. The information obtained from the study may suggest ways to improve the flight training of student pilots.

Confidentiality. All information obtained in this study will remain strictly confidential. When results of the study are presented publicly, you will not be identified. You will be assigned a number and that number will be used to identify your data.

Voluntary participation. Your participation in this study is completely voluntary. You may withdraw at any time without penalty. Your participation in the study, or your withdrawal from the study, will not affect your grades in any of your courses. If you are currently enrolled in a class taught by Mr. Rantz, your willingness to participate or your later withdrawal from the study will not affect your grade in the current class or any future class you may take with him. At the end of the study, the experimenter will answer any questions you have and explain how your data will help to learn more about how post-flight feedback may improve performance.

Who to contact if I have questions. If you have any questions about this study you can call Bill Rantz at 269-492-2881. You may also call Mr. Rantz's faculty advisor, Dr. Dickinson, at 387-4473. In addition, you may also contact the Chair, Human Subjects Institutional Review Board (387-8293), or the Vice President for Research (387-8298), if questions or problems arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

Your signature below indicates that you have read the above information and agree to participate in the study.

Participant Signature: _______________________________ Date: ______

Please keep the attached copy of this form for your records.
Appendix E

HSRIB Research Approval Letter
Date: October 2, 2006

To: Alyce Dickinson, Principal Investigator
    William Rantz, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number: 06-08-25

This letter will serve as confirmation that your research project entitled “The Effects of Feedback on the Accuracy of Completing Flight Checklists” has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: October 2, 2007
Appendix F

Technical Flight Pattern Parameters and Narration
Technical Flight Pattern Parameters and Narration
Flight Pattern 1 KBTL

(EXPERIMENTER): Session start, please begin. Contact tower when ready for takeoff.

Please do a short-field takeoff.

Pre Take-off checks completed (17 checklist items)

(PARTICIPANT): Battle Creek Tower Western 45 ready for departure runway 23.

(EXPERIMENTER): Western 45 you are cleared for departure. Fly runway heading climb and maintain 2,500'.

(PARTICIPANT): Fly runway heading climb and maintain 2,500' Western 45

Apply full power for takeoff roll

After take-off checks completed above 500' (2 checklist items)

(EXPERIMENTER): Western 45 contact Kalamazoo Approach on 119.2.

(PARTICIPANT): Contacting Kalamazoo Approach on 119.2 Western 45.

(PARTICIPANT): Kalamazoo Approach Western 45 is with you heading 230 climbing to 2,500.

(EXPERIMENTER): Western 45 roger.

(EXPERIMENTER): Western 45 turn left heading of 120.

(PARTICIPANT): Turning left to a heading of 120 Western 45.

Level at 2,500, cruise checks complete (5 checklist items)

(EXPERIMENTER): Western 45 turn left heading of 050.

(PARTICIPANT): Turning left to a heading of 050 Western 45.

Approach briefing and approach checks complete (7 checklist items)

(EXPERIMENTER): Western 45 turn left to a heading of 320.

(PARTICIPANT): Turning left to a heading of 320 Western 45.
(EXPERIMENTER): Western 45 turn left to a heading of 270 cleared for the ILS 23 contact Battle Creek Tower 126.825.

(PARTICIPANT): Contacting Battle Creek Tower on 126.825. Western 45.

(PARTICIPANT): Battle Creek Tower this is Western 45 on the ILS 23.

(EXPERIMENTER): Western 45 you are cleared to land runway 23.

(PARTICIPANT): Cleared to land runway 23 Western 45.

Pre landing checks complete (5 checklist items)

Approximate Localizer intercept- flaps should be at 10 degrees, airspeed 90 knots, pilot should maintain 2,500’ until established on the glide slope. Once established on glide slope a descent rate of +- 500 feet per minute is established. Airspeed decreasing 90-70 knots.

Airspeed 70 knots over threshold of runway with landing on Runway 23

(EXPERIMENTER): Western 45 you may hold on the runway and stand by for further clearance.

