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EFFICACY OF LOW-COST PC-BASED AVIATION TRAINING DEVICES

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ABSTRACT

Aim/Purpose	The aim of this study was to explore whether a full cost flight training device (FTD) was significantly better for simulator training than a low cost PC-Based Aviation Training Device (PCATD).
Background	A quasi-transfer study was undertaken to ascertain whether a Civil Aviation Authority certified Flight Training Device (FTD) was more effective at improving pilot proficiency in the performance of a standard VFR traffic pattern (Overhead Rejoin Procedure) than a customised low cost PCATD.
Methodology	In this quasi-transfer study, a high fidelity FTD rather than an aircraft was used to test both training and transfer tasks. Ninety-three pilots were recruited to participate in the study.
Contribution	The use of PCATDs is now well established for pilot training, especially for Instrument Flight Rules (IFR) skills training. However, little substantive research has been undertaken to examine their efficacy for VFR training.
Findings	There was no evidence of a pre-test/post-test difference in VFR task performance between participants trained on the PCATD and the FTD, when post tested on the FTD. The use of both PCATD and FTD demonstrated significant improvements in VFR task performance compared to a control group that received no PCATD or FTD training.
Recommendations for Practitioners	We discuss the possibility that low cost PCATDs may be a viable alternative for flight schools wishing to use a flight simulator but not able to afford a FTD.

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Recommendation for Researchers	We discuss the introduction of improved low cost technologies that allow PCATDs to be used more effectively for training in VFR procedures. The development and testing of new technologies requires more research.
Impact on Society	Flight training schools operate in a difficult economic environment with continued increases in the cost of aircraft maintenance, compliance costs, and aviation fuel. The increased utilisation of low cost PCATD's especially for VFR instruction could significantly reduce the overall cost of pilot training
Future Research	A new study is being undertaken to compare the effectiveness of a PCATD and a FTD at training transfer of other VFR task procedures such as forced landing training, forced landing after take-off, and low-level navigation exercises.

Keywords PC-based aviation training device, flight training device, visual flight rules, quasi-transfer, simulator, pilot training

INTRODUCTION

Rapid advances in computer technology have enabled flight simulator manufacturers to develop efficient and realistic fixed-base Flight Training Devices (FTDs) (Elite, 2016). The cost of 'flying' an hour in a simulator is significantly less than in a real aircraft (particularly if it is multi-engine). Several well established flight training organisations (FTOs) in New Zealand own and operate FTDs as an integral part of their flight training programmes (Eagle Flight Training, 2015; Massey News, 2007), but, even though the cost of certified FTDs has fallen considerably in the last decade (Frasca, 2015), they are still beyond the financial reach of most flight training schools in NZ. For many years, FTOs have investigated the possibility of more cost effective ways of being able to provide flight simulation devices (Dennis & Harris, 1998; Redbird, 2016) for flight schools that operate in a difficult economic environment with continued increases in the cost of aircraft maintenance, compliance costs, and imported aviation fuel. An alternative strategy to the use of FTDs is to use PC-Based Aviation Training Devices (PCATDs) for some aspects of ab-initio training; indeed, such devices could be critical to a flight school's continued operation (Koonce & Bramble, 1998; Wu & Sun, 2014), as they may offer a low cost but effective training tool for flight instruction, classroom demonstrations and procedural training tasks, and instrument training in particular (EASA, 2016; Massey News, 2008).

The primary goal of this research was to determine whether PCATDs could be developed with improved visual fidelity to be effective in VFR task skills training with a particular focus on VFR procedures and navigation. Traditionally, flight instructors tend to be conservative and favour high fidelity FTDs which they had mostly trained on (Williams, 2006). They are, in many cases, reluctant to accept new technology such as PCATDs because they lack experience in using these devices and have limited knowledge of their training potential (Alessandro, 2008). The hypothesis to be tested was, therefore, that FTDs would perform better than PCATDs. If no evidence is found to support this hypothesis, it will imply that efficacy is no reason to prefer FTDs to PCATDs.

LITERATURE REVIEW

As their name suggests, some desktop PCATDs can fit on a large table (or desk); furthermore, they also have flight controls and instrumentation similar to real aircraft or FTDs and can emulate many of the features found in sophisticated FTDs. For these reasons, the integration of PCATDs into a flight training school's syllabus has the potential to result in significant cost savings, if some aircraft training is substituted with PCATD training. Indeed, studies have indicated that even although the fidelity of PCATDs is relatively low when compared to high-end FTDs or to real aircraft, especially in flight control loading and flight dynamics, importantly, there is evidence of a positive transfer of training from PCATD to the aircraft (Flight1 Aviation Technologies, 2016; Koonce & Bramble, 1998; Taylor et al., 1999; Taylor et al., 2003). However, studies have also indicated that the introduction of PCATDs into the training environment should be treated with some caution. PCATD's can offer a better learning environment than the aircraft (e.g., a 'flight' may be paused to discuss some aspect of control), however, they do have some limitations; for example, they may be detrimental when used solely to teach psychomotor skills for basic flight manoeuvers (Dennis & Harris, 1998). If PCATDs have the potential to create poor flying techniques, then for some students this may mean extensive (and expensive) re-training in the air. While they may be efficient and cost effective training tools for the rehearsal of procedures, their training effectiveness may decrease rapidly with overuse (Alessandro, 2008).

PCATD training sessions are now well established in many pilot training programs, especially for Instrument Flight Rules (IFR) skills training (Stewart II, Dohme, & Nullmeyer, 2002; Yeo, 2016). Although, the fidelity of PCATD software and hardware has improved significantly in recent years, little research has been undertaken to establish whether PCATDs are equally as effective for VFR procedures training (Leland, Rogers, Boquet, & Glaser, 2009). Problems with limited field of view, lack of visual fidelity, and fixation on instrument displays by student trainees have caused flight instructors to question their effectiveness for VFR procedures training (Williams, 2006). Despite their limitations, the potential benefits of using PCATDs for VFR pilot training has grown steadily due to the emergence of innovative and cost effective PCATD technologies, such as super wide-view high resolution projection (Zahradka, 2017), artificially intelligent aircraft traffic (Vatsim, 2015), and high definition terrain with animated ground vehicles (VLC, 2016).

