Comparing the Effects of Simulated, Intelligent Audible, Checklists and Analog Checklists in Simulated Flight

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by

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This study examined the effect of using a simulated intelligent audible checklist in simulated flight as compared to a standard analog (paper) checklist. Participants were three Western Michigan University students in the College of Aviation. All participants were licensed pilots with instrument ratings. The main dependent variable was the number of checklist errors or omissions committed by the pilots in simulated flight. During each flight, each participant could make up to 42 errors. The error count would initiate at the appropriate time to perform the "before-take off checklist" and would end one minute after parking the plane, the logical time to complete an "after landing checklist."

A multiple baseline design was implemented in this research with the treatment being implemented at a different point in time for each participant. Either stability in performance or a decrement in performance determined the introduction of the audible checklist. Once stability or a descending trend in paper checklist use had been established, each participant was placed in the intervention phase. During baseline phase the three participants averaged 22.7% compliance per flight. After the simulated audible intelligent checklist intervention was introduced compliance increased to 97%. During the reversal phase compliance decreased to an average of 34%. Visual inspection of the

data suggests that an intelligent audible checklist used during actual flights may decrease in-flight errors and possibly decrease aviation incidents and accidents.

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Bryan Hilton

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CHAPTER 1

INTRODUCTION

Airplane checklists are used during different segments of flight to sequence specific, critical tasks and aircraft adjustments that correspond to specific environmental demands (Degani & Wiener, 1990). These checklists include items for each segment of a flight such as *before take off, climb, cruise, descent, before landing,* and *after landing.* Each checklist has specific tasks for each segment, as well as points that work as continued checks on the airplane's configuration in flight. The complexity of these checklists cannot be overstated. For example, on some checklists, the "before engine start" sub-section has 76 items for the first flight of the day, and 37 items for subsequent flight segments (Degani & Wiener). Though many checklists designed by different aircraft companies have similar items, very few are identical. Even different model aircraft made by the same manufacturer typically have different checklists that pertain to different options for those aircraft. Even though these differences exist, checklists have become the main strategy to standardize pilot performance and increase flight deck safety (Rantz, Dickinson, Sinclair, & Van Houten, 2009.) 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; Rantz and Van Houten, 2011; Rantz, Dickinson, Sinclair, and Van Houten, 2009).

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 accidents (Degani, 1992, 2002; Degani & Wiener; Diez, Boehm-Davis, & Holt, 2003; Turner, 2001). 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 (Rantz and Van Houten, 2011). In a study funded by Boeing, Lautmann and Gallimore ran a survey of twelve airlines and compiled the data, which showed that errors involved with using the checklist contributed to a substantial occurrence of accidents and incidents. Helmreich et al. conducted a series of studies sponsored by the National Aeronautics and Space Administration to identify the particular errors flight crews commit. Crews were observed while flying. 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). Between 1997 and 1998, LOSAs were conducted at three airlines with 184 flight crews on 314 flight segments (Helmreich et al., 2001). In this study the possible errors were broken down into five categories. Checklist errors fell into the category of "Rule-Compliance" errors. The category of Rule-compliance errors had the highest frequency of errors at 54% of all errors recorded. Checklist errors accounted for the highest number of errors in that category. A similar study using LOSAs between 2002 and 2006 indicate that procedural errors account for about half of all observable errors with checklist errors the most common type within that category (Merritt and Klinect, 2006).

Rantz, Dickinson, Sinclair, and Van Houten (2009) said,

> 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). Degani and Wiener (1990, 1993) observed flight crews while flying, interviewed flight 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 (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 safety culture issues erlated to support of misuse or nonuse of checklists 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 (p. 498).

Degani and Wiener (1990) mention the creation and description of a computerized device which gives audio prompts of checklist items but they listed no published studies that have compared the use of the audio checklist with any other type of checklist. A review of the literature reveals no comparison studies or behavioral studies of the efficacy of an audio checklist in aviation. Despite the lack of studies there have been several audio checklist devices patented for the use in aviation applications. One device was patented by Harshaw, Burkey, Doell and Keith in1990 and another by O'Rourke in 2001.

Palmer and Degani (1991) indicate that computerized devices that sense completion for the pilot increased checklist errors. In this study, pilots would tend to trust the technology each time they, (a) detected all the mis-configured items when using the paper checklist, (b) detected some of the manual-sensed items displayed by the electronic checklist and (c) did not detect any of the mis-configured item when using the automatic-sense electronic checklist. In the current study, we looked to emulate the function of the paper checklist, only we have removed the need for the physical list during the intervention and workload associated with finding and reading the paper list.

In organizational studies in non-aviation settings (i.e., manufacturing, hotels, banks, offices, retail establishments, and restaurants), checklists have been employed as part of package interventions to improve a diverse array of performances. These performances include: Cleaning and housekeeping tasks (Altus, Welsh, & Miller, 1991; Anderson, Crowell, Hantula, & Siroky, 1988; Anderson, Crowell, Sponsel, Clarke, & Brence, 1982); office tasks (Bacon, Fulton, & Malott, 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 (Crowell, Anderson, Abel, & Sergio, 1988). Interestingly, none of the studies monitored whether or not employees actually used the checklists. This may be because the checklists were used to inform employees what they were supposed to be doing and thus were considered to be a necessary part of the intervention, but were not viewed as the important motivating variables. The other independent variables that were implemented along with the checklists (i.e., feedback, goals, and rewards) were viewed as the important variables improving compliance. In all of these studies, the checklists were used as an independent variable, not a dependent variable. We were not able to find any study that examined how to increase the use of a checklist in this literature base."

Despite the lack of research in the aviation field there have been studies done in other fields that indicate that the use of audio prompting checklists can increase performance in a variety of situations. Davies, Stock, and Wehmeyer (2002) increased the performance and completion of vocational activities by individuals labeled with mental retardation by the use of a palm top computer which annunciated an audible checklist where items needed to be checked off after they were completed. In this study the use of the palm computer reduced the number of errors per activity from 2.25 to 0.75.

The current study will examine whether digital audio, intelligent checklist system can increase the accuracy of pilots checklist performance compared to a standard paper checklist.

CHAPTER 2

METHOD

Setting

The experimental setting was the simulation lab in Wood Hall at WMU's main campus. The lab was set up in two adjacent rooms, the simulator room and the control room. The simulated cockpit, cameras, audio system and projector were located in the simulator room (see Figure 1). The computers and systems used to control and monitor the flight were located in the adjacent control room (see Figure 2).

Figure 1. Cockpit PC-ATD in Simulation Room

Figure 2. Control Room

Participants

Participants for this study were sophomore and juniors enrolled in the WMU College of Aviation Flight Program. Each participant had a single engine instrument rating. Each participant had a minimum of 100 total flight hours up to 272 flight hours, including simulation time with an average of 177 total flight hours and a range of 172 hours. All participants were male and were selected by their willingness to participate and the ability pass the introductory flight session. No female pilots volunteered for this study.

Recruitment

Participants for this study were recruited by either flyers placed on bulletin boards throughout the campus (see appendix A), digital copy of the flyer presented in the

College of Aviation training software, or in class recruitment. (See appendix B). Once recruits came in for their introductory flight each filled out an eligibility questionnaire to confirm eligibility (Appendix H). Before filling out the eligibility questionnaire each participant read and signed an informed consent document (Appendix I).

Experimental Task

A personal computer – aviation-training device (PC-ATD) emulating the Cessna 172R was used during the baseline, intervention and reversal phases of this experiment. The flight pattern that participants flew was divided into six segments: (a) pre-takeoff (18 items), (b) after takeoff (2 items), (c) cruise (5 items), (d) arrival (8 items), (e) pre-landing (6 items), and (f) after landing (3 items). The flight pattern was approximately 30 minutes in duration to complete. To realistically simulate an actual flight pattern and insure that it was flown in a consistent manner across trials and participants, the experimenter provided typical air traffic control instructions throughout the flight pattern (See ATC Scripts Appendix C). These instructions were transmitted using a commercially available intercom system. The speaker was placed next to the PC-ATD and the experimenter, who was in an adjacent area, used the push-to-talk feature on the monitor to transmit the air traffic control instructions. The pilots were instructed to communicate with ATC (experimenter) by speaking aloud. The experimenter, without the participant needing to press any buttons or take any additional steps, could hear all sounds from the simulator room. The specific flight parameters for the normal workload flight patterns and script for both the experimenter (i.e., the air traffic control instructions) and pilot responses are listed in narrative form in Appendix C.

