ASSESSING AND IMPROVING INTER-RATER AND REFERENT-RATER AGREEMENT OF PILOT PERFORMANCE EVALUATION

by

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LIST OF ABBREVIATIONS

AQP – Advanced Qualification Program

ATC – Air Traffic Control

ATP – Airline Transport Pilot

BOT – Behavioral-Observation Training

CFI – Certified Flight Instructor

CRM – Crew Resource Management

DV – Dependent Variable

FAA – Federal Aviation Administration

FAR – Federal Aviation Regulations

FOR – Frame-of-Reference Training

FTD – Flight Training Device

F/O – First Officer

HRPP – Human Research Protection Program

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

ICC – Intra-Class Correlation

ID – Identification

IRA – Inter-Rater Agreement

IRB – Institutional Review Board

IRR – Inter-Rater Reliability

IV – Independent Variable

I/E – Instructor/Evaluator

MAD – Mean Absolute Deviation

MAPP – Model for Assessing Pilots' Performance

NOTECHS – Non-Technical Skills of Crew Members

PC – Personal Computer

PDT – Performance-Dimension Training

PIC – Pilot-in-Command

PTS – Practical Test Standards

QRH – Quick Reference Handbook

RET – Rater Error Training

RRA – Referent-Rater Agreement

RRR – Referent-Rater Reliability

SIC – Second-in-Command

SME – Subject Matter Expert

SOP – Standard Operating Procedures

ABSTRACT

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The Federal Aviation Administration (FAA) has been promoting Advanced Qualification Program (AQP) for pilot training and checking at Federal Aviation Regulations (FAR) Part 121 and Part 135 air carriers. Regarding pilot performance evaluation, instructors and evaluators assign scores to a student based on specific grading standards. To ensure the best possible quality of training and the highest level of safety, it is vital for different instructors and evaluators to grade students based on the same standard. Therefore, inter-rater and referent-rater agreement are paramount in calibrating the performance evaluation among different instructors and evaluators. This study was designed to test whether a focused workshop could increase the level of inter-rater and referent-rater agreement. A pre-test post-test control group experiment was conducted on a total of 29 Certified Flight Instructors (CFIs) at Purdue University. Participants were asked to watch several pre-scripted video flight scenarios recorded in an Embraer Phenom 100 FTD and give grades to the student pilots in the videos. After a rater training workshop that consisted of Behavior-Observation Training, Performance-Dimension Training, and Frame-of-Reference Training, participants in the treatment group were able to achieve a significantly higher level of inter-rater and referent-rater agreement.

CHAPTER 1. INTRODUCTION

This chapter provides an overview of the study by presenting a background of the problem area. In addition, the research questions, significance, assumptions, limitations, and delimitations are discussed in this chapter.

1.1 Background

According to the Boeing Company (2018), over the next twenty years from 2018 to 2037, there will be a demand of 790,000 pilots around the globe, including 261,000 in Asia, 206,000 in North America, 146,000 in Europe, 64,000 in the Middle East, 57,000 in Latin America, 29,000 in Africa and 27,000 in Russia/Central Asia. This demand cannot be fulfilled without the support from pilot training organizations, such as universities, flight schools and airline training departments. Modern data-driven technology has enabled more advanced methods of pilot training. For instance, the Advanced Qualification Program (AQP), introduced by the Federal Aviation Administration (FAA) in the 1990s, allowed Federal Aviation Regulations (FAR) Part 121 and Part 135 Air Carriers to develop aviation training programs utilizing the newest innovations in training techniques (FAA, 2017). Instead of "satisfactory or unsatisfactory" on a checkride (FAA, 2017), students are evaluated by instructors based on a grading standard for each flight event throughout their training. Also, many FAR Part 61 and Part 141 regulated flight schools and collegiate aviation programs require instructors and evaluators to give grades to students as part of the students' performance records.

The accuracy of instructors and evaluators in grading is critical to a student's success in training. Without proper standardization and calibration, different instructors and evaluators may assign conflicting scores to the same flight event conducted by the same crew, resulting in low

inter-rater agreement (IRA) and/or referent-rater agreement (RRA). This study was designed to test whether a rater training workshop can potentially increase the level of inter-rater and referent-rater agreement.

1.2 Research Questions

This study was designed to answer the following question:

- Can utilization of a focused workshop significantly affect rater agreement of pilot performance evaluation conducted by instructors and evaluators (i.e., raters)?

Based on the research question, the following sub-questions were also addressed in this study:

- After receiving the training, is there a significant increase in the level of agreement among different raters?
- After receiving the training, is there a significant increase in the level of agreement between the raters and the referent standard?

1.3 Significance

Safety is always the first priority in aviation, and pilots are ultimately responsible for the safe operations of an aircraft. It is crucial to ensure pilots are well educated in technical and non-technical aspects of operation. Examples of technical skills include takeoff and landing, navigation and knowledge such as aircraft systems (Mavin & Dall'Alba, 2010). Examples of non-technical skills include "co-operation, leadership and management skills, situation awareness and decision making" (Flin et al., 2003, p. 98). Instructors and evaluators are responsible for providing high-quality training to pilots. High-quality training could not be achieved without adequately trained instructors who have specialized technical expertise and are

familiar with the grading standard. Having a high level of inter-rater and referent-rater agreement could not only improve the overall quality of pilot training, but also reduce the training time and cost for air carriers. Well trained pilots could contribute to a safer aviation industry. Therefore, it is essential to address inter-rater and referent-rater agreement issues for instructors and evaluators in aviation.

1.4 Assumptions

The assumptions of this study were as follows:

1. Participants held the appropriate qualifications and requirements to participate.
2. Participants were familiar with the Standard Operating Procedures (SOP) of the Embraer Phenom 100 aircraft.
3. Participants provided their responses in an honest manner.
4. Participants completed the tests independently, and there was no participant crosstalk during the experiment.

1.5 Limitations

The limitations of this study were as follows:

1. The sample size was limited to candidates who held a Certified Flight Instructor (CFI) certificate and were completing or have completed AT395 Turbine Aircraft Simulation Lab Course at Purdue University.
2. Participants had different backgrounds and experience in flight instruction and evaluation.
3. Participants had different levels of experience in the operations of Embraer Phenom 100 aircraft.

1.6 Delimitations

The delimitations of this study were as follows:

1. The Embraer Phenom 100 was the only aircraft type used in this study.
2. The video recording was conducted in a FAA Level 6 Flight Training Device (FTD), not in the real aircraft.
3. Participants issued a grade on a 4-point scale for each pre-scripted video scenario.
4. No actual student grades were involved in this study.
5. Only the pilot flying in the left seat was graded by the participants.
6. Only a certain number of selected scenario events were evaluated by the participants, and each event scenario was independent from each other.

1.7 Summary

This chapter provided the background, significance, research questions, assumptions, limitations, and delimitations for this study.

CHAPTER 2. REVIEW OF LITERATURE

This chapter provides a literature review on the problems of pilot performance evaluation, inter-rater agreement (IRA), referent-rater agreement (RRA), rater training, and the determination of training effectiveness.

2.1 Importance of Rater Agreement

It is essential to establish a high level of agreement on assessments conducted by instructors and evaluators in aviation. By assessing IRA, researchers are able to quantify the degree of agreement among different raters who make independent judgments on the same subject (Hallgren, 2012). High IRA can lead to transparent and traceable ratings, thus enhancing the training quality (Gontar & Hoermann, 2015). If instructors and evaluators do not agree with each other's assessment and are not grading based on the same standard, performance ratings become more subjective and instructor-dependent. A low IRA would deliver negative consequences for pilots as well as air carriers. If assessors are overly strict in their ratings, the pass rate will become extremely low, which will result in additional training costs for the air carrier as well as negative effects on an applicant's pilot and career record. If assessors become too lenient on their ratings, sub-proficient pilots may be allowed to work on the line, which will create adverse impacts to aviation safety.

A good evaluator has a sensible understanding of performance standards and can apply the standards in a fair manner among different crews (Hamman, Beaubien, & Holt, 1999). Good evaluators could not only improve the training quality for students, but also improve the level of safety and decrease the cost of training. Therefore, the goal of IRA/RRA training is to let assessors become "good evaluators".

2.2 The Process of Assessing Students

To understand the reasons behind low IRA/RRA, it is vital to understand the process of how instructors and evaluators give grades to a student. Baker and Dismukes (2002) developed a framework for understanding the process of pilot performance assessment. The framework consists of three critical activities: The first activity is the observation of the crew's behaviors. The second action is the evaluation of both technical and non-technical performance concerning their effectiveness. The third activity is to weigh the results of this evaluation process, assign respective scores, and record them on the grading sheet (Baker & Dismukes, 2002).

Roth (2015) described the typical process of assigning grades. Most evaluators used the documentary method to interpret pilot performance. Flight examiners tended to construct narrative descriptions first, and then made the judgements based on the recorded notes. The examiners looked for multiple supporting observations as evidence to idealize the underlying issue that caused the problem (Roth, 2015).