After landing checks (4 items)

(EXPERIMENTER): This session is over. Please engage the (pause button) brake on the PC-ATD. Please relax and I will join you in a few minutes.
Technical Flight Pattern Parameters and Narration
Flight Pattern 2 KAZO

(EXPERIMENTER): Session start, please begin. Contact tower when ready for takeoff. Please do a short-field takeoff.

Pre take-off checks completed (17 checklist items)

(PARTICIPANT): Kalamazoo Tower Western 45 ready for departure runway 35.

(EXPERIMENTER): Western 45 you are cleared for departure. Fly runway heading climb and maintain 3,000'.

(PARTICIPANT): Fly runway heading climb and maintain 3,000' Western 45

Apply full power for takeoff roll

After take-off checks completed above 500' (2 checklist items)

(EXPERIMENTER): Western 45 contact Kalamazoo Approach on 121.2.

(PARTICIPANT): Contacting Kalamazoo Approach on 121.2 Western 45.

(PARTICIPANT): Kalamazoo Approach Western 45 is with you heading 350 climbing to 3,000.

(EXPERIMENTER): Western 45 roger.

(EXPERIMENTER): Western 45 turn left heading of 260.

(PARTICIPANT): Turning left to a heading of 260 Western 45.

Level at 3,000, cruise checks complete (5 checklist items)

(EXPERIMENTER): Western 45 turn left heading of 180.

(PARTICIPANT): Turning left to a heading of 180 Western 45.

Approach briefing and approach checks complete (7 checklist items)

(EXPERIMENTER): Western 45 turn left to a heading of 080.

(PARTICIPANT): Turning left to a heading of 080 Western 45.
(EXPERIMENTER): Western 45 turn left to a heading of 030 cleared for the ILS 35 contact Kalamazoo Tower 118.3.

(PARTICIPANT): Contacting Kalamazoo Tower on 118.3 Western 45.

(PARTICIPANT): Kalamazoo Tower this is Western 45 on the ILS 35.

(OBSERVER: Western 45 you are cleared to land runway 35.

(PARTICIPANT): Cleared to land runway 35 Western 45.

Pre landing checks complete (5 checklist items)

Approximate Localizer intercept- flaps should be at 10 degrees, airspeed 90 knots, pilot should be maintain 3,000’ until established on the glide slope. Once established on glide slope a descent rate of +/- 500 feet per minute is established. Airspeed decreasing 90-70 knots.

Airspeed 70 knots over threshold of runway with landing on Runway 35

(EXPERIMENTER): Western 45 you may hold on the runway and stand by for further clearance.

After landing checks (4 items)

(EXPERIMENTER): This session is over. Please engage the (pause button) brake on the PC-ATD. Please relax and I will join you in a few minutes.
Session start, please begin. Contact tower when ready for takeoff.

Please do a short-field takeoff.

Pre take-off checks completed (17 checklist items)

(participant): Lansing Tower Western 45 ready for departure runway 10R.

(experimenter): Western 45 you are cleared for departure. Fly runway heading climb and maintain 2,500'.

(participant): Fly runway heading climb and maintain 2,500' Western 45

Apply full power for takeoff roll

After take-off checks completed above 500' (2 checklist items)

(experimenter): Western 45 contact Lansing Approach on 133.475.

(participant): Contacting Lansing Approach on 133.475 Western 45.

(participant): Lansing Approach Western 45 is with you heading 100 climbing to 2,500.

(experimenter): Western 45 roger.

(experimenter): Western 45 turn right heading of 190.

(participant): Turning right to a heading of 190 Western 45.

Level at 2,500, cruise checks complete (5 checklist items)

(experimenter): Western 45 turn right heading of 280.

(participant): Turning right to a heading of 280 Western 45.

Approach briefing and approach checks complete (7 checklist items)

(experimenter): Western 45 turn right to a heading of 010.