During all flights, participants had access to either a paper or simulated audible flight checklist (Independent Variable) and were instructed to use either in the way they would normally use a checklist (See Appendix D). Both the paper and simulated audible checklist contained 42 items divided into sections that correspond to each of the six flight segments identified above. The flight checklist was a modified version of the checklist standard to the Cessna 172R. Certain segments on the standard checklist (starting engine, before taxiing, and taxiing) were eliminated to reduce the overall time required to conduct each flight trial. The standard paper checklist was provided to the participant with approach plates. The simulated audible checklist would be initialed by configuration of the plane in-flight- simulating an intelligent system design that monitored flight characteristics such as altitude, flight duration, speed, and vector.

Current paper checklists are currently used in two ways. The first is to follow a challenge-response called a "do list". The pilot must read an individual item and perform the required operation or check before proceeding to the next item on the checklist. The second method is the "flow check". Pilots use memorized flow patterns to check items within a checklist segment. Only after the flow pattern is complete will the pilot return to the checklist to confirm each item is complete. This study provided an audible checklist that replaced both the paper "do list" and memorized "flow list."

It should be noted that the provision of the simulated, intelligent audible checklist system also theoretically emulates a two person flight crew if one of the crew were to provide "challenge and response" to the other pilot in flight.

Method of Data Collection

A multiple baseline across participants design with a reversal to test for maintenance was employed in this study. The design was used to compare simulated audible checklists and standard paper checklists.

The checklist compliance behavior of each participant was remotely monitored via high definition *EZWatchPro* brand digital cameras and software and scored using the checklist observation form (Appendix D). The experimenter/observer would occupy an area adjacent to the PC-ATD . The three digital cameras had built in microphones which allowed the observer to see and hear both the verbal and nonverbal responses required to complete checklist items on the computer monitor and speakers located in the observer's area. Secondarily, a *Sansa* digital audio recorder was also placed next to the PC-ATD to capture audio that may have been too faint for the camera microphones. One camera was mounted above the projection screen approximately 48 inches in front of the participant to capture hand and arm movements. One other was positioned on a wall 5 feet behind the participant to observe the participant's interaction with the flight panel. The third camera was mounted 24 inches to the side rear of the participant to also capture hand and arm movements from a different vantage point. In addition to the cameras, the experimenter was able to see the same screen that each participant saw on a monitor in the separate adjacent "control" room. All flights were recorded and stored digitally for the purposes of conducting inter-observer agreement.

Independent Variable

The independent variable in this study was the presence of either a paper (analog) checklist or a simulated, intelligent audible checklist. The simulated, intelligent audible checklist system was designed by the experimenter and assembled from commercially available components. The system simulated an intelligent computer system that monitored aircraft configuration and automatically started a digital voice that would list the checklist items appropriate for that segment of flight. The trained observers scored accuracy of checklist use. There were three phases (baseline, intervention, and reversal) with a minimum of three to four trials per phase.

Dependent Variables

The main dependent variable consisted of the number of checklist items completed correctly per flight. There were a total of 42 checklist items that could have been counted as correct or incorrect. An item was marked correct if the item was done in the proper order and at the correct time in flight. An item would be marked incorrect if the item was done out of order, done at the wrong time, generally incorrect (performing a task improperly such as setting radios to an incorrect frequency), or omitted. If the participant did a segment of the checklist at an incorrect time, but then also re-did the list at the correct time, the items would be counted as correct. Each item on the checklist was worth one point except for the “pre-flight” checklist. That checklist is different than the other segments in that it must be done twice. The checklist must be done first as a “flow list” from memory and then as confirmatory “do-list” item by item from the actual checklist (not from memory). Because of that difference, this section was graded in half points. The participant would have to complete an item twice to receive the full point. If an item were only done once, the participant would receive ½ a point.

Baseline

Participants were asked to fly one of the four simulated flight patterns (Jackson, MI Airport, Battle Creek, MI Airport, Lansing, MI Airport, or Kalamazoo, MI Airport) three to five times randomly selected during baseline phase. Each flight was a pattern around a different airport than the one they had just previously flown. Four flights were flown per two-hour session under instrument conditions (cloud bottoms at 600 feet and visual sight distance less than three nautical miles. The instructional scripts read to participants are contained in Appendix E. Participants were instructed to use the paper checklist as they would in any normal flight and were also instructed to touch and audibly announce each item as it was completed.

Intervention

The participants were asked to fly one of the four listed flight patterns in instrument conditions with four randomly selected flights per two-hour session. When the time that the participant would traditionally begin using the paper checklist, a red light would illuminate on the dash board; and directly following the illumination of the light, a digital voice would begin to list the checklist items specific to that segment of flight. The simulated audible checklist was a digitized checklist set to replay a digital voice for each item on the list selected by the experimenter. Before the pilot went into the intervention phase, but after the pilot had finished the baseline phase, the pilot was given an explanation of how the intelligent, digital audible checklist would function. Then, each participant was told to announce “check” after the digital audible system listed each item and the item was completed. Once initiated, the system would continue with a brief pause between items, but would not stop unless instructed by the participant. If the items were not completed by the participant and the audible checklist had finished the red light would stay on until the pilot restarted the checklist by saying “restart.” The instructional script read to each participant may be found in Appendix F. After they said “check” the next item on the checklist was presented until the checklist was complete at which time the red indicator light on the control panel of the plane would shut off. The participant was further instructed to say “pause” if they needed to pause, and “resume” when they were ready to begin again.

Reversal

During the reversal phase each participant was told that there would no longer be an audible checklist and that experimenter would return the paper checklist to the cockpit. During the reversal phase, each participant was also told to use the checklist as he would in any normal flight and to touch and announce each item as it was completed. The simulated flight flown during the reversal phase was identical to the preceding two conditions. The instructional script read to each participant before a reversal flight was the same script as used in Baseline (Appendix E).

Debriefing

Immediately after participants completed the last session of the reversal condition, each was debriefed in regard to all information pertinent to the study. The experimenter read the debriefing script (see Appendix G), and answered any questions that the participant had.

Duration of the Study

Including the introductory session, participants were asked to attend three to four sessions (one to two sessions a week) over a period of two to three weeks. Each participant flew a total of 11-12 flights, though each had different numbers of baseline and reversal flights.

Analysis of Data

For each participant, the number of checklist items completed correctly and incorrectly (omissions included as incorrect) were charted for each session. Changes across the phases were visually analyzed.

Inter-Observer Agreement (IOA)

Inter-observer agreement was calculated on 80% of the total flights across all conditions and participants. For flights that were graded for IOA, two of the trained experimenters would independently grade each flight. The IOA for this experiment was 98.42%.

CHAPTER 3

RESULTS

After the audible checklist was introduced the checklist compliance behavior went from 22.7 % correct in baseline to 97% correct during the intervention. The reversal phase showed a decrease in correct use to 34%, which was somewhat higher than the level obtained during the paper checklist baseline. Each participant showed a marked increase in proper checklist use following the introduction of the audible checklist, but Participant 3 had the widest range of scores from intervention to either baseline or reversal. Much of the reason for the wide range of scores for Participant 3 relates to the fact that while in baseline, the pilot completely omitted setting the navigation system. That omission made the pilot unable to find the airport on two flights despite Air Traffic Control (ATC) rerouting his flight to re-intercept the localizer on approach twice per flight. In reversal, Participant 3 failed to contact the respective airport tower or change radio frequencies to enable contact to the tower on two of the three flights. Those omissions were in direct conflict with instruction from Approach Control to contact the tower and change frequency. The third flight of reversal for Participant 3 once again had a failure to set navigation resulting in multiple missed approaches of the airport. The combined segment data for each participant may be seen in Figure 3. The scores for each participant by segment may be found in Figure 4.