2.3 Rater Agreement and Rater Reliability

In a number of research studies, the terms "agreement" and "reliability" have been used interchangeably (Kottner, Gajewski & Streiner, 2011; Gisev, Bell & Chen, 2013). The boundaries between the concepts of "agreement" and "reliability" were not clear, even among experts (Santos, Bernardes & Ayres-de-Campos, 2011). Kottner and Streiner (2011) claimed that conceptual differences exist between "agreement" and "reliability". The term "agreement" represents the absolute degree of measurement error. The term "reliability" represents the variability among scores of the different raters. Inter-rater agreement aims to measure if raters assign the exact same score for each item, while inter-rater reliability (IRR) aims to measure if raters distinguish different items consistently on the same measurement scale (Gisev, Bell &

Chen, 2013). In other words, IRR is focused on the relative consistency between judges, while IRA is focused on absolute consensus (LeBreton & Senter, 2008). De Vet, Terwee, Knol and Bouter (2006) argued that agreement parameters were more stable over different population samples, compared to reliability parameters.

2.4 Reasons for Low IRA/IRR

Weber, Roth, Mavin, and Dekker (2013) conducted qualitative research on six captains working for the same airline. The captains formed in three pairs and were asked to critique two videotaped scenarios. Results showed that two pairs of captains decided to fail the videotaped crew, while one pair decided to pass the videotaped crew. Participants identified different crew performance issues in the scenarios, as only 17% to 33% of the problems were simultaneously addressed by all three pairs. Results showed considerable difference among the assessments from different raters (Weber et al., 2013).

Based on the assessment process, there are several reasons that may lead to low IRA/IRR. The first issue occurs during the "behavior observation" stage (Roth, 2015). Instructors may miss one or several key points during the observation of the crew's performance. For example, in the study conducted by Weber (2016), the captain ordered an emergency evacuation while the turboprop engine on one side was still spinning. Only 4 out of 18 assessor pairs identified this behavior, and all assessor pairs who identified this behavior failed the crew. Raters might be distracted and miss the mistake while being saturated with other tasks, such as acting as Air Traffic Control (ATC), setting up the simulator, or writing down notes. In a different case, raters simply ignored the crew's behavior because they were not aware of the importance of this behavior. It is impossible for instructors and evaluators to observe and note every single detail.

In short, effective behavioral observation training is essential for raters to identify and record the key points.

Even if all assessors identify the same behaviors, problems may also occur during the evaluation stage, that would lead to IRA/IRR issues. Weber et al. (2013) found out there were several occasions when the assessor pairs recognized the same problem but gave different scores. Moreover, there were several occasions when the raters identified different issues but arrived at the same rating. Assessors may be unfamiliar with the grading standard or grading sheet, which may result in incorrect ratings for the event. For example, Hamman et al. (1999) identified a common group of assessors called the "Midline Evaluators". This group of evaluators tended to give more "3" (Standard Performance) ratings on a 4-point scale. The authors cited that the rater's unfamiliarity with the grading criteria could be one of the reasons that they tended to give "standard" scores (Hamman et al., 1999).

Furthermore, assessors may be comparing the student's performance with other students instead of comparing with the standard. Some raters may be comparing the student's current performance with the same student's past performance. To prevent this issue, raters should be adequately trained to evaluate students based on the same, clearly established performance standard. Without a grading standard, some instructors may think the behavior is acceptable, while other instructors may feel the same behavior is unsatisfactory.

The other reason for low IRA/IRR is subjective bias. Flight examiners develop a general sense of proficiency of a pilot in the early stages of the evaluation (Roth, 2015). If a flight examiner has a negative feeling of the student at the beginning, the examiner tends to look for evidence to support a low score throughout the evaluation. In this case, the examiner is no longer grading students based on the performance standards.

The difference in the total amount of evaluation experience may also play an important role. More experienced instructors may be able to evaluate students more effectively due to their familiarity with different scenarios, as well as proficiency in identifying and gauging the importance of errors in operation. Roth (2015) identified that more experienced flight examiners tended to use the overall assessment documentary sense to determine whether a pilot who is performing at the borderline would pass or not. In comparison, junior flight examiners devoted a lot of energy on small errors, rather than providing overall assessments.

Weber et al. (2013) also noted that care should be taken when assessing IRR, as a high IRR may not indicate that raters had the same observations. To find out if evaluators genuinely agree with one another, it is necessary to identify the reasons behind raters' judgments.

2.5 Studies on IRA/IRR

Inter-rater agreement and reliability issues are often studied in disciplines that require evaluators to assign subjective ratings to the performance of a candidate. For example, the performance of flight crew, athletes, students, and conditions of patients are often assessed by evaluators, and IRA/IRR studies are often conducted in these areas.

There are several different goals pursued in the studies of IRA/IRR. Some studies utilized IRA/IRR to examine if a testing instrument or assessment method would work well (Ergai et al., 2016; Kelly, 2005; Lindeman, Libkuman, King, & Kruse, 2000; Mulcahey et al., 2011). Other studies tried to determine if dedicated training could improve IRA/IRR (Jackson, Atkins, Fletcher, & Stillman, 2005; Lin et al., 2013; Sattler, McKnight, Naney, & Mathis, 2015). Likewise, some studies attempted to examine both rater training as well as different testing instruments (Brannick, Prince, & Salas, 2002; Gontar & Hoermann, 2015; Holt, Hansberger, & Boehm-Davis, 2002).

The analytical methods varied widely, from utilizing the "percentage of agreement" to conducting complex variance calculations. More than 15 different methods to evaluate IRA/IRR were used across the studies investigated in the review of literature. As part of an ongoing research, there is not a "best" method to measure IRA/IRR. Most of the studies reported results of more than one type of analysis.

As an example, in the aviation industry, Smith, Niemczyk, and McCurry (2008) conducted an IRR analysis on four flight instructors at a flight school. Researchers videotaped the performance of 10 different students flying the same flight pattern in a simulator, and four instructors were asked to grade the performance of these students. Results showed that the IRR was low based on the Cohen's Kappa Coefficient. However, researchers identified that one of the instructors caused a significant decrease in IRR. Consequently, removing scores from this instructor improved the IRR.

Similar to the aviation industry, IRA/IRR has shown to be an equally significant issue in academic literature. Nicolai, Schmal and Schuster (2015) conducted a meta-analysis of the IRA issues regarding journal peer review in the field of academia. Results showed that rater agreement among the reviewers of several management journals was low. The authors further reviewed several chemistry and physics journals and revealed that five out of six journals had substantial reviewer variance.

Subjective judgments are also common in sports. Fort-Vanmeerhaeghe, Montalvo, Lloyd, Read and Myer (2017) conducted research on the scoring system of the Tuck Jump Assessment, a common test for evaluating sport technique as well as in injury screening. Two raters evaluated 24 volleyball athletes and assigned scores across ten different criteria. Results showed excellent IRA/IRR with a 92.1% agreement and an Intra-Class Correlation (ICC) coefficient of 0.94.

2.6 Referent-Rater Agreement/Referent-Rater Reliability

Referent-rater reliability (RRR) resembles the level of agreement between instructor ratings and a standard or referent (Transport Canada, 2007). In the aviation industry, the referent score is called the "Gold Standard" (Baker & Dismukes, 2002).

Goldsmith and Johnson (2002) argued that RRA/RRR could be a better metric than IRA/IRR because RRA/RRR has more accurate training implications and can be used to measure an evaluator's grading ability. RRA/RRR has three crucial training implications (Holt, Johnson, & Goldsmith, 1997): First, a high RRA/RRR implies a high IRA/IRR. If all raters are assigning the same scores with the gold standard, the IRA/IRR would be high as well. In contrast, a high IRA/IRR may not indicate a high RRA/RRR. Second, the referent score provides a basis for comparing the distribution of actual evaluator scores. Instructors and evaluators could be trained to match the distribution of referent ratings, such as the mean, skewness and variance of their grades. Third, the utilization of RRA/RRR could eliminate the problem of the incorrect group norm. By measuring RRA/RRR, evaluators can be trained toward the referent standard instead of an incorrect group standard. The main disadvantage of training based on RRA/RRR is the extra time and resources needed to construct the referent. The referent must have a high level of precision, as a wrong referent could render the entire training ineffective (Holt, Johnson, & Goldsmith, 1997).

2.6.1 Determining the Referent Standard

To effectively utilize RRA/RRR training, Goldsmith and Johnson (2002) recommended the referent grade, or the gold standard, to be established by a board of subject matter experts (SMEs) or supervisory level evaluators. The SMEs would independently evaluate the scenarios and then discuss their agreements/disagreements as a group. If significant disagreement occurs

among SMEs, and the conflict could not be resolved, it may indicate: "(a) the relevant behavior is not clearly represented in the video, (b) the performance item is not clearly stated on the grade sheet, or (c) the link between the item and the appropriate qualification standard is not clearly defined" (Goldsmith and Johnson, 2002, p. 236).

Beaudin-Seiler and Seiler (2015) used a similar method to determine gold standards, as a committee consisting of the program manager and flight faculty members formed a board of SMEs. The SMEs independently graded the video scenarios and then collaborated to discuss any agreement or disagreement. After the review and discussion, the SMEs established the gold standard.