(participant): Turning right to a heading of 010 Western 45.
(EXPERIMENTER): *Western 45 turn right to a heading of 060 cleared for the ILS 10R contact Lansing Tower 119.9.*

(PARTICIPANT): *Contacting Lansing Tower on 119.9 Western 45.*

(PARTICIPANT): *Lansing Tower this is Western 45 on the ILS 10R.*

(OBSERVER): *Western 45 you are cleared to land runway 10R.*

(PARTICIPANT): *Cleared to land runway 10R Western 45.*

Pre landing checks complete (5 checklist items)

Approximate Localizer intercept- flaps should be at 10 degrees, airspeed 90 knots, pilot should be maintain 2,500’ until established on the glide slope. Once established on glide slope a descent rate of +- 500 feet per minute is established. Airspeed decreasing 90-70 knots.

Airspeed 70 knots over threshold of runway with landing on Runway 10R

(EXPERIMENTER): *Western 45 you may hold on the runway and stand by for further clearance.*

After landing checks (4 items)

(EXPERIMENTER): *This session is over. Please engage the (pause button) brake on the PC-ATD. Please relax and I will join you in a few minutes.*
(EXPERIMENTER): Session start, please begin. Contact tower when ready for takeoff.

Please do a short-field takeoff.

Pre take-off checks completed (17 checklist items)

(PARTICIPANT): Jackson Tower Western 45 ready for departure runway 24.

(EXPERIMENTER): Western 45 you are cleared for departure. Fly runway heading climb and maintain 3,000'.

(PARTICIPANT): Fly runway heading climb and maintain 3,000' Western 45

Apply full power for takeoff roll

After take-off checks completed above 500' (2 checklist items)

(EXPERIMENTER): Western 45 contact Lansing Approach on 127.3.

(PARTICIPANT): Contacting Lansing Approach on 127.3 Western 45.

(PARTICIPANT): Lansing Approach Western 45 is with you heading 240 climbing to 3,000.

(EXPERIMENTER): Western 45 roger.

(EXPERIMENTER): Western 45 turn left heading of 150.

(PARTICIPANT): Turning left to a heading of 150 Western 45.

Level at 3,000, cruise checks complete (5 checklist items)

(EXPERIMENTER): Western 45 turn left heading of 060.

(PARTICIPANT): Turning left to a heading of 060 Western 45.

Approach briefing and approach checks complete (7 checklist items)

(EXPERIMENTER): Western 45 turn left to a heading of 330.

(PARTICIPANT): Turning left to a heading of 330 Western 45.
(EXPERIMENTER): *Western 45 turn left to a heading of 280 cleared for the ILS 24 contact Jackson Tower 120.7.*

(PARTICIPANT): *Contacting Jackson Tower on 120.7 Western 45.*

(PARTICIPANT): *Jackson Tower this is Western 45 on the ILS 24.*

(OBSERVER): *Western 45 you are cleared to land runway 24.*

(PARTICIPANT): *Cleared to land runway 24 Western 45.*

**Pre landing checks complete (5 checklist items)**

Approximate Localizer intercept- flaps should be at 10 degrees, airspeed 90 knots, pilot should be maintain 2,700’ until established on the glide slope. Once established on glide slope a descent rate of +- 500 feet per minute is established. Airspeed decreasing 90-70 knots.

Airspeed 70 knots over threshold of runway with landing on Runway 24

(EXPERIMENTER): *Western 45 you may hold on the runway and stand by for further clearance.*

**After landing checks (4 items)**

(EXPERIMENTER): *This session is over. Please engage the (pause button) brake on the PC-ATD. Please relax and I will join you in a few minutes.*
Technical Flight Pattern Parameters and Narration
Flight Pattern 5 KGRR

(EXPERIMENTER): Session start, please begin. Contact tower when ready for takeoff.

Please do a short-field takeoff.

Pre take-off checks completed (17 checklist items)

(PARTICIPANT): Grand Rapids Tower Western 45 ready for departure runway 8R.

(EXPERIMENTER): Western 45 you are cleared for departure. Fly runway heading climb and maintain 2,700'.

(PARTICIPANT): Fly runway heading climb and maintain 2,700' Western 45

Apply full power for takeoff roll

After take-off checks completed above 500' (2 checklist items)

(EXPERIMENTER): Western 45 contact Grand Rapids Approach on 128.4.