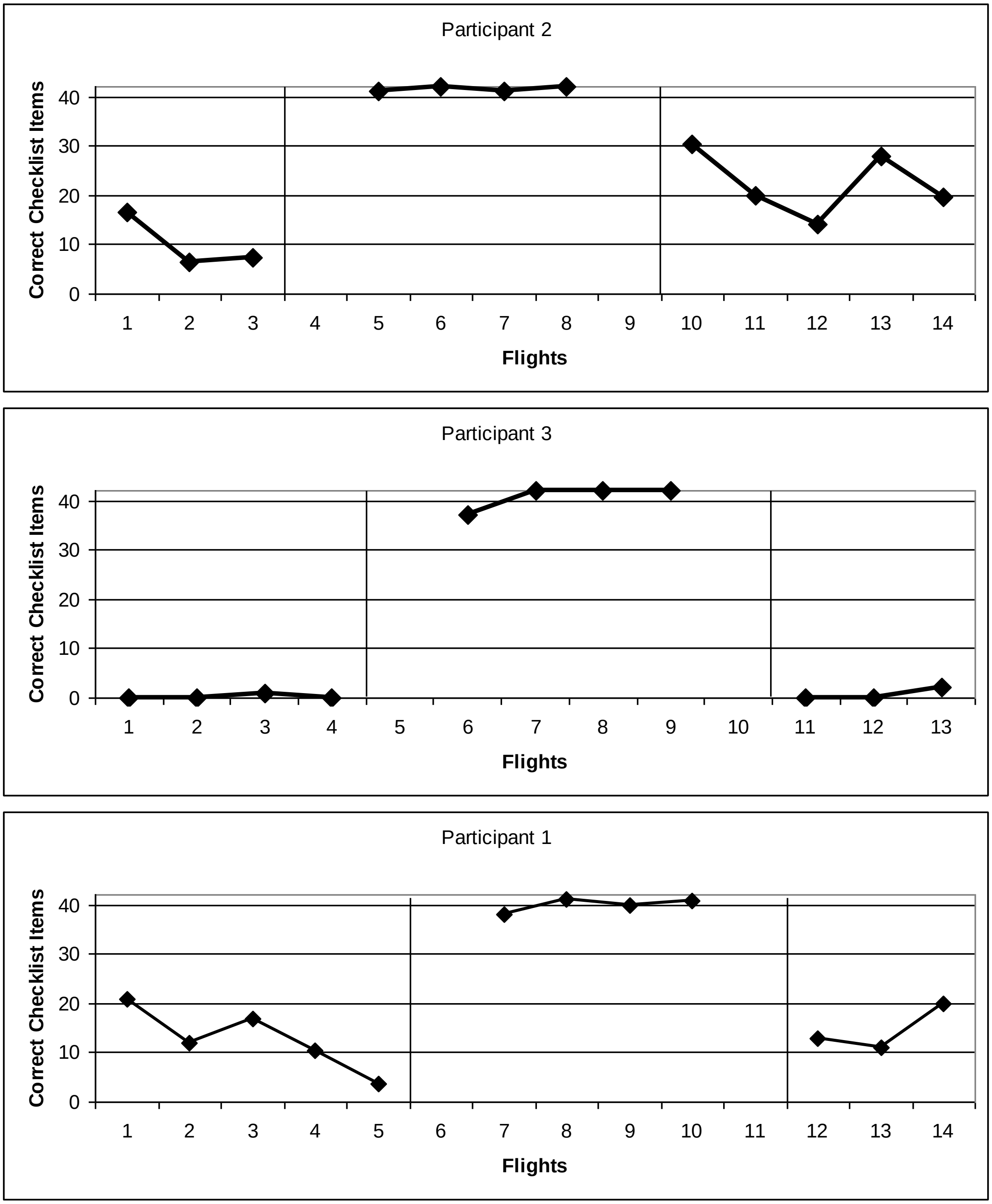

Figure 3. Per Flight Data for Each Participant

P1	Pre-Takeoff	After Takeoff	Cruise	Arrival	Pre Landing	After Landing
BL1	14	2	5	0	0	3
BL2	8	2	2	0	0	0
BL3	8.75	2	0	0	6	0
BL4	8.5	0	0	0	0	0
BL5	1.75	2	0	0	0	0
IN1	14.25	2	5	8	6	2
IN2	18	2	5	8	6	2
IN3	16.25	2	5	8	6	3
IN4	17	2	5	8	6	3
R1	8	2	0	0	0	0
R2	9	2	0	0	0	0
R3	9	2	5	0	0	3
P2	**Pre-Takeoff**	**After Takeoff**	**Cruise**	**Arrival**	**Pre Landing**	**After Landing**
BL1	8.5	1	5	0	0	0
BL2	6.5	0	0	0	0	0
BL3	7.5	0	0	0	0	0
IN1	18	2	5	8	6	3
IN2	18	2	5	8	6	3
IN3	18	2	5	7	6	3
IN4	18	2	5	8	6	3
R1	8.5	2	5	8	6	0
R2	9	0	5	0	6	0
R3	9	0	5	0	0	0
R4	9	0	5	8	6	0
R5	8.5	0	5	0	6	0
P3	**Pre-Takeoff**	**After Takeoff**	**Cruise**	**Arrival**	**Pre Landing**	**After Landing**
BL1	0	0	0	0	0	0
BL2	0	0	0	0	0	0
BL3	0	1	0	0	0	0
BL4	0	0	0	0	0	0
IN1	13	2	5	8	6	3
IN2	18	2	5	8	6	3
IN3	18	2	5	8	6	3
IN4	18	2	5	8	6	3
R1	0	0	0	0	0	0
R2	0	0	0	0	0	0
R3	1	0	0	0	0	0

Figure 4. Scores per Segment for Each Participant

Figure 5. Scores for Each Checklist and Change Percentages

Pre-Flight Checklist

For the Pre-Flight checklist P1 had the highest number of correct items in baseline at a mean score of 45.8 % correct and had an increase in intervention to 91.6% correct, an increase from baseline to intervention of 45.8%. In reversal phase P1 decreased in correct checklist items by 45.4% to a mean score of 46.2% correct, slightly better than his baseline score. P2 had the second highest mean baseline score for this checklist at 41.6% correct and in intervention had an increase of 58.34% to make his mean score in intervention 100% correct. In reversal, P2 decrease his mean correct score by 51.2% leaving his mean reversal score 48.8% correct. P3 had the lowest mean baseline score at 0% correct. However, his mean intervention score was 83.25% higher than baseline with

P2	BL1	BL2	BL3	BL4	BL5	I1	I2	I3	I4	R1	R2	R3	R4	R5	BL Mean	I Mean	R Mean	Change BL I	Change I R
Pre-flight	8.5	6.5	7.5	na	na	18	18	18	18	8.5	9	9	9	8.5	7.5	18	8.8	58.34%	-51.20%
After Takeoff	1	0	0	na	na	2	2	2	2	2	0	0	0	0	0.33	2	0	83.50%	-100%
Cruise	5	0	0	na	na	5	5	5	5	5	5	5	5	5	1.67	5	5	66%	0%
Arrival	0	0	0	na	na	8	8	7	8	8	0	0	8	0	0	7.75	3.2	96.80%	-56.8
Pre-Landing	0	0	0	na	na	6	6	6	6	6	6	0	6	6	0	6	4.8	100%	-20%
After-Landing	2	0	0	na	na	3	3	3	3	0	0	0	0	0	0.67	3	0	77.70%	-100%
P3	BL1	BL2	BL3	BL4	BL5	I1	I2	I3	I4	R1	R2	R3	R4	R5	BL Mean	I Mean	R Mean	Change BL I	Change I R
Pre-flight	0	0	0	0	na	13	18	18	18	0	0	1	na	na	0	16.75	0.33	83.25%	-81.40%
After Takeoff	0	0	0	0	na	2	2	2	2	0	0	0	na	na	0	2	0	100%	-100%
Cruise	0	0	0	0	na	5	5	5	5	0	0	0	na	na	0	5	0	100%	-100%
Arrival	0	0	0	0	na	8	8	8	8	0	0	0	na	na	0	8	0	100%	-100%
Pre-Landing	0	0	0	0	na	6	6	6	6	0	0	0	na	na	0	6	0	100%	-100%
After-Landing	0	0	0	0	na	3	3	3	3	0	0	0	na	na	0	3	0	100%	-100%
P1	BL1	BL2	BL3	BL4	BL5	I1	I2	I3	I4	R1	R2	R3	R4	R5	BL Mean	I Mean	R Mean	Change BL I	Change I R
Pre-flight	14	8	9	8.5	1.75	15	18	16	17	8	9	9	na	na	8.25	16.5	8.33	45.80%	-45.40%
After Takeoff	2	2	2	2	2	2	2	2	2	2	2	2	na	na	2	2	2	0%	0%
Cruise	5	2	0	0	0	5	5	5	5	0	0	5	na	na	1.4	5	1.66	72%	-66.80%
Arrival	0	0	0	0	0	8	8	8	8	0	0	0	na	na	0	8	0	100%	-100%
Pre-Landing	0	0	6	0	0	6	6	6	6	0	0	0	na	na	1.2	6	0	80%	-100%
After-Landing	3	0	3	0	0	2	3	3	3	0	0	3	na	na	1.2	2.75	1	51.60%	-58.30%

his mean intervention score 93% correct. This score represents the largest change from baseline to intervention, though his mean intervention score was second highest of the three participants. In reversal phase, P3 also had the largest decrease in mean score at 81.4% to make his mean reversal score to 1.8%.