Baker and Dismukes (2002) recommended that the gold standards criteria could be set up for both instructor training and instructor testing. For example, only instructors who provide grades that closely reflect the gold standards (within a set number of deviations) could be certified to conduct student performance evaluation. A low RRA/RRR indicates that additional training is required to ensure that the evaluator can provide scores consistent with the gold standard.

2.7 Types of Rater Training Design

There are two primary goals for rater training in aviation (Brannick et al., 2002): The first goal is to correctly evaluate and document the quality of students' performance; the second goal is to effectively provide debrief and feedback to the students for future performance improvement.

The design of rater training is crucial to the achievement of the outcomes above. Several different training approaches (treatments) were investigated by Holt et al. (2002) and Feldman, Lazzara, Vanderbilt, & DiazGranados (2012): Rater-Error Training (RET), Frame-of-Reference

Training (FOR), and Performance-Dimension Training (PDT). Additionally, Behavioral-Observation Training (BOT) could be conducted to enhance the observational skills of the instructors and evaluators, so they can correctly identify all the problems and mistakes made by students (Weber et al., 2016).

Even though Woehr and Huffcutt (1994) discovered that RET may not be the best method of training raters, this type of training was still widely used. The goal of RET is to provide detailed feedback to individual instructors on their grading differences within the whole group.

FOR training, according to Woehr and Huffcutt (1994), is a better method of rater training. FOR training aims to train evaluators to a common frame-of-reference. A gold standard is established for each event and may include the descriptions of behaviors that contributed to the specific score. The rater's grading needs to be consistently compared to that of the referent (Holt, Johnson, & Goldsmith, 1997). Extra training could be devoted to the low-agreement grading items between individual evaluations and the gold standard. Baker and Dismukes (2002) claimed that FOR training was the most effective training method to improve the accuracy of ratings. Reinforcing this conclusion, experiments conducted by Gorman and Rentsch (2009) showed that FOR-trained participants graded significantly more accurately compared to the control group. However, Cook, Dupras, Beckman, Thomas, & Pankratz (2009) argued that FOR training may not be as effective in some scenarios because the referent is often case-specific and cannot be generalized.

Roch, Woehr, Mishra, and Kieszczynska (2012) conducted a meta-analysis on FOR training studies. More than 90% of the research studies utilized the following components: a gold standard based on ratings by SMEs; a presentation of specific behaviors that correspond to their

respective performance dimensions; and practice grading based on written and videotaped behaviors (Roch et al., 2012).

PDT aims to ensure the raters' familiarity with grading scales (Woehr & Huffcutt, 1994). Raters must be adequately trained to recognize the appropriate behaviors and be able to associate them with the dimension targeted (Feldman et al., 2013). For example, if raters are unfamiliar with the grading dimensions of an "A" or a "B" performance, they may face difficulty in determining which grade to give to a well-performing student who made several minor errors. PDT allows instructors and evaluators to recognize the specific skills or competencies for each performance dimension.

On the other hand, Weber, Roth, Mavin, and Dekker (2014) recommended BOT to improve the observation skills of an assessor. Raters cannot provide the correct grades unless they are able to observe and identify all critical behaviors. BOT should consist of two elements (Woehr & Huffcutt, 1994): First, the techniques on how to observe and record a student's behavior, such as note-taking methods. Second, systematic observational errors need to be recognized and discussed. For example, contamination from previous observations and over-reliance on a single source of information are common observational errors (Woehr & Huffcutt, 1994). According to Baker and Dismukes (2002), BOT is a very effective training strategy to improve observational accuracy.

There are several other recommendations for rater training design. The International Air Transport Association (IATA, 2013) recommended that "IRR training should be presented as a group process beginning with an overview of IRR, followed by the critical nature of crew assessment, the IRR measures, the grade sheet, rating scales, and examples of the criteria for each point on the scale" (p. 24). Goldsmith and Johnson (2002) stated that the rater calibrating

session could be carried out for individual evaluators instead of a group of evaluators, thus ensuring greater flexibility and more specific feedback.

2.7.1 Typical Process of Rater Training

In the study by Holt et al. (2002), the rater training delivery consisted of four steps: "(a) developing the metrics and visualizations for measuring reliability, (b) preparing materials before the workshop, (c) delivery of the training program in a workshop setting, and (d) development of postsession summary feedback" (p. 311).

Regarding the basic elements of a rater training workshop, Mulqueen, Baker and Dismukes (2002) included the following components: a grading process overview, a review of the grading sheets, and an exercise on grading tasks. The first two elements were achieved through in-class lecture, discussion and demonstration. During the grading task exercise, participants were asked to watch and grade several video scenarios. The results were analyzed by researchers and fed back to the participants. Discussion of the results was conducted to further calibrate the raters. Finally, participants graded the performance of additional video scenarios to determine the level of IRA/IRR after training, and further issues were discussed (Mulqueen et al., 2002).

Mavin, Roth, and Dekker (2012) utilized a similar method for rater training, with some slight differences among captains, first officers and flight examiners. All captains and first officers went through a training course that lasted one day, while the flight examiners went through a two-day training course. The first part of the course was a PowerPoint presentation describing the assessment model, including review of the assessment form and the theoretical concepts of each performance dimension. In the afternoon, participants were asked to grade three video scenarios independently and discussed the results of their assessments. For the examiners,

a discussion of briefing philosophy and a training course on briefing technique was conducted on the second day (Mavin et al., 2012).

It is essential to provide training on the assessment model. The training conducted by Weber (2016) included PowerPoint presentations as well as discussion sessions, to familiarize participants with the assessment model. The grading sheet was explained in detail, including the assessment categories and descriptions of the performance grading scale. The theoretical concepts of decision making and situational awareness were also discussed as part of the training. After the presentation and discussion, participants were asked to grade at least three different video scenarios using the assessment model (Weber, 2016). Similarly, Flin et al. (2003) addressed the training requirements for an assessment model. The training needs to be focused on the understanding of assessment methodology, the specific use of grading scales, and should include a rater judgment calibration process with debriefings. The authors recommended the length of training to be two days or longer.

In the training program developed by Holt et al. (2002), both RET and FOR training were utilized. Also, the training program used the problem-solving process to tackle deficiencies in IRR. Participants were asked to give grades to sample video scenarios. Scores were analyzed by the researchers and feedback was provided. This training lasted approximately one day.

Brannick et al. (2002) organized a three-day training course for instructors. In comparison, PDT and BOT were utilized, with a focus of crew coordination. Most of the three-day session was spent on watching videotapes, practicing observations, as well as discussion about the ratings.

Gold standard training was utilized by Beaudin-Seiler and Seiler (2015). Participants were asked to grade the pilot's performance in each video. Then, the gold standard was presented,

and participants discussed with flight faculty members to align their scores with the gold standard grades. The authors claimed that the gold standard training increased participants' understandings of the grading scale.

In the medical discipline, Lin et al. (2013) conducted a 1-month training program for raters on dentist performance assessment. The training included role-playing sessions, grading practice using videotapes, group discussion, checklist development and case studies. The goal of this training was to "improve raters' abilities to define the key components of competence for specific clinical skills and develop criteria for satisfactory performance" (Lin et al., 2013, p. 257).

Similarly, Yule et al. (2008) utilized a "Non-Technical Skills for Surgeons" rater training course which lasted 2.5 hours. The training started with an introduction of non-technical skills, followed by an explanation of the grading system. Then, participants were trained on how to effectively assess behavioral skills, with practice grading on three video scenarios.

In the nursing home quality assessment study conducted by Mor et al. (2003), the research nurses went through a five-day training process. The training covered the methods to conduct evaluations, and the use of information from multiple sources. Video scenarios were shown to be used as a practice in coding. Role-playing exercises were conducted to improve interviewing skills. The training also included case presentations and guided discussion. The final step was to complete a case assessment with individual debrief to show the candidate's competency in assessment (Mor et al., 2003).

Weitz et al. (2014) organized a 90-minute FOR training session for raters on the assessment of physical examination. First, assessment standards and the rating dimensions were introduced. Next, four different videos indicating different levels of performance were shown,

and raters were asked to grade each of the video. The assessors then discussed their difference in the assessments as a group.

In the field of education, Sattler, McKnight, Naney and Mathis (2015) utilized an 11-minute training video to improve IRR in research grant peer review. The video was designed to help raters review grant proposals and provided a guideline on how to assign a value on the rating scale based on the quality of grant proposal.

Recurrent training is also imperative to maintain a high level of IRA/IRR, as suggested by Smith et al. (2008). The recurrent training should be focused on reinforcements of the grading criteria and differentiation between similar scores such as “3” and “4”. Also, it is recommended to train new instructors to grade simple maneuvers first, and then progress to complex maneuvers.

2.7.2 Video Scenarios for Rater Training

For rater training and evaluation, it is not practical for multiple raters to observe actual flying of the same crew at the same time. As a result, a commonly used method is to record crew performance in videotapes and ask raters to evaluate videotaped scenarios. Baker and Dismukes (2002) recommended that a minimum of three different practice video scenarios to be developed, reflecting excellent, average, and unsatisfactory performance.