In 2006, a new pilot qualification was established by the International Civil Aviation Organisation (ICAO, 1993). The Multi Crew Licence (MPL) was a new initiative adopted by the Joint Aviation Authority (JAA) and the European Aviation safety Authority (EASA). The establishment of the MPL was the result of pressure from the aviation industry for better ways to train airline co-pilots and mounting evidence that deficiencies in aircrew teamwork were major contributors to airline accidents (Sheck, 2006). The MPL is designed to develop and enhance the abilities of pilots to fly multi-crew aircraft. In addition, the main philosophy of MPL is to limit trainee exposure to actual flight in non-relevant light aircraft and the bulk of instructional time is transferred to multi-crew flight simulation (ECA, 2014). Using PCATDs for multi-crew flight simulation reduces overall training time and lowers costs for pilot trainees, and flight schools. Under MPL rules, students can also increase the level of self-guided practice of most flight tasks and manoeuvers in PCATDs, thereby improving their skills and proficiency in a cost effective manner (Kozuba & Bondaruk, 2014).

At the commencement of this study, virtually all FTDs used by NZ flight training schools were developed by commercial companies based overseas (Elite, 2016; Frasca, 2015) Local PCATD developers commonly use untested hardware technologies combined with software and hardware interfaces that were developed in-house as there were no commercially available equivalents (Zahradka, 2017). In addition, the production of training documentation for inclusion into the training curriculum is also a challenging task for the PCATD developer (KiwiFlyer, 2012). Although the development and certification of a customised PCATD is a difficult challenge (CAANZ, 2011), flight training can be significantly enhanced with the development and adoption of such cost effective technologies into the flight-training curriculum.

METHOD

DESIGN

Quasi-transfer studies have been used successfully in a number of experiments to test augmented information as an instructional variable for landing (Lintern, Koonce, Kaiser, Morrison, & Taylor, 1997) and for air-to-ground attack (Lintern, Sheppard, Parker, Yates, & Nolan, 1989). They have been used to examine scene detail for out-of-cockpit visual scenes (Lintern & Koonce, 1992), the effect of simulator platform motion (Go et al., 2003) and transfer of training on a vertical motion simulator (Zaal, Schroeder, & Chung, 2015). The advantage of quasi transfer design is that when used with ab-initio pilot trainees it can determine the level of training transfer with minimal interference from the effects of prior flight experience (Taylor, Lintern, & Koonce, 1993). Quasi-transfer of training studies differ from traditional transfer of training studies in that a high fidelity flight simulator rather than an aircraft is used to test both training and transfer tasks. For example, one group would train on a high fidelity flight simulator and the other group would train on an experimental flight simulator. Both groups would then transfer to the high fidelity flight simulator that is a close representation of the real aircraft (McDermott, 2005) for final evaluation. In the current study, participants were first randomly assigned to one of three groups (two experimental groups, and the control group), at which point a pre-test was administered to each group. In the pre-test scenario, the participants completed a standard VFR rejoin procedure on the Frasca TruFlite Flight & Navigational Procedures Trainer (Frasca FNTP), commonly referred to as the Frasca FTD, at a specified aerodrome with a designated aircraft (Figure 1). The accuracy of their performance across a number of flight variables was measured using assessment software installed in the training simulator. Then the independent variable was implemented; that is, group 1 received training on a PCATD (Figure 2) and group 2 received training on the Frasca FTD (the experimental groups), and group 3 received no additional training (control group). Finally, each group of participants was given a post-test, which was identical to the pre-test procedure using the Frasca FTD.

The primary comparisons of interest for each of the eight outcome variables were whether pre-test/post-test difference scores differed by condition, which was assessed by examining the interaction term of a factorial ANOVA. A lack of evidence that FTDs performed better than PCATDs would be taken as evidence that PCATDs provide a useful low cost alternative to the use of FTDs for the procedures tested in this study.

Figure 1. Frasca FTD (Single Engine PA-28) Figure 2. PCATD (Single Engine PA-28)

Participants

Ninety-three pilots participated in this study. They were recruited from the following organisations: a university aviation-training organisation (n = 35); a private sector aviation-training organisation (n = 35); two small aviation training organisations within the local geographic area (n = 10); other aviation organisations (e.g., Air Training Corps) (n = 8); and local educational institutions (n = 5). Participants' flight experience ranged from airline and military trainee pilots (n = 3), pilots who had just completed CPL or PPL certification, ab-initio pilots with less than ten hours of single engine flight time, and potential aviators who had only flown a few trial flights. The mean age of participants was 23.1 years (SD = 8.7, range 16–40). Eighty per cent were aged between 19–25 years old. Fifteen of the participants in the study were female and seventy-eight were male. Of those employed as pilots, participants' occupations in the study included one experienced Boeing 737-800 pilot; two helicopter pilots, two military pilots, and one glider pilot. Sixty percent of participants were ab-initio pilot trainees who had completed less than sixty hours of flight training and had minimal training hours on either the PCATD and/or the Frasca FTD. Thirty percent of participants had completed sixty to two hundred and fifty hours of training up to and including PPL level but also minimal training hours on either the PCATD and/or the Frasca FTD. In addition to undertaking flight training, the flight trainees had completed a wide variety of aviation related subjects that included meteorology, principles of flight, navigation, human factors, and aviation law. The overhead rejoin manoeuver the participants were required to practice and complete on the PCATD and FTD is a reasonably difficult flight control task and requires some flight experience to perform accurately. The pilots purposively chosen for this study had a relatively wide range of flight experience to establish whether transfer of training on the PCATD or FTD was unduly influenced by previous flight experience.

Trainee pilots that belonged to relatively large aviation training organisations (Group 1 & 2) were selected for the study because their FTO has operated a similar model of a Frasca TruFlite FTD. In addition, their practical flight training programs were very similar and their student populations had similar demographics. Candidates from small aviation training organisations Group 3-5 did not have ready access to a PCATD or FTD for training purposes. Therefore, they were invited to travel to a flight-training centre closest to them, where the appropriate simulation devices were located, to participate in the comparative study.