After Takeoff Checklist

P1 had the highest baseline mean score for this checklist at 100% correct, during intervention and reversal this participant consistently completed this checklist correctly and had no change of scores from the original mean baseline score. P2 had the second highest mean baseline score at 16.5% correct and had an increase of 83.5% in intervention, with a mean intervention score of 100% correct. In reversal, P2 decreased mean score by 100%, with a mean reversal score of 0% correct. Again, P3 had the lowest mean score during baseline condition at 0% correct, but also had the largest increase in correct performance with a change of 100% into intervention, with a mean score of 100% correct. In this checklist P3 also had the largest decrease going from intervention into reversal decreasing to mean score 0% correct, matching his baseline score.

Cruise Checklist

During the baseline for the cruise checklist P2 had the highest mean score at 33.4% correct. In the intervention phase, P2 increased his mean score by 66% to a mean score of 100% correct for intervention. During the reversal phase this participant had no decrease in performance and maintained a mean score in reversal of 100% correct. P1 had the second highest mean baseline score for the cruise checklist at 28% correct. In the intervention phase P1 increased the mean score by 72% to 100% correct. During the reversal phase this participant decreased the mean score by 66.8% to a mean score in reversal of 33.2% correct, slightly better than his baseline score. P3 had the lowest mean score during baseline, 0% correct. Again P3 displayed the largest increase in score when in intervention by 100%, making his mean score for the intervention phase 100%. During the reversal phase P3 decreased score to 0% correct, a 100% change, back to matching the baseline score.

Arrival Checklist

All three participants had a mean baseline score of 0% correct for the arrival checklist. Both P3 and P1 increased their mean scores to 100% correct in the intervention phase. P3 and P1 also decreased by 100% in the reversal phase, both with a mean score of 0% correct in reversal. P2 did not increase his score to 100% in the intervention phase, but close with an increase of 96.8% correct to give him a mean score of 96.8% correct in intervention. Though P2 did not increase to 100% in intervention, he had the highest score in reversal compared to the other two participants. P3 decreased the score in reversal by 56.8% to give him a mean reversal score of 40%.

Pre-Landing

For this checklist P1 had the highest mean baseline score of 20% correct. Both P3 and P2 had mean baseline scores of 0% correct. All three participants increased the mean score to 100% correct during the intervention phase. During the reversal phase P2 had a decrease in performance of 20% making his reversal mean score 80%correct. Both P3 and P1 decreased scores to 0% correct during the reversal phase.

After Landing Checklist

P1 had the highest mean score during baseline for this checklist at 40%. P2 had the second highest mean baseline score for this checklist at 22.3%. P3 had a mean baseline score of 0% correct. P3 had the largest change from baseline to intervention with an increase of 100% to 100% correct during the intervention phase. P2 also increased the mean score to 100% correct during intervention, but had a change factor of 77.7% from the baseline score to intervention score. P1 increased his score by 51.6% to a mean score during intervention of 91.6% correct. Both P2 and P3 decreased their score to 0% correct in the reversal phase. During reversal phase P1 decreased his score by 58.3% to a mean score of 33% correct during reversal.

Aggregate Mean Checklist Scores

Pre Flight checklist had a mean score of 29.1% correct during baseline phase when all three participant mean scores are combined. Intervention phase had a mean score of 94.9% correct when participant scores were combined. Reversal mean score was 32.3% correct, an increase of 3.2% correct above baseline.

The After Takeoff Checklist had a mean aggregate baseline score of 38.8% correct and increased to 100% correct during the intervention phase. During reversal the aggregate mean score dropped to 33% correct, a decrease of 5.8% compared to baseline aggregate mean scores.

The cruise checklist had an aggregate baseline mean score of 42.7% correct and increased to 100% correct during the intervention phase. During reversal the aggregate mean score dropped to 44.4% correct, an increase of 1.7% correct above baseline condition.

The arrival checklist had an average mean score of 0% correct when all participant mean scores are combined. During the intervention phase the averaged mean score increased to 98.9% correct. During the reversal phase the averaged mean score decreased to 13.3% correct. A 13.3% increase above the baseline condition.

The Pre Landing checklist had an average mean score in baseline of 6% correct. Correct items increased to 100% average mean score in the intervention phase and then decreased in the reversal phase to 26.6% correct. The difference between baseline and reversal scores is 20.6% with the increase in correctness occurring in the reversal phase.

The After Landing checklist had an aggregate mean score of 20.8% correct in the baseline condition. The aggregate mean score increased to 97.2% correct during the intervention phase. Correct checklist items decreased to 11% during the reversal phase a 9.2% decrease from the baseline score.

Error Type Statistics

There were four different types of errors the participant could have made during flights. The first type of error was a *Time Error*. Checklist time errors would occur is the participant did a checklist item too soon in flight or too late in flight. The average percentage of time errors across all three participants and all flights was about 26.8%. The second type of error that could be committed was *Response Error*. This error would occur if the checklist item was completed, but done incorrectly. An example would be setting radio frequency, but setting the wrong frequency. This error had 0% occurrence throughout the study. The third type of error was *Order Error*. This type of error occurred when checklist items were done out of order in comparison to the actual checklist. This error had a mean percentage of occurrences of about 5.9% across all participants and flights. The final type of error was *Omission Error*. This error was counted when a participant simply did not perform the checklist item. Omission Errors represent the largest component of all errors committed across all participants and flights with a mean score of 67.3%. These figures may be seen in Figure 6.

	Time Error	Response Error	Order Error	Ommision Error	TOTAL
P1	56.80%	0%	7.90%	35.30%	100.00%
P2	23.50%	0%	5.40%	71.10%	100.00%
P3	0%	0%	4.50%	95.50%	100%
Mean Percentage	0.26766667	0	0.05933333	0.673	1

Figure 6. Error Type Statistics

Omissions of Full Checklist Segments

A second way of looking at the data is with the complete segment checklist omissions removed. The statistics to this point have included omissions of individual items, such as not checking flaps, and omissions of complete checklist segments, such as the omitting every item on the arrival checklist. The omitted item may be a simple mistake and can certainly be changed by our intervention as is. The complete segment checklist omission can also be changed by the intervention of this study, but the difference is that it is possible that a list that was completely omitted, may only need a single prompt to initiate and complete the segment checklist without the multiple prompts as was provided by the simulated, intelligent audible checklist system. Because of that below are the compiled graphs of the participants total errors per flight with complete checklist omissions removed . The intervention has shown a clear effect for Participant 1 and Participant 2. The data for Participant 3 in Figure 4 appears misleading and may indicate that he was flying perfectly without errors for many of the flights or even that the intervention increased his errors in reversal, which was not the case. The bulk of the errors committed by Participant 3 were total list omissions, so the removal of that list gives a false impression of his errors in flight.