In aviation training, most video scenarios were filmed in flight simulators. In several studies (Beaudin-Seiler & Seiler, 2015; O’Connor et al., 2002; Weber et al., 2013; Weber, 2016), the scenarios were scripted in advance. Pilots in the videos were considered as “actors” and flew the pre-scripted scenarios in a flight simulator. In the medical field, scenarios utilized by Yule et al. (2008) were filmed using patient simulators. The advantage of a scripted scenario is that performance criteria could be pre-identified, and scenarios could be developed based on that referent performance standard. For example, a scenario could be specifically designed to reflect

an unsatisfactory performance. Also, the scenario selection process could be shorter, as the scenarios are pre-defined. The disadvantages are the extra time needed to construct and record the scenarios, and the potential lack of realism (Goldsmith & Johnson, 2002).

There are also several studies (Brannick et al., 2002; Gontar & Hoermann, 2015; Holt et al., 2002; Lin et al., 2013; Smith et al., 2008) that used actual student performance recordings. First, a large pool of videotapes needs to be available. The scenarios for rater training must be selected by a group of SMEs. For example, Gontar and Hoermann (2015) selected four video scenarios from a pool of 30 videotapes to reflect different levels of performance. The use of actual training footage may require approval from flight school administration or the pilot union. Students' identity data may have to be erased in the video. The overall quality of the video may be lower than the pre-scripted scenarios (Goldsmith & Johnson, 2002).

2.8 Design of Scoring Rubric

A robust scoring rubric must be provided to improve IRA/IRR. Smith et al. (2008) cited a paragraph from the manual of the flight school in the study: "An Excellent (5) grade will be issued when a student's performance far exceeds and is well above the comparison standards" (Smith et al., 2008, p. 91). However, the terms "far exceeds" and "well above" were somewhat blurry and difficult to define. The authors recommended to precisely define each grading point and fine-tune the standards and criteria (Smith et al., 2008).

Brannick et al. (2002) compared three types of grading forms: grading specific behaviors; grading the overall handling of an event set; grading various Crew Resource Management (CRM) behaviors. Results showed that the inter-judge agreement was highest for "specific behaviors"

followed by “overall grading”, and the agreement on CRM evaluation was the lowest (Brannick et al., 2002).

Mavin and Dall’Alba (2010) introduced a Model for Assessing Pilots’ Performance (MAPP). Researchers claimed that technical and non-technical skills should not be graded separately, as the flight is conducted holistically. The MAPP integrates all skills into a single model. The highest level in the model is “situational awareness”. “Situational awareness” is supported by two essential skills: “aircraft flown within tolerances” and “decisions considerate of risk”. These essential skills are further supported by three enabling skills: “aviation knowledge”, “management of crew” and “communication amongst crew” (Mavin & Dall’Alba, 2010, p. 2).

Flin et al. (2003) targeted on the non-technical skills only. The article presented a European non-technical skills assessment system called Non-Technical Skills of Crew Members (NOTECHS). There are four different categories under NOTECHS: “co-operation, leadership and managerial skills, situation awareness and decision making” (Flin et al., 2003, p. 98). Each category is defined by several elements, and each element is further explained by different behavioral markers.

IATA (2013) recommended the following eight areas of competencies in their Evidence-Based Training Program Manual: “Application of Procedures; Communication; Aircraft Flight Path Management, Automation; Aircraft Flight Path Management, Manual Control; Leadership and Teamwork; Problem Solving and Decision Making; Situation Awareness; Workload Management” (p. 27). These key areas of competencies provide a reference for the design of scoring rubric.

2.9 Analyzing IRA/IRR

In the classical test theory developed by Lord (1959) and Novick (1965), observed score (X) equals to the sum of a true score (T) and an error (E) due to measurement.

$$\mathrm{Var(X)} = \mathrm{Var(T)} + \mathrm{Var(E)}$$

$$\mathrm{Reliability} = \frac{\mathrm{Var(T)}}{\mathrm{Var(T)} + \mathrm{Var(E)}}$$

There are several methods to analyze IRA/IRR. Each of them has its own advantages and disadvantages. The best method has always been under constant debate, as the same method may be criticized by some researchers, while being recommended by other researchers. Most studies have used more than one type of measurement methods to analyze IRA/IRR.

2.9.1 Percentage of Agreement

The most direct method that researchers often use to assess IRA/IRR is to calculate the percentage of agreement among different evaluators. However, this method does not make corrections for agreements that is expected by chance. It is possible that this statistic may overestimate the level of agreement (Hallgren, 2012). Despite the limitations of this method, the percentage of agreement was commonly reported on research studies as the baseline reference.

2.9.2 Kappa Statistic

One frequently used statistic for IRA/IRR is the Kappa statistic. In contrast to the percentage of agreement, Kappa statistic accounts for the possibility of chance or grading due to uncertainty.

Cohen's Kappa is a robust statistic used in testing IRA/IRR between no more than two raters. Cohen's Kappa has the following formula (Cohen, 1960):

$$\kappa = \frac{\mathrm{Pr(a)} - \mathrm{Pr(e)}}{1 - \mathrm{Pr}(e)}$$

$Pr(a)$ is the actual observed agreement, and $Pr(e)$ is the expected chance agreement (Cohen, 1960).

One of the limitations of Cohen's Kappa is that, Cohen's Kappa can only be used to measure not more than two raters. To cope with this issue, Fleiss (1971) generalized Scott's Pi statistic to allow the measurement of IRR among multiple raters and developed the Fleiss' Kappa.

Both Cohen's Kappa and Fleiss' Kappa could be interpreted as follows: "values ≤ 0 indicates no agreement, 0.01-0.20 indicates none to slight agreement, 0.21-0.40 indicates fair agreement, 0.41-0.60 indicates moderate agreement, 0.61-0.80 indicates substantial agreement, and 0.81-1.00 indicates almost perfect agreement" (Landis & Koch, 1977, p. 165). The Kappa value should be no greater than 1.00 but could be lower than 0.

2.10 Analyzing RRA/RRR

One method to analyze RRA/RRR is to calculate the percentage of agreement of the scores given by the raters compared to the referent score (Feldman et al., 2012).

O'Connor et al. (2002) and Yule et al. (2008) measured the RRA by comparing the mean of "absolute deviation" between the raters' scores and the referent score. For example, if a participant rated a "3" and the gold standard is "2", the absolute deviation is "1". A low mean absolute deviation (MAD) indicates a high RRA.

Lobo, Huyse, Herzog, Malt and Opmeer (1996) used another method to calculate RRA/RRR. Each rater's score was individually compared with the referent score. Researchers calculated the percentage of agreement for both nominal and ordinal variables. Kappa coefficient was calculated for nominal variables and some ordinal variables with symmetrical distribution. Also, the intra-class coefficient (ICC) was calculated for continuous and some ordinal variables

with symmetrical distribution. The authors created a term called “reliable raters”, to identify the raters with high RRA/RRR (Lobo, Huyse, Herzog, Malt, & Opmeer, 1996).

2.11 Analyzing Likert Scale Data

There is an ongoing debate on whether parametric tests, such as t-test and ANOVA, should be used for Likert scale data. The debate comes from whether Likert scale data is continuous (the distance between each scale point is equal). Most Likert scale data is considered as ordinal data. Some researchers claimed that the data needs to be on interval scale or above, before parametric tests can be used (Jamieson, 2004). However, Norman (2010) used actual and simulated data to argue that parametric tests can be used for Likert scale data, even if there is a small sample size, the variance is unequal, or the distribution is non-normal. Sullivan and Artino (2013) also indicated that parametric tests are robust enough for analyzing Likert scale data. Norman (2010) further claimed that intra-class correlation is usable for Likert scale data. A parametric test may be more powerful than a non-parametric test in determining statistical significance.

2.12 Determine Training Effectiveness

Training workshops are widely used in different industries. There are different methods to measure and determine the effectiveness of a training program. Kirkpatrick and Kirkpatrick (2006, p. 21) utilized four levels to assess training effectiveness: “reaction, learning, behavior and result”. This is one of the most commonly used frameworks to determine training effectiveness (Arthur, Bunnett, Edens, & Bell, 2003; Santos & Stuart, 2003).

The “reaction” level only measures how the subjects reacted to the training (Kirkpatrick and Kirkpatrick, 2006). The reaction level is usually self-reported by the subjects. For example,

reaction is measured when trainees write a post-training satisfaction survey that asks whether the training is beneficial or not.

The “learning” aspect of the framework measures the learning outcomes of a training event, usually in terms of knowledge, skill or attitude (Kirkpatrick and Kirkpatrick, 2006). Learning results are often measured by written tests or performance tests.

In comparison, the “behavior” facet focuses on the subject’s change in job behavior after the training (Santos & Stuart, 2003). This could be measured by the subject’s post-training work performance based on established performance indicators, or supervisor’s evaluations of performance.

The “results” criterion measures the overall effectiveness of training on the macro scale (Santos & Stuart, 2003). Depending on the anticipated training outcome and the mission statement of the organization, the results criteria can be increased efficiency, improved safety, reduced costs, better product quality and lower turnover. This level of performance is not typically reported, as it is often difficult to evaluate.

A similar but slightly different measurement framework was developed by Burke and Day (1986, p. 232): “subjective learning, objective learning, subjective behavior and objective results”. In Burke and Day’s view, the main difference from Kirkpatrick’s framework is on the definition of “subjective” and “objective”. The term “subjective” measures the training effectiveness in terms of opinion, judgment or belief from the trainee or trainer (Burke & Day, 1986), while the term “objective” measures by objective means such as a standardized test.