(PARTICIPANT): Contacting Grand Rapids Approach on 128.4 Western 45.

(PARTICIPANT): Grand Rapids Approach Western 45 is with you heading 080 climbing to 2,700.

(EXPERIMENTER): Western 45 roger.

(EXPERIMENTER): Western 45 turn right heading of 170.

(PARTICIPANT): Turning right to a heading of 170 Western 45.

Level at 2,700, cruise checks complete (5 checklist items)

(EXPERIMENTER): Western 45 turn right heading of 260.

(PARTICIPANT): Turning right to a heading of 260 Western 45.

Approach briefing and approach checks complete (7 checklist items)

(EXPERIMENTER): Western 45 turn right to a heading of 350.

(PARTICIPANT): Turning right to a heading of 350 Western 45.
(EXPERIMENTER): Western 45 turn right to a heading of 040 cleared for the ILS 8R contact Grand Rapids Tower 128.4.

(PARTICIPANT): Contacting Grand Rapids Tower on 128.4 Western 45.

(PARTICIPANT): Grand Rapids Tower this is Western 45 on the ILS 8R.

(OBSERVER: Western 45 you are cleared to land runway 8R.

(PARTICIPANT): Cleared to land runway 8R Western 45.

Pre landing checks complete (5 checklist items)

Approximate Localizer intercept- flaps should be at 10 degrees, airspeed 90 knots, pilot should be maintain 2,400’ until established on the glide slope. Once established on glide slope a descent rate of +- 500 feet per minute is established. Airspeed decreasing 90-70 knots.

Airspeed 70 knots over threshold of runway with landing on Runway 8R

(EXPERIMENTER): Western 45 you may hold on the runway and stand by for further clearance.

After landing checks (4 items)

(EXPERIMENTER): This session is over. Please engage the (pause button) brake on the PC-ATD. Please relax and I will join you in a few minutes.
Session start, please begin. Contact clearance delivery when ready for takeoff. Please do a short-field takeoff.

Pre take-off checks completed (17 checklist items)

South Bend Clearance Delivery Western 45 ready for departure runway 27.

Western 45 you are cleared for departure. Fly runway heading climb and maintain 2,500'.

Fly runway heading climb and maintain 2,500' Western 45

Apply full power for takeoff roll

After take-off checks completed above 500' (2 checklist items)

Western 45 contact South Bend Approach on 118.55.

Contacting South Bend Approach on 118.55 Western 45.

South Bend Approach Western 45 is with you heading 270 climbing to 2,500.

Western 45 roger.

Western 45 turn left heading of 180.

Turning left to a heading of 180 Western 45.

Level at 2,500, cruise checks complete (5 checklist items)

Western 45 turn left heading of 090.

Turning left to a heading of 090 Western 45.

Approach briefing and approach checks complete (7 checklist items)

Western 45 turn left to a heading of 360.
(PARTICIPANT): *Turning left to a heading of 360 Western 45.*

(EXPERIMENTER): *Western 45 turn left to a heading of 310 cleared for the ILS 27 contact Benton Harbor CTAF 123.0.*

(PARTICIPANT): *Contacting Benton Harbor CTAF on 123.0 Western 45.*

(PARTICIPANT): *Benton Harbor traffic Western 45 on the ILS 27.*

**Pre landing checks complete (5 checklist items)**

Approximate Localizer intercept- flaps should be at 10 degrees, airspeed 90 knots, pilot should be maintain 2,500’ until established on the glide slope. Once established on glide slope a descent rate of +- 500 feet per minute is established. Airspeed decreasing 90-70 knots.

Airspeed 70 knots over threshold of runway with landing on Runway 27.