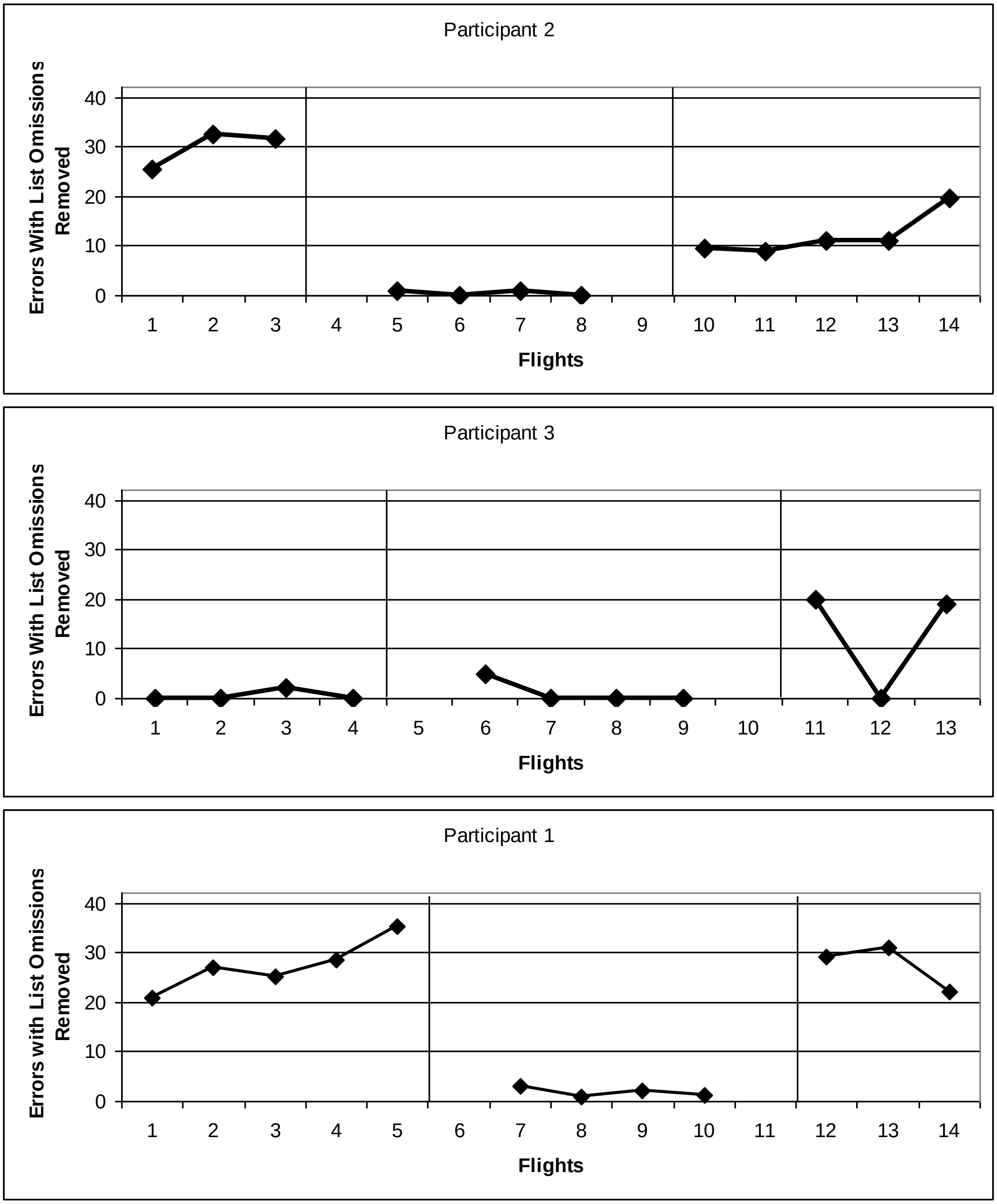

Figure 7. Errors–List Omissions Removed

CHAPTER 4

DISCUSSION

The simulated, intelligent audible checklist increased performance for all three participants. Participant 3 showed the greatest amount of improvement from baseline and also illustrated why it is so critical that pilots properly use checklists. Though none of the pilots crashed while flying in the simulator, Participant 3 failed to set the navigation aids a total of three times, twice in baseline and once in reversal and failed to contact the tower and set proper radio frequencies for communication twice while in reversal.

The simulated, intelligent audible checklist system seems to affect behavior by reducing workload such as: flipping pages, reaching for, and reading the aircraft manual. The system also provided proper time prompts for completion of specific checklists. The reversal to a higher level of errors after removal of the intervention provides evidence that once workload reverted to the standard, errors also reverted to close to baseline levels. The small difference between baseline and reversal performance may be explained by changes in pilot behavior resulting from increased knowledge of the intent of the study. In short, participants may have had a behavior change based on the knowledge that the observer was specifically watching and appraising their checklist compliance/non-compliance behaviors.

Over all this study suggests that an intelligent audible checklist system could serve to significantly reduce pilot errors and theoretically reduce aviation accidents and incidents. The system as described in this study could easily be designed and implemented using modern computer software and GPS systems.

REFERENCES

Adamski, A., & Stahl, A. (1997). Principles of design and display for aviation technical messages. *Flight Safety Digest*, *16*(1), 1-29.

Altus, D., Welsh, T., & Miller, K. (1991). A technology for program maintenance: Programming key researcher behaviors in a student housing cooperative. *Journal of Applied Behavior Analysis*, *24*, 667-675.

Alvero, A. M., Bucklin, B. R., & Austin, J. (2001). An objective review of the effectiveness and essential characteristics of performance feedback in organizational settings (1985-1998). *Journal of Organizational Behavior Management, 21*(1), 3-29.

Anderson, C. D., Crowell, C. R., Hantula, D. A., & Siroky, L. M. (1988). Task clarification and individual performance posting for improving cleaning in a student-managed university bar. *Journal of Organizational Behavior Management*, *9*(2), 73-90.

Anderson, C., Crowell, C., Sponsel, S., Clarke, M., & Brence, J. (1982). Behavior management in the public accommodations industry: A three-project demonstration. *Journal of Organizational Behavior Management*, *4*(1/2), 33-66.

Austin, J., Weatherly, N. L., Gravina, N. E. (2005). Using task clarification, graphic feedback, and verbal feedback to increase closing-task completion in a privately owned restaurant. *Journal of Applied Behavior Analysis, 38*, 117-120.

Bacon, D. L., Fulton, B. J., & Malott, R. W. (1982). Improving staff performance through the use of task checklists. *Journal of Organizational Behavior Management, 4*(3/4), 17-25.

Balcazar, F. E., Hopkins, B. L., & Suarez, Y. (1985-86). A critical, objective review of performance feedback. *Journal of Organizational Behavior Management*, *7*(3/4), 65-89.

Boorman, D. (2001). Today's electronic checklists reduce likelihood of crew errors and help prevent mishaps. *ICAO Journal, 1*, 17-21.

Crowell, C. R., Anderson, D. C., Abel, D. M., & Sergio, J. P. (1988). Task clarification, performance feedback, and social praise: Procedures for improving the customer service of bank tellers. *Journal of Applied Behavior Analysis, 21*, 65-71.

Davies, D.K., Stock, S.E., & Wehmeyer, M.L. (2002) Enhancing Independent Task Performance for Individuals with Mental Retardation Through the Use of a Handheld Self-directed Visual and Audio Prompting System. *Education and Training in Mental Retardation and Developmental Disabilities,* 37(2), 209-218.

Degani, A. (1992). *On the typography of flight-deck documentation* (NASA Contractor Rep. 177605). Moffett Field, CA: NASA Ames Research Center.

Degani, A. (2002, April). *Pilot error in the 90s: Still alive and kicking*. Paper presented at the meeting of the Flight Safety Foundation of the National Business Aviation Association, Cincinnati, Ohio.

Degani, A., & Wiener, E. L. (1990). *Human factors of flight-deck checklists: The normal checklist* (NASA Contractor Rep. 177549). Moffett Field, CA: NASA Ames Research Center.

Degani, A., & Wiener, E. L. (1993). *Cockpit checklists: Concepts, design, and use. Human Factors, 35*(2), 28-43.

Degani, A., & Wiener, E. L. (1994). *On the design of flight-deck procedures* (NASA Contractor Rep. 177642). Moffett Field, CA: NASA Ames Research Center.

Diez, M., Boehm-Davis, D., & Holt, R. (2003). Checklist performance on the commercial flight-deck. *Proceedings of the 12th International Symposium on Aviation Psychology* (pp. 323-328). Columbus, OH: The Ohio State University.

Federal Aviation Administration. (1995). *Human performance considerations in the use and design of aircraft checklists*. Washington, DC: Author.

Federal Aviation Administration. (1996). *Advisory circular 120-64: Operational use and modification of electronic checklists*. Washington, DC: Author.

Federal Aviation Administration. (2000). *Advisory circular 120-71: Standard operating procedures for flight deck crewmembers*. Washington, DC: Author.

Gross, R. (1995). Studies suggest methods for optimizing checklist design and crew performance. *Flight Safety Digest*, *14*(5), 1-10.

Harshaw, Robert C., Ronald S. Burkey, James T. Doell, Dennis G. Keith. (1990). Computerized Checklist System (Heads Up Technologies, Inc.). *U.S. Patent No. 4970683*. Washington, DC: U.S. Patent and Trademark Office.

Helmreich, R. L. (in press). Culture, threat, and error: Assessing system safety. *Proceedings of the Royal Aeronautical Society Conference*. London: The Royal Aeronautical Society.