A meta-analysis conducted by Arthur et al. (2003) aimed to test the training effectiveness on 397 data points from 162 sources. Results indicated that 59% of the 397 data points reported learning changes, 31% reported behavioral changes, followed by 7% for result changes and 4%

for reaction changes. The weighted effect size for the sample was 0.60 to 0.63 (Arthur et al., 2003).

However, Arthur et al. (2003) claimed that rater training was qualitatively different from traditional training programs. As a result, rater training was not presented in their analysis. In contrast, Burke and Day (1986) considered rater training as one of the content areas in managerial training programs and included rater training in their meta-analysis. Results showed small to moderate effect size of training effectiveness for the 70 managerial training studies conducted. Rater training was shown to have a medium to large effect size (d = 0.64) in the "objective results" criterion.

Woehr and Huffcutt (1994) executed a meta-analysis on studies that utilized RET, FOR, PDT and BOT. Results showed that FOR (d = 0.83) and BOT (d = 0.77) were the most effective methods to improve rating accuracy. In addition, a meta-analysis conducted by Roch, Woehr, Mishra, and Kieszczynska (2012) focused on the review of FOR rater training. Results showed the overall effect size of FOR training was 0.5 based on 36 studies, which was considered as a medium effect size. The effect size for recall and behavioral accuracy was high (d = 0.88).

2.13 Results of Rater Training Effectiveness in Different Studies

Holt, Hansberger, and Boehm-Davis (2002) conducted a case study at a regional airline on rater calibration issues among instructors and evaluators over a three-year period. The regional airline implemented rater training to all their instructors and evaluators. During the three-year period, there was a general improvement in their benchmarks from year 1 to year 2. However, benchmarks remained mostly the same, with a slight decrease in some items from year 2 to year 3. The authors claimed that there was a large number of turnovers during the 3-year period, as well as a change in scoring instrument on the third year. In addition to the reasons

above, as a case study, the constraints in time, resources and lack of researcher's control may contribute to the results. The authors recommended further research to "evaluate the effectiveness of the IRR training by gathering and analyzing either pre- or post-training evaluations or by comparing the evaluation results of a trained group of I/Es versus an untrained group" (Holt, Hansberger & Boehm-Davis, 2002, p. 328).

Weber (2016) compared the IRA/IRR of participants from two different airlines. Participants from Airline A received training on the assessment model, while participants from Airline B did not receive any training. The results showed that participants from Airline B gave significantly lower scores than Airline A. Participants from Airline A had lower standard deviation and a narrower range of scores compared to Airline B. This indicated that participants who were trained with the assessment model had higher IRA and lower scoring variation, compared to participants who were not trained with the assessment model. Also, a pass-fail analysis was conducted. Participants from Airline B were much stricter regarding pass or fail judgements, compared to Airline A (Weber, 2016).

The testing of NOTECHS training was conducted by a joint research committee consisted of several airlines and universities in Europe (Flin et al., 2003). Participants include a total of 105 instructors from 12 different countries in Europe. Results showed that 80% of instructors graded consistently under NOTECHS. The difference between the instructors' ratings and the referent rating was less than 1 on a 5-point scale. The results showed a high level of IRA and a high level of internal consistency (Flin et al., 2003). However, the researchers found out that the variation was more significant when raters were grading based on pass/fail, compared to grading based on a 5-point scale. Also, "situational awareness" and "decision making" categories were the hardest to grade accurately (O'Connor et al., 2002).

The study conducted by Beaudin-Seiler and Seiler (2015) focused on the IRA/RRA issues of flight instructors in a collegiate aviation program. The rater training sessions had a positive effect on flight instructors with one year or less of experience. For flight instructors with 13 months to two years of experience, there was an improvement in agreement, but not as significant compared to less experienced flight instructors. For instructors with more than two years of experience, the researchers only found a slight improvement in agreement. Even though there was an improvement after training, the IRA was still not at an acceptable level, and there was still a gap between instructors' ratings and the gold standard (Beaudin-Seiler & Seiler, 2015).

Rater training was effective in the study conducted by Sattler et al. (2015) regarding university grant peer review. Results showed that the training (treatment) group had significantly higher ICC compared to the untrained group. The authors also compared the raters' results with the referent score and showed that the treatment group provided more similar scores to the referent. A similar study was conducted by Schroter et al. (2004) to test if an in-person training workshop or a self-study training program could improve the IRA of journal peer review. Participants were randomly assigned into three groups: a control group, a workshop group, and a self-taught group. A pre-test was administered in the form of a sample paper for participants to complete three tasks: assign quality review instrument, identify the number of major errors and to accept/reject the paper. The first post-test was given two to three months after the treatment, and a second post-test was given six months after the treatment. Results showed that the self-study group scored highest in terms of review quality, number of errors identified, and rejection rate during the first post-test, compared to the control group. The workshop group also scored significantly higher during the first post-test, but slightly lower than the self-study group. However, for the second post-test, the author did not detect a significant difference among all

groups. The author concluded that short training programs would provide a slight impact on peer review quality, but the treatment would not be as effective over time (Schroter et al., 2004).

The results of training were also positive in the field of dentistry. Lin et al. (2013) used a one group pre-test post-test design to analyze IRR among nine raters. After the pre-test, the participants received a one-month rater assessment training, followed by the post-test. The results showed that the training program was efficient to significantly improve IRR.

In addition, Jackson et al. (2005) utilized the FOR training method to train management assessors on evaluation of behaviors and traits. Results showed that IRR improved significantly after the training, for both behavior measures and trait measures.

However, several research studies showed little or no improvement after training. In the medical field, Cook et al. (2009) utilized a training workshop on Mini-Clinical Evaluation Exercise. The training workshop consisted of PDT, RET, BOT and FOR training. Results showed that the training workshop did not significantly improve IRR/RRR. The authors cited the sample size, the short workshop, and the problems with FOR training as possible reasons for non-significant improvements.

Weitz et al. (2014) used a post-test only control group design to test FOR training on the assessments of physical examination skills. The results indicated that the rater training did not create a significant impact on rating accuracy. However, the treatment group was significantly more stringent on the ratings, and the level of stringency was closer to the referent. The author claimed that the FOR training could not effectively adjust individual rater's judgments on real-life assessments (Weitz et al., 2014).

Lundstrom (2007) utilized FOR training to evaluate biodata on applicants' résumés. Results showed that there was an improvement in grading accuracy after FOR training, and there

was an improvement in IRR. However, the scores of the treatment group did not reach the same level when comparing with the referent score.

In conclusion, there has been mixed results regarding the effectiveness of rater training. A pre-test post-test control group design may be ideal to examine training effectiveness in a controlled experimental condition.

2.14 Addressing the Issues Identified in Literature Review

Through the literature review, no study was found in aviation that utilized a pre-test post-test control group design to investigate IRA/RRA issues. Also, several studies examined IRA/RRA of a scoring instrument, instead of determining the effectiveness of rater training.

Conducting experimental studies at air carriers is not an easy task due to constraints in costs and resources. However, there is a possibility to perform IRA/RRA research studies under the collegiate environment. The SOP of the Embraer Phenom 100 at Purdue University is identical to the one used by air carriers, and students are trained to the FAA Airline Transport Pilot (ATP) standard. Baker and Dismukes (2002) recommended the use of experimental design to test the effectiveness of rater training programs. A pre-test post-test control group design can be utilized to test if there is statistical significance between and within groups.

There were several constraints in the case study by Holt et al. (2002). The case study was conducted on a regional airline over a period of three years, and researchers had little control over the nuisance factors. There was a large turnover rate of the participants. Novice instructors who joined in the middle of the study, as well as experienced instructors who left the study may have created impacts on the results. Also, there was a major revision to the evaluation worksheet on the third year. A more robust experimental design could be developed, with a random

assignment of raters, as well as a reduction in research timespan to minimize turnovers. With this in mind, a pre-test post-test control group design would be ideal to further investigate this issue.

The study conducted by Weber (2016) compared participants from two different airlines, in which one airline utilized an assessment model, while the other airline did not. These two airlines operated different types of aircraft with different SOPs. There was possible confounding on whether the airlines themselves caused the difference, or the assessment model caused the difference. The author recommended a more rigorous experiment design with highly identical conditions among all participants, hopefully operating the same aircraft type, and working for the same company. It would be ideal to utilize the pre-test post-test control group design, with participants from the same flight program.

The study of IRR among four flight instructors by Smith et al. (2008) was limited in sample size ($n = 4$). There was one outlier that significantly lowered the overall Cohen's Kappa Coefficient. Also, there was no demographic information collected on the subjects. As a result, the backgrounds of these flight instructors were unknown. The authors suggested future research to include larger sample size, more flight events and collect demographic information (Smith et al., 2008).

2.15 Summary

This chapter provided a literature review on the problem of pilot training, inter-rater reliability/agreement, referent-rater reliability/agreement and rater training. The next chapter presents the methodology to be used in this study.