(EXPERIMENTER): *Western 45 you may hold on the runway and stand by for further clearance.*

**After landing checks (4 items)**

(EXPERIMENTER): *This session is over. Please engage the (pause button) brake on the PC-ATD. Please relax and I will join you in a few minutes.*
Appendix G

Flight Checklist
<table>
<thead>
<tr>
<th>PRE TAKE-OFF</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Carburetor Heat</td>
<td>Off</td>
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<tr>
<td>Fuel Quantity</td>
<td>Check</td>
</tr>
<tr>
<td>Flight Instruments</td>
<td>Check/Set</td>
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<tr>
<td>Controls</td>
<td>Full, Free, Correct</td>
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<tr>
<td>Throttle Friction Lock</td>
<td>Check/Set</td>
</tr>
<tr>
<td>Flaps</td>
<td>A/R</td>
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<tr>
<td>Elevator Trim</td>
<td>Set for Takeoff</td>
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<tr>
<td>Fuel Selector</td>
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<td>Transponder</td>
<td>ALT</td>
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<tr>
<td>Takeoff Briefing</td>
<td>Complete</td>
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<td>Avionics</td>
<td>Set</td>
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<td>Pitot Heat</td>
<td>A/R</td>
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<tr>
<td>Strobes</td>
<td>On</td>
</tr>
<tr>
<td>Mixture</td>
<td>Rich</td>
</tr>
<tr>
<td>Landing Light</td>
<td>On</td>
</tr>
<tr>
<td>Compass</td>
<td>Check</td>
</tr>
<tr>
<td>Time</td>
<td>Start</td>
</tr>
<tr>
<td><strong>AFTER TAKE-OFF</strong></td>
<td></td>
</tr>
<tr>
<td>Flaps</td>
<td>Up</td>
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<tr>
<td>Engine Instruments</td>
<td>Check</td>
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<td><strong>CRUISE</strong></td>
<td></td>
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<td>Landing Light</td>
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<td>Mixture</td>
<td>Lean</td>
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<td>Engine Instruments</td>
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<td>Check</td>
</tr>
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<td>Check</td>
</tr>
<tr>
<td>Altimeter</td>
<td>Check/Set</td>
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<tr>
<td>Mixture</td>
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<tr>
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<td>Complete</td>
</tr>
<tr>
<td><strong>PRE LANDING</strong></td>
<td></td>
</tr>
<tr>
<td>Carburetor Heat</td>
<td>On</td>
</tr>
<tr>
<td>Fuel Selector</td>
<td>Both</td>
</tr>
<tr>
<td>Mixture</td>
<td>Rich</td>
</tr>
<tr>
<td>Flaps</td>
<td>A/R</td>
</tr>
<tr>
<td>Parking Brake</td>
<td>Off</td>
</tr>
<tr>
<td><strong>AFTER LANDING</strong></td>
<td></td>
</tr>
<tr>
<td>Carburetor Heat</td>
<td>Off</td>
</tr>
<tr>
<td>Flaps</td>
<td>Up</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Lights &amp; Pitot Heat</td>
<td>Off</td>
</tr>
<tr>
<td>Parking Brake</td>
<td>On</td>
</tr>
</tbody>
</table>
Appendix H