Materials

The primary flight-training device (FTD) used in this study was the Frasca TruFlite Flight & Navigational Procedures Trainer (Frasca, 2015). This device is certified for assessing pilot competency in IFR and VFR flight rules. IFR is defined as flying by reference to instruments in the flight-deck, and navigation is accomplished by reference to electronic signals (FAA, 2008b). VFR procedures is a set of regulations under which a pilot operates an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going .

The TruFlite FTD was configured as a single-engine PA-28 Piper Warrior, as this was the most common aircraft used by the participants in the study, and networked to a PC Based Graphical Instructor Station (GISt). The Frasca TruFlite also had a FAA Level 6 Qualification which requires the simulator to be built to a high level of fidelity (FAA, 2008a). Requirements include an authentic aircraft cockpit, electric flight control loading, and high fidelity visual display system. In this case, Frasca developed their TruVision visual display system with a field of view of 170 degrees for this FTD model (Frasca, 2015).

Virtually all previous transfer of training studies that examined low-fidelity/PC-based simulation used subjective flight instructor ratings to measure flight performance (Talleur, Taylor, Emanuel, Rantanen, & Bradshaw, 2003; Taylor, et al., 1999). Despite well-defined rating criteria and standards, it has been difficult to prevent personal bias or unreliable flight instructor ratings (Roessingh, 2005). The Graphical Instructor Station GISt is a computer-based interface that uses Graphical User Interface (GUI) software to control the Frasca FTD. One of its main functions is data collection and it was developed to assist flight instructors in reviewing a flight student's performance in the FTD. GISt can be used to record and analyse over one hundred flight performance variables. The analysis of flight data generated by GISt is a more objective and accurate measure of VFR task performance. GISt contains a core group of functions and the most important function for this study was the USA National Intercollegiate Flying Association (NIFA) Score Editor. The NIFA Score Editor originated as a program used to measure and compare the performance of pilots as they attempted to fly an established flight pattern. This module records the performance of different pilots—and that of the same pilot at different stages training—with more objectivity than an appraisal by a flight instructor. The program can record the number of errors committed by participants across a number of selected flight variables.

For example, the actual NIFA formula to calculate the number of penalty points for each variable is NIFA Score = Absolute Value (ABS) - (Actual Value-Pattern Value) x Weights per second. A high score (e.g., 20 penalty points per second) represented a high number of errors and a poor performance, and vice versa.

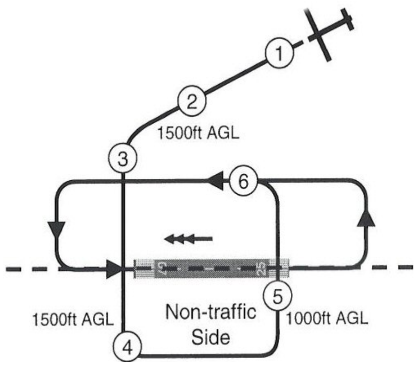
A low cost PCATD system ($NZ 20,000) was developed from off-the-shelf commercial software and hardware (the Frasca FTD used for this comparative study cost approximately $NZ 500,000). The PCATD hardware system included a PC with an Intel Core I7 2.66 GHZ processor as the flight simulation engine, an additional PC with a Core I5-750 processor as the instructor station, coupled with NVIDIA GeForce video cards. Specialised hardware included Precision Flight Controls (Yoke, Throttle Quadrant, and Rudder Pedals) and Go-Flight Radio & Navigation Modules. Software included Windows 7 (32 Bit), Microsoft Flight Simulator Version 9.0 and 10.0, a customised PA-28 (Piper Warrior) Flight Model & Digital Instrument Panel, and customised terrain modules representing local geographic features in the flight training areas. Multiple screens were used for the out-of-cockpit-view. A 35-inch Liquid Crystal Display (LCD) main view screen was combined with two 19-inch LCD side-views. A total horizontal base of 61.72 inches with a 20 inch height (53 pixels per inch) on the main screen, and 9 inch height on the side screens (93 pixels per inch). The display resolution of all three screens was set at 1280x1024 pixels. An additional screen 19-inch LCD was used for the instrument display. Finally, a 19-inch LCD screen was connected to the networked instructor station PC. The utilisation of third party software (Active Camera) provided scan capabilities and snap views, which increased the field of view to 220 degrees (Middleton, 2006). Activation of the software was initiated by a push button situated on the yoke controls. The software allows a number of pre-set views so that moving to different cockpit viewpoints is automated with the push button. Another button on the yoke was programmed to provide a zoom function for the cockpit view. The display system with one front screen and two smaller side screens was designed to replicate the large front view and limited side views of the PA-28 Piper Warrior training aircraft.

The PCATD instructor station used two flight variable recording software packages. The first package, Flight Data Recorder 8.0 (Fltrec) was used to play back recorded flights in Flight Simulator Version 9.0 in real time and rescan flight variables if necessary (Hernandez-Ros, 2012). The second software package was Visor 2000. This software was capable of recording flight variables such as altitude, track, pitch, approach path, and vertical speed, and angle of bank. It could also display these flight variables in a graphical form (Pardo, 2012). The software was flexible and was capable of displaying a binary file produced by the Fltrec utility (Hernandez-Ros, 2012).

Procedure

The current study was designed to establish whether a CAANZ certified FTD was more effective than a low cost PCATD at improving pilot proficiency in the performance of a standard VFR traffic pattern operation (Figure 3). The VFR overhead rejoin procedure evaluated in this study required the utilisation of a FTD or PCATD that could provide a minimum of 120 degrees FOV, (to provide the participants with adequate peripheral views) so that correct entry points and correct spacing could be applied during the procedure. Each participant was then given a briefing on the experimental procedure. In the first stage of the procedure, the participant entered the traffic pattern at a height of no less or no more than 1500 feet AGL (1600 feet AMSL) and a magnetic heading of 160°-170°. The learning transfer that took place was measured to ascertain the effects on task performance by measuring eight dependent flight performance variables while executing the traffic pattern operation. These variables were maintaining correct altitude; maintaining correct attitude; maintaining correct airspeed; overall performance; maintaining correct magnetic heading; implementing procedural turns; intercept and maintain Glide Slope; and implementing an accurate Overhead Rejoin pattern. For the purposes of this study the airfield was deemed to be serviceable, there was no wind, and standard temperature and atmospheric pressure had been set in accordance with ICAO standards (ICAO, 1993). The runway in use was 070°, the circuit was left hand, and there was no traffic on the circuit. The circuit area was defined as the area within a radius of three nautical miles from the airfield reference point.