CHAPTER 3. METHODOLOGY

This chapter provides the methodology used in this study. A randomized pre-test post-test control group design was utilized. The goal of this research is to determine the effectiveness of a training workshop in improving inter-rater agreement (IRA) and referent-rater agreement (RRA) of pilot performance evaluations conducted by instructors and evaluators (i.e., raters).

3.1 Research Design

According to Campbell and Stanley (1963), true experimental design is one of the most recommended research designs to examine cause and effect relationships. There are a few requirements for the study to be considered a true experimental design (Shuttleworth, 2008): first, a control group, that does not receive any treatment, must exist; second, the subjects must be randomly assigned to the different groups, and third, only one variable is changed and tested, which is the independent variable.

Campbell and Stanley (1963, p. 8) identified the following types of true experimental designs: “the pre-test post-test control group design, the post-test only control group design and the Solomon four-group design”. The basic principles of true experimental designs are: randomized assignment of experimental units to different treatments, repeated treatments on multiple experimental units, and comparing two or more experimental conditions (Moore, McCabe, & Craig, 2014).

The pre-test post-test control group design is one of the most widely used design methods (LoBoindo-Wood, Haber, Cameron, & Singh, 2014). This type of design allows researchers to conduct the study in a more controlled environment. With the pre-test post-test control group

design, the comparison between pre-test and post-test, as well as the comparison between control group and treatment group, can be conducted.

In the pre-test post-test control group design used in this study, participants were randomly assigned to a control group and a treatment group. Both groups received the same pre-test. After administration of the pre-test, participants in the treatment group attended the training workshop (treatment), while participants in the control group did not receive any treatment. Finally, a post-test was conducted for both groups.

$$R \rightarrow O_1 \rightarrow X_c \rightarrow O_2$$

$$R \rightarrow O_1 \rightarrow X_t \rightarrow O_2$$

R= Random Assignment O_1= Pre-test

X_c= Control Group (No Treatment)

X_t= Treatment O_2= Post-test

3.2 Types of Statistical Error

There are several types of statistical errors that may render the conclusion invalid, even if the statistical test is significant. A type I error occurs when the null hypothesis is rejected incorrectly (Banerjee, Chitnis, Jadhav, Bhawalkar, & Chaudhury, 2009): even though the null hypothesis is true in the entire population, the researcher still rejects the null hypothesis based on the experiment. Type I error is regarded as α (alpha) error. A commonly used α value is 0.05, and a conventional range for α is between 0.01 and 0.10 (Banerjee et al., 2009).

A type II error occurs when the null hypothesis is retained incorrectly (Banerjee et al., 2009): the researcher fails to reject the null hypothesis based on the experiment, even though the null hypothesis should be rejected in the entire population. Type II error is regarded as β (beta)

error. A commonly used β value is 0.2, and a conventional range for β is between 0.05 and 0.20 (Banerjee et al., 2009).

Increasing the sample size would reduce the chance of Type I and Type II errors. However, the increased sample size requires additional cost and resources, which may be impractical for some research studies.

3.2.1 Power

Power is the probability that the null hypothesis is rejected when it should be (Banerjee et al., 2009). The power is equal to 1- β. If β = 0.3, then Power = 0.7. The higher the power, the higher the chance of observing an effect, considering the specific effect size. A commonly-used power value is 0.80 (Banerjee et al., 2009).

3.2.2 Effect Size

Even if the treatment effect is statistically significant, the results may not be meaningful or helpful. For example, the treatment showed a 1% increase, which was statistically significant. However, the 1% increase may not have any practical meaning. Statistical significance only measures whether two groups are different. It is equally important to test how much of a difference exists. In this case, the effect size needs to be determined.

One of the most common methods to measure effect size is Cohen's D (Cohen, 1988). The formula is as follows (Stangroom, 2018):

$$d = \frac{M_{group1} - M_{group2}}{SD_{pooled}}$$

An effect size of 1 means that the difference between means is one standard deviation. According to Cohen (1992), 0.2 is considered as a small effect size, 0.5 represents a medium effect size, and 0.8 is a large effect size.

If the effect size is very small, even if the difference is statistically significant, the difference is trivial, and the practical meaning of that difference is negligible. The larger the effect size, the larger the difference between groups; the smaller the effect size, the harder to determine the actual difference between groups.

3.3 Sampling Approach

To participate in this study, candidates were required to fulfill two requirements: to hold an FAA CFI certificate, and to be currently enrolled or have completed AT395 (Turbine Aircraft Simulations Lab) at Purdue University. An ideal situation is that all candidates who meet the requirements will participate in this study. However, as a human subject study, researchers cannot force people to participate. All participants were recruited under an established and approved process, and all participants voluntarily agreed to participate.

The researchers utilized multiple methods to advertise this study and recruit participants. First, all Professional Flight Technology students (junior standing or above) received an email soliciting participation. The email is included in Appendix B. A sign-up webpage hyperlink was included as part of the email. If a potential participant was interested in the study, he/she was able to type in and submit his/her email address on the webpage.

Second, the researchers worked with instructors of the following Purdue University courses: AT388 (Large Aircraft Systems), AT395 (Turbine Aircraft Simulation Lab), AT396 (Turbine Aircraft Flight Lab), and AT487 (Transport Aircraft Simulation Lab), to recruit students who were enrolled in these courses. A paper form was provided for potential participants to write down their email addresses, if they were interested.

Third, additional advertisements were posted at the Purdue University Airport facilities, including Niswonger Hall of Aviation Technology, Airport Terminal, Hangar 5, Hangar 6, and

Holleman-Niswonger Simulator Center. A Quick Response Barcode was included in the poster. If potential candidates were interested, they could scan the Barcode to enter the sign-up webpage. To thank participants for their time and effort in the study, participants received a gift card award if they completed the experiment.

Based on the literature review, instructional experience of the individual participants may be a nuisance factor for this study. New instructors have less experience in performance evaluation. To compensate for this issue, the participants were classified in two blocks: Participants with less than 100 hours of experience as a flight instructor (Block A), and participants with 100 hours of experience as a flight instructor or more (Block B).

Before the start of the pre-test, each participant was assigned a random identification (ID) number and were asked to report their total time as a flight instructor (dual-given time). Based on these reported data, participants became part of either Block A or Block B. Within these two blocks, a random assignment was conducted. By using this method, the difference in instructional experience could be minimized between the two groups.

According to Kottner et al. (2011), few studies have investigated the sample size issues for IRA/IRR research. However, a wide variety of methods could be used to determine the required sample size. In IRA/IRR studies, the total number of observations ($n_{Observations}$) is determined by the total number of raters (*k*) multiplied by the number of items they grade ($m_{Specimens}$). The total number of grading items can be controlled by the researchers, by adjusting the number of video scenarios available. It is desirable to find a balance between the total number of raters and the total number of grading items while considering the limitations in time and resources, to determine the optimized sample size.

By using an independent t-test to compare the mean absolute deviation (MAD) between the groups, Cohen (1992) suggested that for two-tailed, medium effect size (d = 0.5), an alpha value of 0.05 and a beta value of 0.20, a sample size of 64 per group is needed.

In order to use a paired samples t-test to compare the statistical significance within the same group between the pre-test and post-test, another sample size calculation is needed. For two-tailed, medium effect size (d = 0.5), an alpha value of 0.05 and a beta value of 0.20, it is required to have a sample size of 34, according to G*Power Version 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007).

Gwet (2013) calculated the number of sample raters needed, based on the percentage of agreement measurements. The author argued that using the percentage of agreement is the most practical approach to determine the sample size in IRA/IRR studies, as many variables may be unknown during the design stage of a study. IRA/IRR research studies usually report two or more different measurements (such as Cohen's Kappa, ICC, Fleiss' Kappa), and selecting the sample size based on percentage of agreement is beneficial to all IRA/IRR measurements. According to Gwet (2013), the variances caused by the raters should be no more than $4p_a^2/r^2$, in which p_a is the percentage of agreement and r is the number of raters. As a result, the required number of raters is determined by the desired variation coefficient.

Calculations showed that in order to ensure the variance caused by the sampling of raters is less than 5%, a total of 40 raters are required (Gwet, 2013). To ensure the variance caused by the sampling of raters is less than 10%, the required number of raters needs to be 20 (Gwet, 2013).

3.4 Unequal Control and Treatment Group Allocations

One of the most challenging factors for human subject research studies is the limited number of candidates who are willing to voluntarily participate. As a pre-test post-test control group design, participants were randomly assigned into two groups. Due to the limited number of participants available, the researchers decided to employ a smaller control group and a larger treatment group. Hutchins, Brown, Mayberry and Sollecito (2015) conducted a simulation of different control group sizes relative to a fixed treatment group size for intervention effects. Results showed that "the mean intervention effect and effect sizes were equivalent regardless of control group size and equal to the actual study effect" (Hutchins et al., 2015, p. 1).

There are several reasons for the utilization of an unbalanced group design. The first and foremost factor is the limitation in cost and resources. Torgerson and Campbell (2000) claimed that for a fixed sample size, an unbalanced design may result in substantial savings in cost, with only limited reduction in statistical power.

The treatment for this study is a training workshop, which implies a "learning" element. Allowing more participants to be assigned to the treatment group may cause a reduction of the possible impact, due to "learning curve" (Dumville, Hahn, Miles, & Torgerson, 2006).