Observer's Checklist Performance Protocol
Observer's Checklist Behavior Protocol

1. **Carburetor Heat**: Tactual contact or (pushing knob) Verbal "Off"
2. **Fuel Quantity**: Tactual contact or (pointing gesture) Quarter Tank Minimum- Verbal "Check"
3. **Flight Instruments**: Airspeed-Zero, Attitude-Erect & level, Altitude-817MSL, Heading-Heading Ind & Compass agree, Tactual contact
4. **Controls**: Rotates yoke from left stop to right stop in forward position, repeated in aft position Verbal "Full Free Correct"
5. **Throttle Friction Lock**: Tactual contact Rotate Lock- Verbal "Set"
6. **Flaps**: Tactual contact Flap Handle- Verbal "Up or ____ Degrees"
7. **Elevator Trim**: Tactual contact Rotate Trim Wheel- Verbal "Set for Takeoff"
8. **Fuel Selector**: Tactual contact Fuel Selector Handle- Verbal "Both"
9. **Transponder**: Tactual contact Code Set To-1200- Verbal "ALT"
10. **Takeoff Briefing**: Verbal "Narrative of Expected Flight Parameters" Expecting radar vectors for an ILS approach to RWY __ with full stop landing
11. **Avionics**: Eye contact Tactual contact Set Comm Freq. _____ Tower / Set Nav Freq. _____ ILS OBS inbound course aligned-Verbal "Set"
12. **Pitot Heat**: If Required Tactual contact Verbal "On" if Not Required No Eye Contact- Verbal "Not Required"
13. **Strobes**: Tactual contact Strobe Switch- Verbal "On"
14. **Mixture**: Tactual contact Mixture Control Full Forward- Verbal "Rich"
15. **Landing Light**: Tactual contact Light switch- Verbal "On"
16. **Compass**: Verbal "Check or ____ Degrees"
17. **Time**: Textual contact Chronometer check- Verbal "Started"
18. **Flaps**: Tactual contact Flap Handle- Verbal "Up"
19. **Engine Instruments**: Tactual contact or (pointing gesture) RPM-1000, Oil Press-50-90, Oil Temp-100-245, Suction-4.5-5.4- Verbal "Check"
20. **Landing Light**: Tactual contact Light switch- Verbal "Off"
21. **Mixture**: Tactual contact Mixture Control Full Forward- Verbal "Lean"
22. **Engine Instruments**: Tactual contact or (pointing gesture) RPM-1000, Oil Press-50-90, Oil Temp-100-245, Suction-4.5-5.4- Verbal "Check"
23. **Fuel Quantity**: Tactual contact or (pointing gesture) Quarter Tank Minimum- Gage & Selector- Verbal "Check"
24. **Altimeter**: Tactual contact or Selector Knob & Pressure in Kohlsman Window (pointing gesture) Verbal "Set"
25. **Landing Light**: Tactual contact Light switch- Verbal "On"
26. **Nav Radios**: Tactual contact Set Comm Freq. / 121.2 / Set Nav Freq. VOR/ILS 109.1, NDB Freq., Marker Beacons, Inbound
27. **Engine**: Tactual contact or (pointing gesture) RPM-1000, Oil Press-50-90, Oil Temp-100-245, Suction-4.5-5.4- Verbal "Check"
28. **Compass**: Verbal "Check or ____ Degrees"
29. **Altimeter**: Tactual contact or Selector Knob & Pressure in Kohlsman Window (pointing gesture) Verbal "Set"
30. **Mixture**: Tactual contact Mixture Control Full Forward- Verbal "Check"
31. **Approach Brief:** Verbal "Narrative of Expected Flight Parameters" Expecting radar vectors for an ILS approach to RWY __ with full stop landing
32. **Carb Heat:** Tactual contact or (pulling knob) Verbal "On"
33. **Fuel Selector:** Tactual contact or Fuel Selector Handle (pointing gesture)- Verbal "Both"
34. **Mixture:** Tactual contact Mixture Control Handle Full Forward- Verbal "Rich"
35. **Flaps:** Tactual contact Flap Handle- Verbal "As Required"
36. **Parking Brake:** Tactual contact Parking Brake Handle- Verbal "Off"
37. **Carb Heat:** Tactual contact or (pushing knob) Verbal "Off"
38. **Flaps:** Tactual contact Flap Handle- Verbal "Up"
39. **Lights & Pitot Heat:** If Required: Tactual contact Light Switch & Pitot Switch- Verbal "Off-Off"
40. **Parking Brake:** Tactual contact Parking Brake Handle- Verbal "On"

*Eye Contact-Refers to the participant's behavior of looking in the direction of a discriminative stimulus such as a instrument, lever, or object
**Tactual Contact-Refers to the participant's behavior of moving a finger or hand to touch a discriminative stimulus
***Pointing Gesture-Refers to the participant's behavior to extend a directed finger at a discriminative stimulus
****Verbal-Refers to the participant's vocal behavior directed at tacting the condition or state of the discriminative stimulus
Appendix I