All participants were pre-tested and post-tested on the Frasca FTD. Participants were randomly allocated to each of the three groups. The participants randomly selected for the PCATD group received training on the PCATD and the remaining participants received training on the FTD. The study protocol is shown in Table 1. The VFR Overhead Rejoin Procedure is used by the pilot to safely join the circuit of controlled and uncontrolled aerodromes (CAANZ, 2014). All participants were given an individual 10-15 minute briefing on the VFR overhead rejoin procedure and a demonstration by a flight instructor on how it was to be completed. This was followed by a 10-15 minute familiarisation period on the TruFlite FTD. The participants were given a demonstration of the various flight controls on the FTD and were shown how the flight performance variables would be recorded on the computer. Then all participants completed the VFR standard overhead rejoin procedure on the FTD. This was the designated pre-test procedure.



Standard Overhead Rejoin Procedures Diagram Key

1. Radio call
2. Track to keep aerodrome on your left (no less than 1500 feet)
3. Determine runway in use: Make all turns in the direction of the circuit
4. Descend on the non-traffic side
5. Cross upwind threshold at circuit altitude
6. Join downwind leg

Figure 3. Diagram of Standard Overhead Rejoin

Table 1. Experimental Procedure

Group	Assignments	Pre Test	Training	Post Test
1	*n* = 31	Familiarisation Lesson / Flight Test in Frasca	Familiarisation Lesson /Three Practice Sessions in PCATD	Flight Test in Frasca TruFlite
2	*n* = 31	Familiarisation Lesson /Flight Test in Frasca	Three Practice Sessions in Frasca TruFlite	Flight Test in Frasca TruFlite
3	*n* = 31	Familiarisation Lesson /Flight Test in Frasca	No Practice Sessions	Flight Test in Frasca TruFlite

The flight was recorded on the GISt and scored using the NIFA module. After the pre-test procedure was completed on the Frasca, Group 1 participants were given a 10-15 minute briefing on the operation of the PCATD followed by a 10-15 minute familiarisation session. Then Group 1 participants practiced the VFR standard overhead rejoin procedure with three 10-15 minute training sessions. Group 2 participants, after completing the Frasca pretest procedure, completed three 10-15 minute training sessions on the Frasca TruFlite FTD. Group 3 (Control Group) participants were pre-tested on the Frasca but did not have any practice sessions on either the PCATD or the FTD. Finally, all the participants were given a short 10-15 minute rest before completing a post-test evaluation of the VFR procedure on the Frasca TruFlite FTD. The experimental procedure was similar to that used in a comparative study of an IFR procedure conducted by McDermott (2005) and Beckman (1998).

A priori power analysis, using the software G*Power (Buchner, Erdfelder, & Lang, 2013), was used to determine that with $a = .05$, a total sample size of $n = 42$ (split between conditions) would be sufficient for experimental power of at least .80, assuming a medium effect size of $f = .25$ for a mixed model ANOVA for the main analysis (i.e., the 3 x 2 ANOVA).

RESULTS

The flight experience variables Total Flight Time, VFR Flight Time, FTD Time, PCATD Time, and Recent Flight Time Mean scores may be inspected in Table 2.

Table 2. Mean Scores (and SDs) for Flight Experience Variables

Experience	Mean Hours	SD
PCATD Time	3.3	21.5
FTD Time	5.4	18.7
Total Flight Time	165	521
VFR Flight Time	151	498
Recent Flight Time	7	10.7

A series of five one-way between subjects ANOVA were used to explore if there were any significant differences in the aviation experience of the participants to suggest that the three groups were not homogenous in terms of aviation experience, which implies that previous aviation flight experience should not confound VFR task performance between the groups on the FTD. The test statistics are shown in Table 3.

Table 3. Tests of Aviation Experience, by Group

Experience	*Df*	*F*	*Sig.*
PCATD Time	2, 90	.173	.84
FTD Time	2, 90	.785	.46
Total Flight Time	2, 90	.568	.57
VFR Flight Time	2, 90	.673	.51
Recent Flight Time	2, 90	.242	.71

The interaction term of a series of eight 3 x 2 mixed model ANOVAs were used to explore if there were statistically significant differences between the Pre-test score and the Post-test score performance between the three groups for each of the eight performance variables.. Analyses were Pitch, Bank, Altitude, Indicated Air Speed, Heading, Total Variable Score (the sum of Pitch, Bank, Alt, IAS, Hdg errors), Glideslope, and Overhead Rejoin Pattern. No significant differences were found between the FTD and the PCATD across all the flight performance variables.

Pitch variable

There was evidence of a statistically significant interaction between training group and pitch performance, $F(2, 90) = 4.191$, $p = .018$, $\eta^2 = .09$, which indicates that the groups did have significantly different changes from Pre-test to Post-test scores. Post hoc analysis (LSD) (Figure 4) indicated that there was significantly less improvement ($p < .05$) in the Pre-test vs. Post-test change score for pitch performance in the control group ($M = -0.15$, $SD = 1.96$), compared to the FTD group ($M = 1.03$, SD = 1.78) or the PCATD group ($M = 1.12$, $SD = 2.05$). There was no significant difference in change score for pitch performance between the PCATD group and the FTD group.