Peckham et al. (2015) analyzed a total of 86 studies with unequal control group and treatment group(s). Results showed that 84% of the studies utilized an unbalanced ratio of 1:2, with 94% of the studies favoring the intervention group. Reasons for the unbalanced design include learning curves, statistical analysis, adverse events, logistical, ethical, economic, and improving recruitment (Peckham et al., 2015).

Based on the research cited, this study utilized a participant ratio of 1:2 between the control group and the treatment group. For the 29 participants in this study, 9 were in the control group and 20 were in the treatment group.

3.5 The 4-Point Grading Scale

Table 3.1 illustrates the four-point grading scale that was used to grade each scenario event, based on the grading scale utilized by Transport Canada (2017).

Table 3.1 The 4-Point Grading Scale

4	Performance is observed to consistently exceed standards, considering existing conditions.
3	Performance is observed to meet standards; however, there are momentary deviations from standards.
2	Performance is observed to meet standards; however, proficiency intermittently falls below standards which requires a de-brief with the student.
1	Performance is observed to include critical errors; proficiency consistently falls below standards.

Goldsmith and Johnson (2002) claimed they have seen grading scales ranging from 2 points, to 5 points. The critical issue was the ability of raters to correctly discriminate the different levels of performance, based on the grading scale. If the grading scale was too wide, evaluators were not able to discriminate performance precisely. If the grading scale was too narrow, potentially useful information was lost (Goldsmith and Johnson, 2002).

Under Advanced Qualification Program (AQP), the FAA (2006) did not establish a common, standardized grading scale. Instead, the FAA allowed individual air carriers to set the grading scale, based on the airlines' own needs.

A 4-point scale was utilized at the air carriers studied by Baker and Dismukes (2002), Holt, Hansberger, and Boehm-Davis (2002), and Mulqueen et al. (2002). It was also used at the collegiate flight program studied by Beaudin-Seiler and Seiler (2014). Moreover, the examples in ICAO (2002) Line Operations Safety Audit used a 4-point grading scale, indicating a 1 as "Poor

observed performance that had safety implications", 2 as "Marginal observed performance that was barely adequate", 3 as "Good observed performance that was effective" and 4 as "Outstanding observed performance that was truly noteworthy" (ICAO, 2002, p. A-2). Delta Airlines used a 4-point scale for procedures and automation proficiency, and a 5-point scale for Stick & Rudder and CRM/TEM (Tovani, 2014).

The 4-point scale has been used and validated by Transport Canada (2017), the aviation authority of Canada. Transport Canada has been utilizing a 4-point grading scale, not only at air carriers, but also for all flight tests (checkrides), ranging from recreational pilot permit to aircraft type ratings. Pilot examiners are required to give grades to each maneuver that a student performed during the flight test, based on a 4-point grading scale. Rather than assigning "pass" or "fail", the 4-point scale was designed to more closely reflect the quality of performance. Transport Canada (2006) stated in their check pilot manual that "the (1) to (4) marking scale is based on accepted instructional design principles and is an integral part of the Advanced Qualification Program (AQP), which is being recognized worldwide and adopted by several major airlines for crew training. The scale is consistent with ICAO proposals for international adoption of competency-based (skill-based) training and evaluation" (p. 59).

A 5-point scale has also been commonly used in the aviation industry, such as the flight school studied by Smith et al. (2008), as well as the air carriers studied by Flin et al. (2003), Mavin, Roth, and Dekker (2013), and Weber (2016). IATA (2013) also demonstrated the use of a 5-point scale.

A grading scale that is too wide may lead to difficulties when grading the student and may result in low IRA. Bamford et al. (2004) conducted analysis on a 10-point scale to measure the severity of rosacea. Results showed that the IRA was low. However, after the scales were

collapsed to a 6-point, 5-point or 4-point scale, the IRA improved significantly. The authors did not find a significant difference in terms of IRA between the 5-point and 4-point scale.

A grading scale that is too narrow may not clearly reflect the candidate's actual performance. Halpin, Halpin, and Arbet (1994) compared the internal consistency of two response formats - a two-choice (true or false) format to a 4-point Likert scale format. Results showed that the internal consistency was significantly improved for the 4-point Likert-type format, compared to the true or false format.

To determine the optimal width of the grading scale, Lozano, Garcia-Cueto, and Muniz (2008) conducted simulated tests on the reliability and validity of grading scales with width from two to nine. A total of 30 items were tested with sample sizes of 50, 100, 200 and 500. Results showed that the optimum number of the grading scale was between four and seven.

In conclusion, a 4-point scale was used for this study. A 4-point scale may be less difficult to train than a 5-point scale, as raters can more easily discriminate students' performance. The disadvantage of a 4-point scale is that the information may not be as detailed as taken using a 5-point scale.

3.6 Scenario Events for Evaluation

The participants in this study were asked to view several videos and grade the videotaped students' flight performance. A total of six videos were created for pre-test, with another six videos created for the post-test. Each set of videos covered six different Areas of Operation. The Areas of Operation were selected from the FAA (2008) Airline Transport Pilot and Aircraft Type Rating Practical Test Standards (PTS). Table 3.2 shows the Areas of Operation and the approximate length of each video scenario.

Table 3.2 The Video Scenarios

Area of Operation	Video Length
IV. Task A: Steep Turns	1 minute
IV. Task B: Approaches to Stalls and Stall Recovery	3 minutes
V. Task C: Precision Approaches - Hand Flown	3 minutes
VI. Task B: Landing from a Precision Approach	1 minute
III. Task F: Powerplant Failure during Takeoff	3 minutes
VIII. Task A. 2(d): Emergency Procedures - Emergency Evacuation	1 minute

Two different scenario events were recorded for each Area of Operation listed above, totaling 12 videos. Six of these scenario events were used for pre-test, and six were used for post-test. Each of the 12 videos was assigned a referent standard score in advance.

For the pre-test, the video scenarios were developed and scripted with the following referent standard scores:

- IV. Task A: 3
- IV. Task B: 2
- V. Task C: 2
- VI. Task B: 3
- III. Task F: 4
- VIII. Task A: 1

For the post-test, the video scenarios were developed and scripted with the following referent standard scores:

- IV. Task A: 2

- IV. Task B: 1
- V. Task C: 3
- VI. Task B: 2
- III. Task F: 3
- VIII. Task A: 4

Each video scenario was scripted and designed based on these scores. The researchers operated an Embraer Phenom 100 Flight Training Device (FTD) and flew the scenarios based on a pre-designed script to reflect different grades of performance for the event sets above. These event sets were videotaped and edited for participants to evaluate.

3.7 Developing the Scenarios Based on the Referent Score

With the referent scores defined above, the script for each video scenario was designed based on these referent scores. Current Phenom 100 full-time instructors (training captains) formed a board of subject-matter experts (SMEs). The SMEs discussed what type of behaviors or performance would represent the gold standard scores listed above and validated the video scenario scripts. To effectively gather information from all participating SMEs, the Delphi Method was used.

The Delphi Method, also called the Delphi Technique, was developed by the RAND Corporation to predict potential future war attacks (RAND Corporation, 2017). It was developed to gather a range of responses from different experts and achieve convergence of different opinions. The Delphi Method could be useful in several situations, such as developing alternatives, exploring underlying assumptions, seeking information, and correlating informed judgments (Hsu & Sandford, 2007).

A common problem during an in-person meeting is that sometimes the opinions and views may be dominated by someone with high status (such as a manager), those with forceful personalities, or from internal and external pressures. Consequently, not everyone's view can be shared equally, and some important opinions may be ignored. The Delphi Method avoids this problem by allowing every member to share their opinions individually and anonymously. With several rounds of discussions, the group may be able to reach a consensus (Thangaratinam & Redman, 2005).

The typical process of the Delphi Method is as follows: The first round of a questionnaire is sent to the group of experts, to gather the individual's opinions, thoughts and ideas. The questionnaire usually consists of open-ended questions. The replies are organized qualitatively by the researchers. The researchers group different views and prepares a compiled response information packet, along with the second questionnaire, which is more specific. This packet is sent back to the experts, and the experts provide one further round of comments. The opinions are then posted back to researchers and further analyzed. Several rounds of comment gathering, and feedback are conducted until a consensus can be formed or the results can be published (Thangaratinam & Redman, 2005).

For this study, a three-round Delphi Method was utilized. The goal of this Delphi Method discussion is to determine the types of behaviors that represent each grade of performance, to determine what exact behaviors will be embedded within each video scenario, and to develop and validate the video scenario scripts.

During the first round of discussion, each SME was asked to brainstorm what behaviors or tolerances would result in certain scores. For example, each SME would determine what type

of behavior would have caused a score of 1 (unsatisfactory) for the steep turn maneuver. The brainstorming questionnaire was included in Appendix D.

After the first round of questionnaires were completed and returned, the researchers summarized all the SMEs' comments and feedback. A scenario script was developed by the researchers, based on the responses from the SMEs. Then, a second round of discussions was initiated. During the second round, the SMEs were asked to provide comments and edits to the scenario script.