Helmreich, R. L., Klinect, J. R., Wilhelm, J. A., & Jones, S. G. (1999). *The Line/LOS Error Checklist, Version 6.0: A checklist for human factors skills assessment, a log for off-normal events, and a worksheet for cockpit crew error management* (Tech. Rep. No. 99-01). Austin, TX: University of Texas, Human Factors Research Project.

Helmreich, R. L., Wilhelm, J. A., Klinect, J. R., & Merritt, A. C. (2001). Culture, error, and crew resource management. In E. Salas, C. A. Bowers, & E. Edens (Eds.), *Improving teamwork in organizations* (pp. 305-331). Hillsdale, NJ: Erlbaum.

LaFleur, T., & Hyten, C. (1995). Improving the quality of hotel banquet staff performance. *Journal of Organizational Behavior Management, 15*(1/2), 69-93.

Lautmann, L., & Gallimore, P. (1987). Control of the crew-caused accident: Results of a 12-operator survey. *Boeing Airliner,* 1-6. Seattle: Boeing Commercial Airplane Company.

Merritt, Ashleigh and Klinect, James.(2006). Defensive Flying for Pilots: An Introduction to Threat and Error Management. The University of Texas Human Factors Research Project, The LOSA Collabrative.

Moses, T., Stahelski, A., & Knapp, G. (2000). Effects of attribute control charts on organizational performance. *Journal of Organizational Behavior Management, 20*(1), 69-90.

Mosier, K. L., Palmer, E. A., & Degani, A. (1992). Electronic Checklists: Implications for decision making. In Proceeds of the Human Factors Society 36th Annual Meeting, Santa Monica, CA: Human Factors and Ergonomics Society.

National Transportation Safety Board. (1969). *Aircraft accident report: Pan American World Airways, Inc., Boeing 707-321C, N799PA, Elmendorf Air Force Base, Anchorage, Alaska, December 26, 1968* (Report No. NTSB/AAR-69/08). Washington, DC: Author.

National Transportation Safety Board. (1975). *Aircraft accident report: Northwest Airlines, Inc., Boeing 727-25, 264US, Near Thiells, New York, December 1, 1974* (Report No. NTSB/AAR-75/13). Washington, DC: Author.

National Transportation Safety Board. (1982). *Aircraft accident report: Air Florida, Inc., Boeing 737-222, N62AF, Collision with 14th Street Bridge, Near Washington National Airport, Washington, DC, January 13, 1982* (Report No. NTSB/AAR-82/08). Washington, DC: Author.

National Transportation Safety Board. (1988a). *Aircraft accident report: BAe-3101 N331CY. New Orleans International Airport. Kenner, Louisiana* (Report No. NTSB/AAR-88/06). Washington, DC: Author.

National Transportation Safety Board. (1988b). *Aircraft accident report: Northwest Airlines, Inc., McDonnell Douglas DC-9-82, N312RC, Detroit Metropolitan Wayne County Airport, Romulus, Michigan, August 16, 1987* (Report No. NTSB/AAR-88/05). Washington, DC: Author.

National Transportation Safety Board. (1989). *Aircraft accident report: Boeing 727-232, N473DA. Dallas-Fort Worth International Airport, Texas* (Report No. NTSB/AAR-89/04). Washington, DC: Author.

National Transportation Safety Board. (1990). *Aircraft accident report: USAir Inc., Boeing 737-400, LaGuardia Airport, Flushing, New York, September 20, 1989* (Report No. NTSB/AAR-90/03). Washington, DC: Author.

National Transportation Safety Board. (1997). *Aircraft accident report: Wheels up landing, Continental Airlines Flight 1943, Douglas DC-9 N10556, Houston, Texas, February 19, 1996* (Report No. NTSB/AAR-97/01). Washington, DC: Author.

Noyes, J. M., Starr, A. F. (2007). A comparison of speech input and touch screen for executing checklists in an avionics application. *International Journal of Aviation Psychology, 11*(3). 299-314.

O'Rourke, James D. (2001). Checklist Device. U.S. Patent Application Publication No. US 2001/0030611 A1. Washington, DC: U.S. Patent and Trademark Office.

Palmer, E., Degani, A. (1991). Electronic checklists: Evaluation of two levels of automation. *Proceedings of the 6th International Symposium on Aviation Psychology* (pp. 178-183). Columbus, OH: The Ohio State University.

Patterson, E. S., Render, M. L., & Ebright, P. R. (2002). Repeating human performance themes in five health care adverse events. *Proceedings of the 46th meeting of the Human Factors and Ergonomic Society* (pp. 1418-1422). Santa Monica, CA: Human Factors and Ergonomic Society.

Porterfield, J., Evans, G., & Blunden, R. (1985). Involving families and staff in service improvement. *Journal of Organizational Behavior Management, 7*(1/2), 117-133.

Rantz, W. G., Dickinson, A., Sinclair, G., Van Houten, R. (2009). The Effect of Feedback on Accuracy of Checklist Completion During Instrument Flight Training. *Journal of Applied Behavior Analysis, 42(3), 497-509.*

Rantz, W.G. & Van Houten, R. (2011) A Feedback Intervention to Increase Digital and Paper Checklist Performance in Technically Advanced Aircraft Simulation. *Journal of Applied Behavior Analysis, 44(1), 144-150.*

Turner, T. (2001). *Controlling pilot error: Checklists and compliance*. New York: McGraw-Hill.

Wilk, L. A., & Redmon, W. K. (1998). The effects of feedback and goal setting on the productivity and satisfaction of university admissions staff. *Journal of Organizational Behavior Management, 18*(1), 45-68.

Wittkopp, C. J., Rowan, J. F., & Poling, A. (1990). Use of a feedback package to reduce machine set-up time in a manufacturing setting. *Journal of Organizational Behavior Management, 11*(2), 7-22.

Appendix A

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 PC-ATD emulating a Cessna 172.

Participants will receive extra simulation instrument flight time to practice local approach procedures in this study. To be eligible to participate you must have a valid instrument rating.

Sessions will be conducted in Wood Hall at WMU's main. The study will last 2-3 weeks (5-10 sessions total). Sessions will be about 2 hours and you will be asked to attend two sessions per week. You will be asked to fly 4 instrument approaches during each session.

If you are interested in learning more about the study, please contact Bryan Hilton. 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 Bryan Hilton
E-mail: bryan.w.hilton@wmich.edu
or
Phone: (616) 634-2923

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Appendix B

Recruitment Scripts

Recruitment Script

Hi. I'm Bryan Hilton and I am a doctoral student in the Psychology Department and a graduate of the College of Aviation. 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 PC-ATD emulating a Cessna 172.

Participants will receive Cessna 172 simulation instrument flight time to practice local approach procedures in this study. To be eligible to participate, you must possess a valid instrument rating.

Sessions will be conducted in Wood Hall at WMU main. The study will last 2-3 weeks (5-10 sessions total). Sessions will be about 2 hours and you will be asked to attend two sessions per week. You will be asked to fly 4 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.

Thank you for your time

Appendix C

Air Traffic Control Scripts

Technical Flight Pattern Parameters and Narration
Flight Pattern 1 KBTL

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

Using flow pattern-Before Takeoff checks completed (18 checklist items) once as flow, once as a do list.

(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 3,000'*. (2 min)

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

Using do-list-Normal Takeoff checks completed (2 checklist items)

After reaching 200' AGL posistive rate and 70 KIAS, but before 1000'

Using flow pattern-Climb checks completed above 1000' (5 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 3000.*

(EXPERIMENTER): *Western 45 roger*.

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

(PARTICIPANT): *Turning left to a heading of 120 Western 45. (2 min.)*

Using flow pattern-Cruise checks complete after level at 3,000' (5 checklist items)

(EXPERIMENTER): *Western 45 turn left heading of 050 descend and maintain 2,500'.*

(9 min – after 5 min, tell the participant we are pausing to check map, then after map is checked , adjust heading if needed, after you hit resume tell participant to check the

compass because checking the map will sometimes cause a change in the adjustable compass)

(PARTICIPANT): *Turning left to a heading of 050 descending to 2,500' Western 45*.

(EXPERIMENTER): *Western 45 turn left to a heading of 320*. (2 min) (after one minute check the map and adjust heading if needed, again tell participant to check compass after you hit resume)

(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 118.1*.

** Arrival checklist to begin here*

(PARTICIPANT): *Contacting Battle Creek Tower on 118.1 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*.

<u>Using flow pattern-Pre landing checks complete prior to FAF (6 checklist items)</u>

2 miles outside FAF-Power 50% 22" MP, flaps 50%, airspeed 100 knots, maintain 2,500' until established on the glide slope.