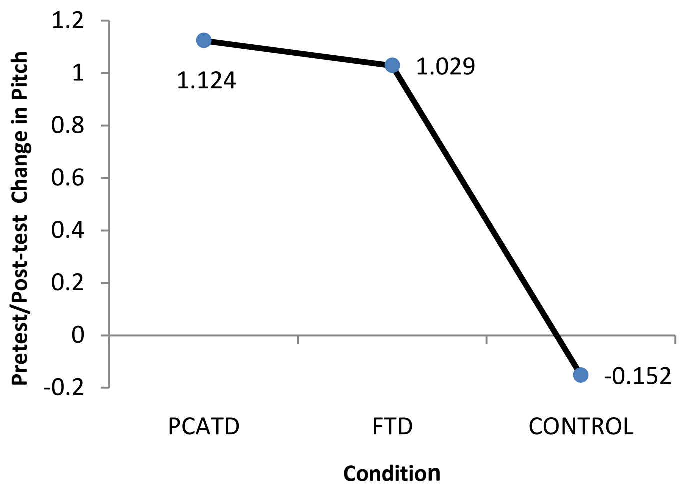


Figure 4. Post Hoc Pitch Change Scores Means Plot

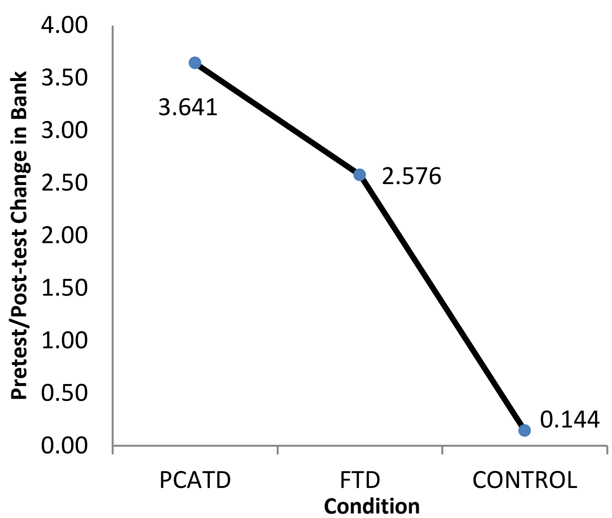


Figure 5. Post Hoc Bank Change Scores Means Plot

Bank variable

There was evidence of a statistically significant interaction between group training and bank performance, $F(2, 90) = 4.814$, $p = .010$, $\eta 2 = .10$, which indicates that the groups did have significantly different changes from Pre to Post-test scores. Post hoc analyses (Figure 5) (LSD) indicated that there was significantly less improvement ($p < .05$) in change score for Bank performance in the control group ($M = 0.14$, $SD = 4.59$) when compared to the FTD group ($M = 2.58$, $SD = 4.48$) and the PCATD group ($M = 3.64$, $SD = 4.57$). There was no significant difference in change score for Bank performance between the PCATD group and the FTD group.

Total variable score

A mixed model ANOVA was conducted to compare three groups of participants on Total Variable Score (combined score of Pitch, Bank, Altitude, IAS, and Heading) performance while completing a VFR Overhead Rejoin Manoeuvre. There was evidence of a statistically significant interaction between group training and Total Variable Score, $F(2, 90) = 3.36$, $p = .039$, $\eta 2 = .07$, which indicates that the groups did have significantly different changes from Pre-test to Post-test scores. Post hoc analyses (LSD) (Figure 6) indicated that there was significantly less improvement ($p < .05$) in Total Variable gain score performance in the control group ($M = -5.33$, $SD = 23.29$) when compared to the FTD group ($M = 18.77$, $SD = 19.71$) and the PCATD group ($M = 16.40$, $SD = 22.23$). There was no significant difference in Total Variable gain score performance between the PCATD group and the FTD group.

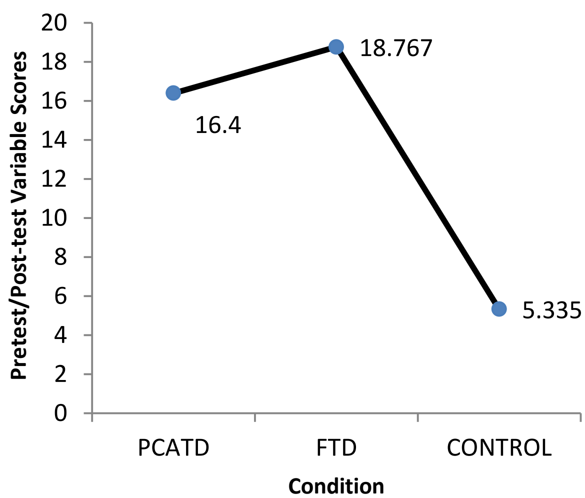


Figure 6: Post Hoc Total Variable Score Means Plot

Altitude variable

There was no evidence of a statistically significant interaction between group training and altitude performance, $F(2, 90) = 1.11$, $p = .333$; that is, there was no significant difference in change score for altitude performance between the PCATD group, FTD group or control group. The interaction plot for this and the following four outcome variables are shown in Figure 7.

Indicated air speed (IAS) variable

There was no evidence of a statistically significant interaction between group training and IAS performance, $F(2, 90) = 1.52$, $p = .224$; that is, there was no significant difference in change score for IAS performance between the PCATD group, FTD group or control group.

Heading variable

There was no evidence of a statistically significant interaction between group training and IAS performance, $F(2, 90) = 1.30$, $p = .277$; that is, there was no significant difference in change score for Heading performance between the PCATD group, FTD group or control group.