Checklist Observation Form
<table>
<thead>
<tr>
<th><strong>PRE TAKE-OFF SEGMENT</strong></th>
<th>Correct</th>
<th>Incorrect</th>
<th>Omitted</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carb Heat ..................Off</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Quantity ............Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Instruments ......Check/Set</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls ..................Full, Free, Correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throttle Friction Lock ...Set</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flaps ....................A/R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevator Trim ..........Set for Takeoff</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Selector ............Both</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transponder .............ALT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takeoff Briefing .........Complete</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avionics ..................Set</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pitot Heat ...............A/R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strobes .................On</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture ..................Rich</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landing Light ............On</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compass ..................Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time .....................Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**AFTER TAKE-OFF**

| Flaps ....................Up |         |           |         |          |
| Engine Instruments ......Check |         |           |         |          |

**CRUISE**

| Landing Light ............Off |         |           |         |          |
| Mixture ..................Lean |         |           |         |          |
| Engine Instruments ......Check |         |           |         |          |
| Fuel Quantity ............Check |         |           |         |          |
| Altimeter ..................Set |         |           |         |          |

**ARRIVAL**

| Landing Light ............On |         |           |         |          |
| Nav Radios ...............Set |         |           |         |          |
| Engine ..................Check |         |           |         |          |
| Compass ..................Check |         |           |         |          |
| Altimeter ..................Check/Set |         |           |         |          |
| Mixture ..................Check |         |           |         |          |
| Approach Brief ............Complete |         |           |         |          |

**PRE LANDING**

<p>| Carb Heat ...............On |         |           |         |          |
| Fuel Selector ............Both |         |           |         |          |
| Mixture ..................Rich |         |           |         |          |
| Flaps ....................A/R |         |           |         |          |
| Parking Brake ............Off |         |           |         |          |</p>
<table>
<thead>
<tr>
<th>AFTER LANDING</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carb Heat....................... Off</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flaps............................ Up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lights &amp; Pitot Heat............... Off</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parking Brake.................... On</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PAUSE BUTTON</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Response/No Response Totals</td>
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</tr>
</tbody>
</table>
Appendix J

Pre-flight Instructional Scripts
Initial Pre-flight Instructional Script

We will be conducting three instrument flights per session. One session should last about an hour. Each of the three flights today will conclude with a different instrument landing system approach to a full stop landing. You will be given assigned headings and altitudes to maintain until you are cleared for the instrument approach. As you can see, we have the instrument approach plate for the ILS runway [runway number] at [name of airport].

Here's the airplane checklist for you to use. It is the standard C-172 model checklist used here at WMU, but I have deleted a few items that cannot be completed on the PC-ATD. Please use the checklist as you would during any normal flight. You should talk aloud and touch each check item to confirm it is complete. Please take a moment to familiarize yourself with the ILS approach plate, the checklist, and the location of each for easy access during the flights. Here is a copy of the latest Automatic Terminal Information Service (ATIS) information. Please be certain you understand how the PC-ATD works and that you are comfortable at the PC-ATD station. I would like to take a couple of minutes to go through the checklist and point out which panel switches control displays on the computer monitor. Let me show you how to set your radios and move the radio frequencies displays between the instrument panel and the navigation instruments. So as not to interfere in your flight, I will be leaving the room while you are conducting your flight and not be able to help you in any way. I will be observing and recording your flight using the web cameras, computer monitor, and flight simulation software to permit me to conduct a post-flight briefing. I will play the role of Air Traffic Control and provide you with appropriate vectors and altitudes. You will need to talk with [name of airport] Tower and [name of airport Approach Control]. After each landing it will not be
necessary to conduct an engine shut down check however you will need to engage the physical parking brake and push the pause button of the PC-ATD. Let me show you how that works. Also after each landing and before you are re-positioned at the end of another runway for another take off, I will provide you with some post-flight information. So there will be a short break of 3-5 minutes before I can return to the room and give you that information. Also, as indicated in the informed consent document, I will be assessing your performance today, and there is a chance that you may be eliminated from the study after today’s session. We are starting the flight at the hold line of runway [runway number] in [airport]. The run up power checks have been completed. Please be certain to set up all your communication and navigation radios during the pre-takeoff segment of the checklist. In order to help us start each flight we ask that you please count down from three and click the reset button on the PC-ATD instrument monitor. Let me demonstrate how that works. Do you have any questions before we begin? If for any reason you feel you need to discontinue the flight, just tell me that by saying it out loud and I will terminate the flight immediately. Please wait for my call to announce the beginning of the flight and that we are ready for your countdown and reset.