FAF inbound and established on glide slope-Power 25% 12" MP, flaps 50%, airspeed 100 knots, descent rate of 500 feet per minute is established.

Short final-Power as required, flaps 100%, airspeed 75 knots over threshold of runway.

(EXPERIMENTER): *Western 45 turn left to exit the active runway and park.*

Using flow pattern-After Landing checks (3 items) Wait 1 minute after the plane has stopped for them to complete after landing list, it not done by them move to the next line below.

(EXPERIMENTER): *This session is over. 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.*

Using flow pattern-Before Takeoff checks completed (18 checklist items) once as flow once as do list

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

(EXPERIMENTER): *Western 45 you are cleared for departure. Fly runway heading climb and maintain 3,500'*. (2 min)

(PARTICIPANT): *Fly runway heading climb and maintain 3,500' Western 45 (2 min)*

Using do-list-Normal Takeoff checks completed (2 checklist items)

After reaching 200' AGL, positive rate and 70 KIAS, but before 1000'

Using flow pattern-Climb checks completed above 1000' (5 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 3,500'.*

(EXPERIMENTER): *Western 45 roger*.

(EXPERIMENTER): *Western 45 turn left heading of 260*. (2 min)

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

Using flow pattern-Cruise checks complete after level at 3,500' (5 checklist items)

(EXPERIMENTER): *Western 45 turn left heading of 170 and descend to 3,000'* (9 min. at 5 minutes check the map and adjust heading if needed, after map is adjusted and you hit resume tell the participant to check the adjustable compass because map can change it.)

(PARTICIPANT): *Turning left to a heading of 170 and descending to 3,000' Western 45*.

(EXPERIMENTER): *Western 45 turn left to a heading of 080*. (2 min, at 1 min check map, adjust heading as needed and tell participant to correct compass if needed)

(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.*

** Arrival Check list here*

(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*.

Using flow pattern-pre Landing checks complete prior to FAF (6 checklist items)

2 miles outside FAF-Power 50% 22" MP, flaps 50%, airspeed 100 knots, maintain 2,500' until established on the glide slope.

FAF inbound and established on glide slope-Power 25% 12" MP, flaps 50%, airspeed 100 knots, descent rate of 500 feet per minute is established.

Short final-Power as required, flaps 100%, airspeed 75 knots over threshold of runway.

(EXPERIMENTER): *Western 45 turn left to exit the active runway and park.*

Using flow pattern-After Landing checks (3 items) Wait for 1 minute after plane is stopped and if checklist not done, score as such and go to next line.

(EXPERIMENTER): *This session is over. Please relax and I will join you in a few minutes.*

Technical Flight Pattern Parameters and Narration
Flight Pattern 3 KLAN

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

Using flow pattern-Before Takeoff checks completed (18 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 3,000'*. (2 min)

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

Using do-list-Normal Takeoff checks completed (2 checklist items)

After reaching 200 AGL, positive rate, 70 KIAS, but before 1000'

(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 3,000.*

(EXPERIMENTER): *Western 45 roger*.

(EXPERIMENTER): *Western 45 turn right heading of 190*. (2 min)

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

Using flow pattern-Cruise checks complete after level at 3,000' (5 checklist items)

(EXPERIMENTER): *Western 45 turn right heading of 280 and descend to 2,500'.(9 min. – at five minutes check map and adjust heading if needed, tell participant to check adjustable compass after hitting resume.)*

(PARTICIPANT): *Turning right to a heading of 280 and descending to 2,500' Western 45.*

(EXPERIMENTER): *Western 45 turn right to a heading of 010*. (2 min, after 1 minute check map and adjust heading if needed, have participant check compass after hitting resume)

(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.*

**Arrival check list*

(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*.

Using flow pattern-pre Landing checks complete prior to FAF (6 checklist items)

2 miles outside FAF-Power 50% 22" MP, flaps 50%, airspeed 100 knots, maintain 2,500' until established on the glide slope.

FAF inbound and established on glide slope-Power 25% 12" MP, flaps 50%, airspeed 100 knots, descent rate of 500 feet per minute is established.

Short final-Power as required, flaps 100%, airspeed 75 knots over threshold of runway.

(EXPERIMENTER): *Western 45 turn left to exit the active runway and park.*

Using flow pattern-After Landing checks (3 items) (wait 1 minute for pilot to complete checklist before moving to the next line of script.)

(EXPERIMENTER): *This session is over. Please relax and I will join you in a few minutes.*

Technical Flight Pattern Parameters and Narration
Flight Pattern 4 KJXN

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

Using flow pattern-Before Takeoff checks completed (18 checklist items) once as flow once as a do list.

(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'*. (2 min)

(PARTICIPANT): *Fly runway heading climb and maintain 3,500' Western 45*

Using do-list-Normal Takeoff checks completed (2 checklist items)

After reaching 200' AGL, with positive rate and above 70 KIAS, but before 1000'

(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 3,500.*

(EXPERIMENTER): *Western 45 roger*.

(EXPERIMENTER): *Western 45 turn left heading of 150*. (2 min)

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

Using flow pattern-Cruise checks complete after level at 3,500' (5 checklist items)

(EXPERIMENTER): *Western 45 turn left heading of 060 and descend to 3,000'*. (9 min. at 5 min. check map and adjust heading as needed, after hitting resume tell participant to check compass and correct if needed)

(PARTICIPANT): *Turning left to a heading of 060 and descending to 3,000' Western 45*.

(EXPERIMENTER): *Western 45 turn left to a heading of 330*. (2 min, after 1 minute check map and adjust heading if needed, after hitting resume tell pilot to check the compass and correct if needed)

(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*.

**arrival check list*

(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*.

Using flow pattern-pre Landing checks complete prior to FAF (5 checklist items)

2 miles outside FAF-Power 50% 22" MP, flaps 50%, airspeed 100 knots, maintain 2,500' until established on the glide slope.

FAF inbound and established on glide slope-Power 25% 12" MP, flaps 50%, airspeed 100 knots, descent rate of 500 feet per minute is established.

Short final-Power as required, flaps 100%, airspeed 75 knots over threshold of runway.

(EXPERIMENTER): *Western 45 turn left to exit the active runway and park.*

Using flow pattern-After Landing checks (3 items) (wait 1 minute of plane is stopped for pilot to complete checklist before moving on to next line in script)

(EXPERIMENTER): *This session is over. Please relax and I will join you in a few minutes.*

Appendix D

Checklist/Checklist Form

PRE TAKE-OFF SEGMENT	Complete	Complete flow	incorrect	Ommited	Comments
Magnetos........................Both					
engine instruments......check					
Fuel Quantity..................Check					
Flight Instruments..........Check/Set					
Controls.......................Full, Free, Correct					
Throttle Friction Lock......Check/Set					
Flaps..........................A/R					
Elevator Trim.................Set for Takeoff					
fuel shutoff valve in					
Fuel Selector.................Both					
Seats,belts, cabin secure					
Avionics.......................Set					
Transponder..................set					
take off briefing...............complete					
Pitot Heat......................A/R					
Strobes.........................On					
Mixture..........................Rich					
Doors and Windows Secure					
AFTER TAKE-OFF					
Flaps............................Up					
Engine Instruments..........Check					
CRUISE					
Fuel.............................check					
Radios...........................set					
Engine ....Check					
compasses...............Check					
Altimeter.......................Set					
ARRIVAL					
Atis ....received					
Fuel...............................check					
Radios...........................set					
Engine ....Check					
Compass........................Check					
Altimeter........................Check/Set					
Landing Light.....................on					
Approach Brief.................Complete					
PRE-LANDING					
Fuel Selector....................Both					
Mixture...........................Rich					
Altimeter.........................set					
Fuel Both					
Seats/belts/cabin check					
Brake.............................Off					
AFTER LANDING					
Flaps..............................Up					
Avionics ....A/R					
External Lights and Pitot heat .....A/R					

Appendix E

Instructional Script Paper Pre-Flight

Paper Checklist Pre-flight Instructional Script

We will be conducting four instrument flights per session. One session should last about two hour. Each of the four 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 is the airplane paper checklist for you to use. Please use the checklist as you would during any normal flight. You should talk aloud and touch each check item while doing your flow checks to confirm it is complete. Please take a moment to familiarize yourself with the ILS approach plate. Here is a copy of the latest Automatic Terminal Information Service (ATIS) information. 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. 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. [(Initial session) 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 before starting engine, engine start, before taxi, and taxiing checklists have been completed. Please be certain to start at the before 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. Are you ready? Please wait for my call to announce the beginning of the flight.