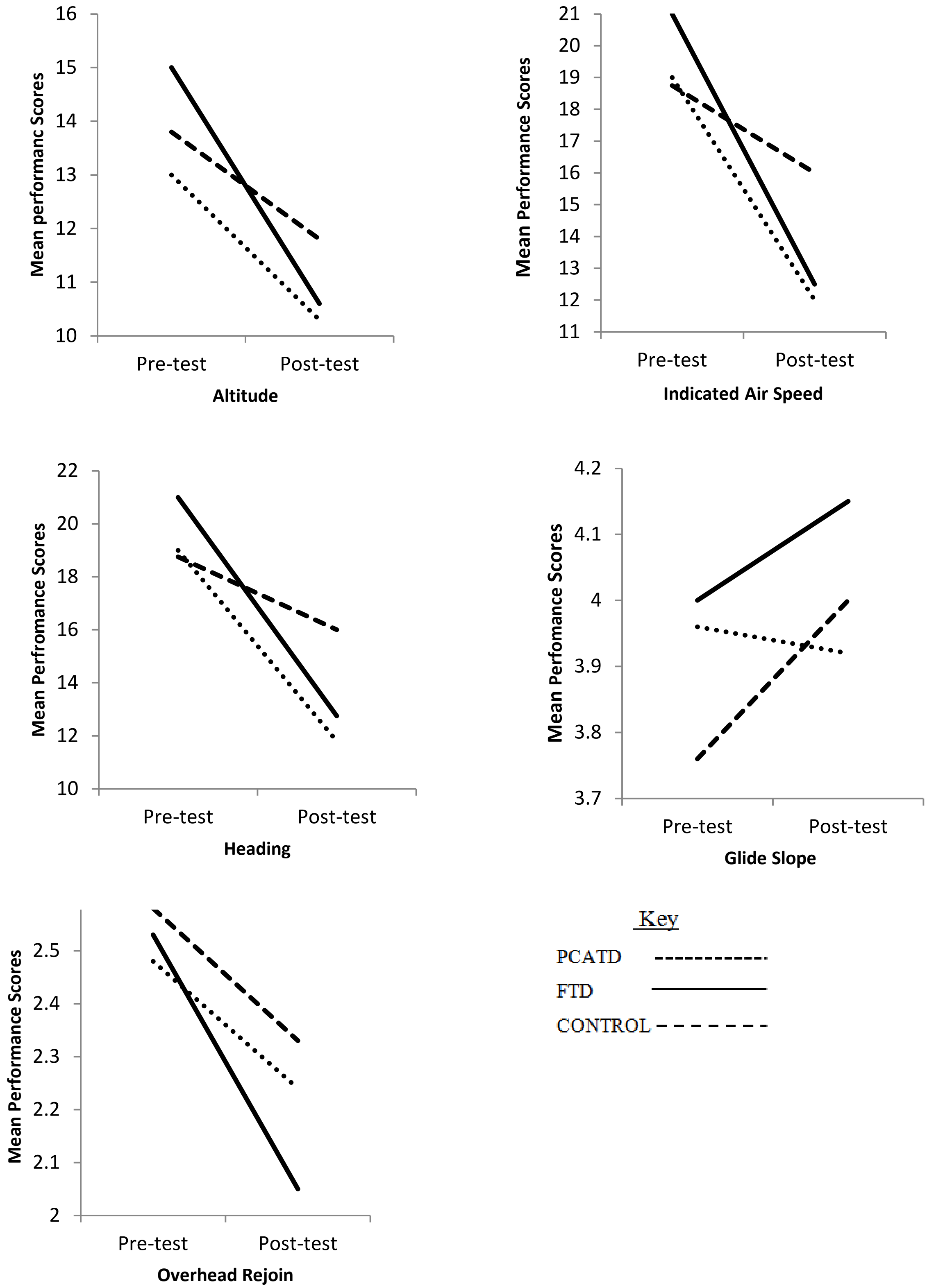


Figure 7. Interaction plots of mean performance scores of condition (PCATD, FTD, Control) by Pretest/Posttest Plots.

Glide slope score

There was no evidence of an interaction between group training and Glide Slope score performance, $F(2, 90) = .297$, $p = .744$; that is there was no significant difference in Glide Slope score performance between the PCATD group and the FTD group.

Overhead rejoin pattern score

There was no evidence of a significant interaction between group training and Glide Slope score performance, $F(2, 90) = .585$, $p = .559$; that is, there was no significant difference in Overhead Rejoin score performance between the PCATD group and the FTD group

Discussion

No overall evidence was found that an FTD performed better than PCATD when used to train pilots to perform a VFR re-join procedure; there was no evidence of a significant difference in Pre-test/post-test change scores across all of the eight variables between the FTD group and the PCATD group. Specifically, while there was strong evidence of the effectiveness of training compared to no training on three variables, there was no evidence of a difference in efficacy of FTD vs. PCATC training. This implies that VFR task training (e.g., Overhead Rejoin Procedure) was just as effective when completed on the low cost PCATD as it was on the certified FTD.

Interestingly, there was no evidence of omnibus differences in performance between the three groups on the variables Heading, Altitude, IAS, Glide slope (GS), and Overhead Rejoin Pattern (ORP). At face value, this suggests that training *per se* on these five outcome variables is ineffective. However, an alternative explanation is that these tasks were simply easier than the three that did show improvement after training (on PCATD and FTD) and that a lack of significant improvement after training was indicative of a ceiling effect. Furthermore, for the variable, Overhead Rejoin Pattern, it is possible that failure to observe an effect may have been due, at least in part, to a lack of sensitivity of the measure; that is, ORP was measured on a five point Likert scale, which may have been insensitive to small differences between groups.

The findings of the current study add to earlier evidence reported by McDermott (2005), who completed a similar quasi transfer study that compared the instrument landing approach performance of 63 pilots randomly assigned to either a PCATD or FTD for training. The FTD trained group was designated as the control group and the PCATD group the treatment group. A pre-test and post-test was conducted on the FTD before and after the training. The results of McDermott's (2005) study found no significant difference in instrument landing approach performance between the group trained on the PCATD and the control group.

A strength of the current study was its use of objective measurement by analysing flight-recording data of FTD and PCATD flight variables, rather than the somewhat more subjective evaluations of flight examiners or instructors. This method provided an unbiased precise measurement of VFR task performance and produced normally distributed data. Only one measurement, the Overhead Rejoin Pattern, was too complex for mathematical analysis and required a categorical assessment by flight instructors.

Few studies were found that used objective measurement in an aircraft or flight simulator instead of subjective evaluation by Subject Matter Experts (SMEs). Roessingh (2005) used objective measurement in the form of special recording equipment installed on the aircraft that recorded twelve flight variables including altitude, IAS, and rates of turn. Only one study was found that combined objective measurement with flight task performance in a PCATD. Smith and Caldwell (2004) used a fixed base F-117 simulator to record flight performance parameters of F-117A pilots undergoing training. Combining flight simulation and objective measurement has only occurred in the last decade as this type of recording technology has only become available on the relatively new models of commercially produced FTDs and PCATDs. New general aviation aircraft with glass cockpits also have flight data recording capability, and flight data for a particular sortie can be easily downloaded from the glass cockpit (i.e., Primary Flight Display or Multi-Function Display). It is hoped that flight data recording, flight data retrieval, and flight data analysis, will become more popular data retrieval tools for research purposes. An objective method that uses simulator-recording technology is cost effective, accurate and can be operated in a strictly controlled environment.