Subsequent Pre-flight Instructional Script

You have been re-positioned near the end of runway [number] for another flight. As you can see, we have the instrument approach plate for the ILS runway [runway number] at [name of airport]. Please use the checklist as you would during any normal flight. You should talk aloud and touch each check item to confirm it is complete. Please take a moment to familiarize yourself with the ILS approach plate, the checklist, and the location of each for easy access during the flights. Once again, I will play the role of Air
Traffic Control and provide you with appropriate vectors and altitudes. You will need to talk with [name of airport] Tower and [name of airport Approach Control]. Here is a copy of the latest Automatic Terminal Information Service (ATIS) information. To remind you, after the landing it will not be necessary to conduct an engine shut down check however you will need to engage the physical parking brake and push the pause button of the PC-ATD. We are starting the flight at the hold line of runway [runway number] at [airport name]. The run up power checks have been completed. Please be certain to set up all your communication and navigation radios during the pre-takeoff segment of the checklist. Do you have any questions before we begin? If for any reason you feel you need to discontinue the flight, just tell me that by saying it out loud and I will terminate the flight immediately. Please wait for my call to announce the beginning of the flight and that we are ready for your countdown and reset.
Appendix K

Technical Flight Pattern Diagram
Technical Flight Pattern Diagram
Appendix L

The Post-flight Technical Briefing Script
The Post-flight Technical Briefing Script

Based on the flight just conducted, I want to show you the technical pattern of your flight. Here is a printout of the altitude and course information for the last approach. Please look at this diagram [point out good features of performance and praise those]. Please initial this diagram and return it to me now before you begin your next flight. Please do not discuss this study with anyone else because we have not yet completed the study and to do so may influence our future observations of other participants.

Thank you.
Appendix M

Checklist Feedback Script and Graphs
Checklist Feedback Script and Graphs

I also want to show you the total number of checklist items that you completed correctly from your last flight and all your previous flights. As you can see, you completed ___ out of 40 items correctly. (If that is an improvement, the experimenter will praise the participant.)

This next graph shows you more specific information. It shows the number of items you completed correctly, incorrectly, and omitted for each of the flight segments. Please look at this graph. Do you have any questions? OK, please initial each graph and return them to me and then we will begin the next flight. Please do not discuss this study with anyone else because we have not yet completed the study and to do so may influence our future observations of other participants.

Thank you.
Checklist Feedback Graphs

Items Completed Correctly

Baseline
Feedback Intervention

Number of Items

Trial

Items Completed Correctly

Participant Number _____ Initial _____

Checklist Items Per Segment

Checklist Segments

Completed Correctly • Incorrect □ Omitted □ Total Items

Participant Number _____ Session _____ Trial _____ Initial _____
Appendix N

Debriefing Script
Debriefing Script

Thank you for participating in this study. The purpose of this study is to determine if the accuracy of checklist performance can be improved by using graphic feedback after a flight. Results of this study will be used as part of the requirements to complete my doctoral training in the Psychology Department at Western Michigan University. I would like to take you through the summary data of your performance during the experiment. During the first part of the study, we did not give you any feedback about how well you completed the checklist. Then we added the graphic feedback during session # (fill in the session number). We then stopped giving you the graphic feedback on checklist performance to see if any increases during the preceding sessions would continue once we no longer gave you that feedback. Do you have any questions about your data, the study or your participation? Please do not discuss this study with anyone else because we have not yet completed the study and to do so may influence our future observations of other participants.

Thank you again for participating in this study.