Appendix F

Instructional Script Simulated, Intelligent Audible

Audible Checklist Pre-flight Instructional Script

You have been re-positioned at [airport] 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]. As before, please be ready to use the checklist at the normal time that you would in a flight, but when the appropriate time for a checklist occurs a red checklist button on the dash board will light, once it has lit the appropriate checklist will begin.. Once the simulated audible checklist begins you should talk aloud and touch each check item while doing your flow checks to confirm it is complete, simply say check after the system says “check”. If you need to pause the audible checklist say “pause”, to resume say “resume”, to repeat the checklist say repeat. After the list is complete the light will turn off until the next appropriate time for a checklist. Please take a moment to familiarize yourself with the ILS approach plate. 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]. To remind you, after the landing it will not be necessary to conduct an engine shut down check. We are starting the flight at the hold line of runway [runway number] at [airport name]. Once again the before starting engine, engine start, before taxi, and taxiing checklists have been completed. Please be certain to start at the before 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. Are you ready? Please wait for my call to announce the beginning of the flight.

Appendix G

Debrief Script

Debriefing Script

Thank you for participating in this study. The purpose of this study is to determine the accuracy differences between paper and audile checklist performance and if either or both 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 masters 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. We assigned you to fly using the [paper/audible] checklist. 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.

Appendix H

Eligibility Questionnaire

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 total ILS approaches have you done?
   _____hrs

5. Approximately how many hours have you flown in the past 3 months? _____hrs

6. How many hours have you flown solo or as PIC after your Private Certificate? ___hrs

7. Approximately how many total landings have you made since learning to fly? _____

8. Approximately how many hours do you have in total? _____hrs

9. Approximately how long can you devote to this study? _______________end date.

10. Is it possible for you to return after the study is complete for one session? _______

11. What aircraft types have you flown?__________________________________

12. How long has it been since you have flown another aircraft other that the SR20 or SR22?______

Thank you!

Appendix I

Informed Consent Document

Western Michigan University
Department of Psychology

Instrument Landing Approaches Using a PC-ATD Emulating a Cessna 172

Principal Investigator: Ron Van Houten, Ph.D.
Co-Principle Investigator: William Rantz, Ph.D.
Student Investigator: Bryan Hilton, M.A.

You are being invited to participate in a research study designed to determine how well pilots can fly an instrument landing approach using a person computer aviation training device (PC-ATD) emulating a Cessna 172. The study is being conducted by Bryan Hilton who is masters student at the Western Michigan University Department of Psychology. Bryan Hilton is conducting this study as a part of his masters training. Dr. Ron Van Houten is his graduate advisor. William Rantz is Co-principle Investigator.

Eligibility requirements. To be eligible to participate, you must have a private pilot certificate and a valid instrument rating. You also must be able to attend at least two one-hour sessions a week for 2-3 weeks.

Study procedures and length of participation. During each session, you will fly four standard instrument landing system approaches to an airport using a PC-ATD. Each session will last approximately two hours and you will be asked to attend from 5 to 10 experimental sessions over a 3-week period. The total number of sessions you will attend will depend upon your performance. Your performance on the Cirrus SR20 FTD 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 and audible checklists 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. 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 and/or may improve performance.

Who to contact if I have questions. If you have any questions about this study you can call Bryan Hilton at (616) 634-2923. You may also call Bryan Hilton's faculty advisor, Dr. Van Houten, at 387-4471. 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 J

HSIRB Application

RECEIVED
OCT 10 2011
H.S.I.R.B.

WESTERN MICHIGAN UNIVERSITY
Human Subjects Institutional Review Board
WMU Mail Stop: 5456 Phone: (269) 387-8293

APPLICATION FOR CONTINUING REVIEW OR FINAL REPORT FORM

In compliance with Western Michigan University's policy that "the HSIRB's review of research will be conducted at appropriate intervals but not less than once per year," the HSIRB requests the following information:

I. PROJECT INFORMATION

PROJECT TITLE: Comparing Effects of Audible Checklists and Graphic Feedback on Accuracy in Simulated Flight
HSIRB Project Number: 09-11-21

Previous level of review: ☐ Full Board Review ☒ Expedited Review ☐ Administrative (Exempt) Review

Date of Review Request: 11/23/11 Date of Last Approval: 11/23/10

II. INVESTIGATOR INFORMATION

Have all investigators completed human subjects protections training at www.citiprogram.org?
☒Yes ☐No (Training must be completed before protocol can be renewed)

PRINCIPAL INVESTIGATOR OR ADVISOR
Name: Ron Van Houten Ph.D.
Department: PSY Mail Stop: 5439 Electronic Mail Address: ron.vanhouten@wmich.edu

(1) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name: Bryan Hilton
Department: PSY Mail Stop: 5439 Electronic Mail Address: bryan.w.hilton@wmich.edu

(2) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name: William Rantz Ph.D
Department: AVS Mail Stop: 5305 Electronic Mail Address: william.rantz@wmich.edu

III. CURRENT STATUS OF RESEARCH PROJECT
Please answer questions 1-4 to determine if this project requires continuing review by the HSIRB.

1. The project is closed to recruitment of new subjects.
   ☐Yes (Date of last enrollment:) ☒No (Project must be reviewed for renewal.)
2. All subjects have completed research related interventions.
   ☐Yes ☐ Not Applicable ☒No (Project must be reviewed for renewal.)
3. Long-term follow-up of subjects has been completed.
   ☐Yes ☐ Not Applicable ☒No (Project must be reviewed for renewal.)
4. Analysis of data is complete.
   ☐Yes ☒No (Project must be reviewed for renewal.)

- If you have answered **"No" to ANY** of the questions above, you must apply for **Continuing Review**. Please complete numbers 5-12 on page 2. If you need to make changes in your protocol, please submit a separate memo detailing the changes that you are requesting.
- If you have answered **"Yes" or "Not Applicable" to ALL** of the above questions, please check the **Final Report** box below and complete questions 5-10 on page 2.
- If your protocol has been open for three years and you still want to collect or analyze data, you must close this protocol by filing a final report using this form **and** apply for approval of a new protocol using an **Application for Initial Review**. Please make a **Final Report** on your project by completing numbers 5-10 on page 2.

IV. ☒ **Application for Continuing Review** **V.** ☐ **Final Report**

Revised 7/03 WMU HSIRB
All other copies obsolete

HSIRB Project Number: 09-11-21

5. Have there been changes in Principal or Co-Principal Investigators? ☐Yes ☒No
   (If **yes**, provide details on an "Additional Investigators" form (available at the HSIRB web site, http://www.wmich.edu/research/compliance/hsirb/hsirb_2.html).)

6. Has the approved protocol been modified or added to with respect to:
   (If **yes** to any item below, provide the details on an attached sheet.)
   a. Procedures ☐Yes ☒No
   b. Subjects ☐Yes ☒No
   c. Design ☐Yes ☒No
   d. Data collection ☐Yes ☒No

7. Has any instrumentation been modified or added to the protocol? ☐Yes ☒No
   (If **yes**, attach new instrumentation or indicate the modifications made.)

8. Have there been any adverse events that need to be reported to the HSIRB? ☐Yes ☒No
   (If **yes**, provide details on an attached sheet.)

9. Total number of subjects approved in original protocol: **4**

10. Total number of subjects enrolled so far: **0**
    If applicable: Number of subjects in experimental group: Number in control group:

- If this is a **FINAL REPORT** you may stop here and return the form electronically.
- If this is an **APPLICATION FOR CONTINUING REVIEW** continue with numbers 11-13 below.

11. Estimated number of subjects yet to be enrolled: **4**

12. **Verification of Consent Procedure:** Provide copies of the consent documents signed by the last two subjects enrolled in the project. Cover the signature in such a way that the name is not clear but there is evidence of signature. If subjects are not required to sign the consent document, provide a copy of the most current consent document being used.

13. **If you are continuing to recruit subjects for this project, please remember to include a clean original of the consent documents to receive a renewed approval stamp.**

10/6/11

Principal Investigator/Faculty Advisor Signature Date

10/6/11

Co-Principal or Student Investigator Signature Date

Approved by the HSIRB:

10/24/11

HSIRB Chair Signature Date

Western Michigan University
Human Subject Institutional Review Board – Mail Stop 5456
(269) 387-8293 research-compliance@wmich.edu

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