One advantage of the PCATD was that some task procedures were easier to accomplish than in the real aircraft. For example, most participants believed that maintaining airspeed in the FTD and PCATD was easier to do than in the real aircraft. This was due to a number of environmental factors that are strictly controlled in PCATDs, such as lack of low-level turbulence, perfectly performing engines, and stabilised flight instruments. In the aircraft, low-level turbulence, slight surges in engine power, vibration and shake in flight instruments are always omnipresent and can affect pilot performance. In addition, the flight models used in the FTD and PCATD provided a fast response to throttle control and flight control inputs. This enabled the participants to adjust power settings frequently and get rapid feedback as to the effect on flight performance. The participants agreed that this responsive feedback provided effective training, and they thought that the acquired skills would easily transfer effectively to the aircraft. The Intercept and Maintain Glide Slope skill was more problematic. In both the FTD and the PCATD the simulated airport did not have an Instrument Landing System and because it was a VFR exercise the glide slope had to be estimated visually and with reference only to basic flight instruments. Both the PCATD and FTD visual display systems have limitations in terms of depth of field (DOF) and field of view (FOV) compared to aircraft in flight. Both groups of participants struggled to improve this VFR skill and fly consistent approaches in the PCATD and FTD. They indicated that this skill would be the least likely to transfer effectively to the aircraft.

CONCLUSIONS

There were at least three potential limitations to the study reported here. First, although participants were in principle blinded to the experimental manipulation, NZ's aviation industry is small and close-knit; it is therefore possible that participants became aware of the experimental manipulation from meetings outside of the study, and were subsequently affected by their own expectations of the benefit of training. However, these expectations would be mitigated by the objective nature of the measurement. Second, it is possible that there were differences between the two experimental groups on one or more outcome variables, but they were not detected (Type II error). Third, the experiment was implemented over a short period and differences in performance may emerge at some later point.

Two further studies are planned. First, to investigate the effectiveness of a low cost PCATD at improving pilot proficiency in the performance of a standard VFR traffic pattern operation between two pilot trainee groups with different aviation experience levels, training environment, and in different geographical locations. Second, is to compare the effectiveness of a low cost PCATD and a CAANZ certified FTD at training transfer of other VFR task procedures such as forced landing training, forced landing after take-off, and low-level navigation exercises.

This study involved the development and evaluation of a low cost PCATD that could be as effective as a CAANZ certified FTD at training transfer of a VFR task procedure (Overhead Rejoin Manoeuver). The results have added to the limited body of research examining the effectiveness of PCATDs for VFR training. There was no significant difference in performance of a VFR Overhead Rejoin Manoeuver between those participants who trained on a PCATD and those trained on the FTD. In addition, the use of objective measurement tools has contributed to the limited research on how PCATDs with the installation of suitable software can be utilised for the objective evaluation of pilot performance.

References

Alessandro, N. (2008). Transference of PC-based simulation to aviation training: Issues in learning. *Indian Aviation News* Retrieved 10 December 2009, from http://indianaviationnews.net/allimages/AlessandroPaper.pdf

Beckman, W. S. (1998). *A comparison of the effectiveness of PC-based aviation training devices and conventional flight training devices for instrument flight training*. Saint Louis University, St Louis, Missouri.

Buchner, A., Erdfelder, E., & Lang, A. (2013). *G* Power: Statistical power analyses for Windows and Mac*. Retrieved 20 Dec, 2014, from http://www.gpower.hhu.de/en.html

CAANZ. (2011). *Application for accreditation of a new or modified aeroplane flight simulator for approved uses*. (CAA 24119/11), 1-9.

CAANZ. (2014). *Vacating and joining at aerodromes.* Retrieved 10 Oct, 2014, from https://www.caa.govt.nz/fig/circuit-training/vacating-and-joining-at-aerodromes.html

Dennis, K. A., & Harris, D. (1998). Computer-based simulation as an adjunct to ab initio flight training. *International Journal of Aviation Psychology, 8*(3), 261-276.

Eagle Flight Training. (2015). *DA42 for instrument flight training*. Retrieved 4 Jul, 2016, from http://www.aviationschool.co.nz/da42-for-instrument-flight-training/

EASA. (2016). *Certification specifications for aeroplane flight simulation training devices*. Retrieved 6 Dec, 2016, from https://www.easa.europa.eu/certification-specifications/cs-fstda-aeroplane-flight-simulation-training-devices

ECA. (2014). *7 years of MPL - 7 things learnt*. Retrieved 12 Feb, 2015, from http://www.eurocockpit.be/stories/20140110/7-years-of-mpl-7-things-learnt

Elite. (2016). *Elite IGate Series Simulator I*. Retrieved 6 December, 2016, from http://flyelite.com/igate-series-simulator/

FAA. (2008a). *FAA approval of basic aviation training devices (BATD) and advanced aviation training devices (AATD* (Vol. Advisory Circular No. AC61-136, 14/07/08). Washington DC: U.S. Department Of Transportation, Federal Aviation Administration

FAA. (2008b). *Instrument flight rules (defined). Instrument flying handbook*. Oklahoma City, OK: U.S. Department Of Transportation, Federal Aviation Administration. .

Flight1 Aviation Technologies. (2016). *The many benefits of PC-based flight simulation*. Retrieved 20 Nov, 2016 from http://www.flight1tech.com/whysimulation.aspx

Frasca. (2015). *Frasca FTD portfolio*. Retrieved 3 May 2012, from http://www.frasca.com/index.php/fixed-wing/portfolio

Go, T., Burki-Cohen, J., Chung, W. W., Schroeder, J. A., Saillant, G., Jacobs, S., & Longridge, T. (2003). *The effects of enhanced hexapod motion on airline pilot recurrent training & evaluation.* Paper presented at the AIAA Modeling and Simulation Technologies Conference and Exhibit, Austin, Texas.

Hernandez-Ros, I. (2012). *Announcing FLTREC.DLL Version 7.0.5*. Retrieved 10 September, 2012, from http://www.flightsim.com/vbfs/content.php?2787-Announcing-FLTRECDLL-Version-705

ICAO. (1993). *Manual of the ICAO standard atmosphere (extended to 80 kilometres (262 500 feet))* (3rd ed.). Montreal,Canada: International Civil Aviation Organisation.

KiwiFlyer. (2012). CAA approved helicopter simultation at HFT. *KiwiFlyer* Retrieved 8 Dec 2012, from http://www.kiwiflyer.co.nz/KiwiFlyer-Issue-20-HeliSim-HFT.pdf

Koonce, J. M., & Bramble, W. J. (1998). Personal computer-based flight training devices. *International Journal of Aviation Psychology, 8*(3), 277-292.

Kozuba, J., & Bondaruk, A. (2014). *Flight simulator as an essential device supporting the process of shaping pilot's situational awareness.* Paper presented at the International Conference of Scientific Paper AFASES, Brasow, Rumania.

Leland, R., Rogers, R. O., Boquet, A., & Glaser, S. (2009). *An experiment to evaluate transfer of low-cost simulator-based airplane upset-recovery training.* Washington, DC: Office of Aerospace Medicine, FAA.

Lintern, G., & Koonce, J. M. (1992). Visual augmentation and scene detail effects in flight training. *International Journal of Aviation Psychology, 2,* 281-301.

Lintern, G., Koonce, J. M., Kaiser, R. H., Morrison, G. A., & Taylor, H. L. (1997). Transfer and quasi-transfer effects of scene detail and visual augmentation in landing training. *International Journal of Aviation Psychology, 7*(2), 149-169.

Lintern, G., Sheppard, D. J., Parker, D. L., Yates, K. E., & Nolan, M. D. (1989). Simulator design and instructional features for air-to-ground attack: A transfer study human factors. *The Journal of the Human Factors and Ergonomics Society, 31*(1), 87-99.

Massey News. (2007). *Maharey hails aviation school's new flight simulator.* Retrieved 20 Mar, 2007 from http://www.massey.ac.nz/massey/about-massey/news/article.cfm?mnarticle=maharey-hails-aviation-schools-new-flight-simulator-16-03-2007

Massey News. (2008). *Low cost flight training simulators to aid pilot training.* Massey News Retrieved 30 Sep, 2008, from http://www.massey.ac.nz/massey/about-massey/news/article.cfm?mnarticle=low-cost-flight-training-simulators-to-aid-pilot-training-24-09-2008

McDermott, J. T. (2005). *A comparison of the effectiveness of a personal computer-based aircraft training device and a flight training device at improving pilot instrument proficiency: A case study in leading regulatory change in aviation education.* Bowling Green State University. United States -- Ohio.

Middleton, P. (2006). *Active Camera 2004. AVSIM commercial utility review.* Retrieved 10 October 2012, from http://www.avsim.com/pages/1104/acam/ActiveCamera.htm

Pardo, G. (2012). *Visor 2000*. Retrieved 12 November 2012, from http://www.tradewind.org/oldhangar/util.html

Redbird. (2016). *Redbird simulators.* Retrieved 2 Feb, 2016, from http://simulators.redbirdflight.com/

Roessingh, J. J. M. (2005). Transfer of manual flying skills from PC-based simulation to actual flight - Comparison of in-flight measured data and instructor ratings. *International Journal of Aviation Psychology, 15*(1), 67-90.

Sheck, M. F. (2006). *Multi crew licence: How many hours of flight training does it take to become an airline pilot?* Masters of Aeronautical Science [Unpublished], Embry-Riddle Aeronautical University, Spangdahlem, Germany

Smith, J. K., & Caldwell, J. A. (2004). *Methodology for evaluating the simulator flight performance of pilots.* Retrieved 11 November 2014, from https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/ADA429740.xhtml

Stewart, J. E., II,. Dohme, J. A., & Nullmeyer, R. T. (2002). US Army initial entry rotary-wing transfer of training research. *International Journal of Aviation Psychology, 12*(4), 359-375.

Talleur, D. A., Taylor, H. L., Emanuel, T. W., Rantanen, E., & Bradshaw, G. L. (2003). Personal computer aviation training devices: Their effectiveness for maintaining instrument currency. *International Journal of Aviation Psychology, 13*(4), 387-399.

Taylor, H. L., Lintern, G., Hulin, C. L., Talleur, D. A., Emanuel, T. W., & Phillips, S. I. (1999). Transfer of training effectiveness of a personal computer aviation training device. *The International Journal of Aviation Psychology, 9*(4), 319-335.

Taylor, H. L., Lintern, G., & Koonce, J. M. (1993). Quasi-transfer as a predictor of transfer from simulator to airplane. *The Journal of General Psychology, 120*(3), 257-276.

Taylor, H. L., Talleur, D. A., Emanuel, T. W. J., Rantanen, E. M., Bradshaw, G. L., & Phillips, S. I. (2003). *Incremental training effectiveness of personal computers used for instrument training.* Paper presented at the 12th International Symposium on Aviation Psychology, Dayton Ohio.

Vatsim. (2015). *VATSIM virtual air traffic network.* Retrieved 10 Jul, 2015, from http://www.vatsim.net/about-vatsim/

VLC. (2016). *Vector land class.* Retrieved 12 Jun, 2016, from http://www.vectorlandclass.co.nz/

Williams, B. (2006). *Microsoft flight simulator as a training aid.* Newcastle, WA: Aviation Supplies & Academics Inc.

Wu, L. N., & Sun, Y. P. (2014). Development of a low-cost flight simulation training device for research and education. In C. Springer (Series Ed.) C. C. Juang J., Yang CF. (Ed.), *Proceedings of the 2nd International Conference on Intelligent Technologies and Engineering Systems*

Yeo, M. (2016). A new approach to ADF pilot training. *Asia-Pacific Defence Reporter, 42*(5), 28-30.

Zaal, P. M. T., Schroeder, J. A., & Chung, W. W. (2015). Transfer of training on the vertical motion simulator. *Journal of Aircraft, 52*(6), 1971-1984.

Zahradka, O. (2017). *SimPit Technologies*. Retrieved 16 Jan, 2017, from http://www.simpit.co.nz/index.php/features-2/projection-display-solutions/simpit-270-centurion

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