After the feedback from the second round was gathered, the researchers made several updates to the scenario script. Then, the third round of the Delphi Method process was conducted. The updated scenario script was sent out for final review and validation. Afterwards, the final version of the scenario script was completed. The video scenario script is included in Appendix E.

3.8 Procedures

As a human subject research study, an Institutional Review Board (IRB) review by Purdue University's Human Research Protection Program (HRPP) is required to ensure the study is "conducted ethically and in a manner that promotes the protection of the rights and welfare of human subjects" (Purdue University, 2018). An IRB request was submitted before any recruitment or experiment process started. The IRB request package consisted of all surveys, recruitment posters, invitation letters, informed consent forms, as well as the step-by-step details of the recruitment and experiment procedures. After one revision regarding the wording of the advertising poster, the IRB permission was granted. The IRB authorization letter is included in Appendix A.

Two independent experiment sessions were planned on two different dates. Each participant could choose which session they would like to voluntarily participate in, and each participant could only participate in one of the two sessions. The two sessions were identical in content.

During each session, two classrooms were used for this study: a computer lab for participants to complete the pre-test and post-test, and a classroom to conduct the training workshop for the treatment group. Both classrooms were located at Niswonger Hall of Aviation Technology at Purdue University, in West Lafayette, Indiana.

3.8.1 Intake of Participants

Participants were welcomed by researchers as they entered the computer lab. As participants entered the classroom, a randomized ID number was assigned to each participant as a method of de-identification. Based on this randomized ID number, they were asked to take the most spread-out seating in the computer lab, to avoid interference with other candidates. Pizza and refreshments were provided before the actual experiment started.

An information briefing was conducted. Researchers introduced the significance of this research and explained the steps and timelines for the experiment. Participants were given time to read through and sign the informed consent form, if they decided to participate. The form also stated that the participant had the right to withdraw from participation at any time without penalty. Signing the form indicated that the participant understood his/her rights in the study, and his/her consent to participate. The informed consent form is included in Appendix C. The participants also confirmed that they were at least 18 years of age. Any additional questions raised by the participants were answered by the researchers.

The welcome session lasted approximately 20 minutes.

3.8.2 Pre-Test

A short survey was conducted to determine the participants' demographics background and instructional experience. The survey is included in Appendix F. Based on the instructional experience information from the survey, participants were assigned randomly into two groups - the treatment group and the control group.

During the pre-test, participants from both groups were asked to evaluate six video scenarios, using the four-point grading scale. The process was done individually on personal computer (PC) stations. Each participant watched the six videos on their PC stations with their headphones on, and gave their ratings on the online grading sheet. Also, participants were asked to list the errors or problems they observed in each of the videos. Copies of the respective pages of the Embraer Phenom 100 SOP, Checklist, QRH, Jeppesen Approach Charts and multiple sheets of blank note paper were provided to the participants.

The pre-test took approximately 30 minutes. After the pre-test, participants in the control group were asked to stay in the computer lab, while participants in the treatment group were asked to move to another classroom for the workshop.

3.8.3 Control Group

Participants in the control group did not receive any treatment. After the pre-test, there was a 10-minute break period. When the break period was over, the control group participants were asked to complete the post-test.

3.8.4 Treatment Group

After the pre-test and a 10-minute break period, participants in the treatment group attended the rater training workshop, conducted by the researcher in a separate classroom. The rater training workshop lasted approximately 75 minutes.

After the rater training workshop, participants in the treatment group received another 10-minute break. After the break period, participates were asked to move back to the computer lab and complete the post-test.

3.8.5 Post-Test

Participants in both the control group and the treatment group were asked to grade the last six video scenarios, using the four-point grading scale. These videos were different from the videos used in the pre-test, but covered the same Areas of Operation. The process was done individually on PC stations. Each participant watched the six videos on their PC stations with headphones on and indicated their ratings on the online grading sheet. Participants were also asked to list the errors or problems they observed in each of the videos. Copies of the respective pages of the Embraer Phenom 100 SOP, Checklist, QRH, Jeppesen Approach Charts and multiple sheets of blank note paper were provided to the participants.

The post-test took approximately 30 minutes. A survey was conducted afterwards, focusing on the participants' feedback and thoughts on performance grading and evaluation. Participants were thanked and asked to leave the classroom when they were finished. The participants were given a Gift Card award as they exited the classroom. At this point, the experiment was considered complete for the participants.

3.9 Design of the Rater Training Workshop

As part of the experiment, participants in the treatment group underwent an interactive rater training workshop. The rater training workshop was similar to the rater academic training used in the airline industry. The training workshop was developed by the researchers and validated by the board of SMEs.

The rater training workshop included the following elements:

3.9.1 Introduction

The workshop started with a discussion of the problem, the importance of standardized grading, the difficulties faced to achieve this goal, as well as the significance of this training workshop. Also, the typical grading process was introduced and discussed.

3.9.2 Behavioral-Observation Training

As part of the BOT, the researchers trained participants on how to effectively observe a student's behavior. Through in-class lectures, videos and discussions, participants were taught on how to observe a student's behaviors, what to specifically look for, how to multi-task, what to do when a mistake was observed, as well as note-taking techniques. Typical observational errors and their antidotes were also discussed. For each of the six Areas of Operation, participants discussed what to look for and what to focus on during the observation process.

3.9.3 Review of Embraer Phenom 100 Operating Procedures

A good instructor is required to be competent with the operating procedures of the specific aircraft type. Due to time constraints, during the workshop, participants only reviewed the relevant normal and abnormal procedures for the Areas of Operation utilized in this study. There was also a discussion on which official document to refer to, if the instructor was unsure of certain issues. Aircraft limitations, such as maximum airspeed and stall airspeed, were also discussed and reinforced. The goal of this review was to refresh the details of Phenom 100 Operating Procedures, similar to a recurrent training ground school.

3.9.4 Performance-Dimension Training

First, the 4-point grading scale was introduced and discussed in detail, including the concepts behind each point on the grading scale. The training was specifically focused on the difference between a score of "2" and a score of "3". Second, the performance standard for each of the six Areas of Operation was discussed individually. Common errors for each maneuver were also discussed as part of the PDT. The goal was to let instructors become an expert with the grading process, based on specific Area of Operation, and effectively utilize the grading scale.

3.9.5 Frame-of-Reference Training

As part of the FOR training, the researchers provided two calibration scenarios for each Area of Operation, and an interactive grading process was initiated. Participants were given four sheets of colored index cards, with "1", "2", "3" and "4" written on each card. Participants were asked to raise the index card that represented the scores they gave to the student, based on their own judgements. Participants' individual evaluation scores were compared with the referent and with other participants. Participants then discussed the reasons behind their judgements and reviewed the discrepancies between the referent and the raters. This interactive process was used to practice grading, calibrate raters, and provide standardization for all raters. The goal was to train participants on a common frame-of-reference.

The training was concluded by a discussion on the topic areas reviewed, and a "questions and answers" session.

The outline of the training is illustrated in Table 3.3.

Table 3.3 Training Workshop Outline

- **Introduction (5 mins)**
  - Problems with inconsistent instructor grading
  - Importance of rater training and standardization
  - Typical grading process
    - Observe student behaviors and take notes
    - Evaluate student behaviors and compare with the grading standard
    - Conclude results and assign scores to the student
- **Behavioral-Observation Training (15 mins)**
  - The observation processes
  - Techniques in behavior observation and what to look at
    - Observing aircraft instruments, hand-flying, automation, pilot flying/ pilot monitoring duties, ATC, intercom/noise and aircraft warnings.
  - Emphasizing multi-tasking skills
    - Acting as an instructor, grader, ATC, simulator operator at the same time
    - Managing distraction
  - Note-taking techniques
    - Best note-taking format
    - Using abbreviations
  - Common observational errors
- **Review of Embraer Phenom 100 Operating Procedures**
  - Review of Phenom 100 limitations
  - Review of Phenom 100 SOPs for the scenarios involved

- Official documents and manuals

➢ **Performance-Dimensions Training & Frame-of-Reference Training (50 mins)**

- Introduction of the 4-point grading scale
  - What is a 4-point performance?
  - What is a 3-point performance?
  - What is a 2-point performance?
  - What is a 1-point performance?
  - Focus: How to distinguish a score of 2 and a score of 3?
- Discussion of the six Areas of Operation in detail
- Common errors for each maneuver
- Practice grading
  - 2 calibration scenarios for each Area of Operation
  - Let the participants grade each behavior
  - Compare the grades given by each person with the referent standard
  - Discussion of results

➢ **Q & A (5 mins)**

3.10 Variables

For this study, the grades given by the participants were the variables obtained through the pre-test and post-test. Analyses were conducted on these scores to determine the IRA/IRR coefficients (percentage of agreement and Fleiss' Kappa), as well as the mean absolute deviations (MAD) from the referent score. The grades given by the participants, as well as the MAD, were the dependent variables (DV) for this study.

The independent variable (IV) was the training workshop completed by the participants in the treatment group.

3.11 Data Analysis

First, descriptive data from the participants were analyzed. The mean and median ratings, as well as the standard deviation were calculated for pre-test control group, pre-test treatment group, post-test control group, and post-test treatment group.

The research questions were analyzed as follows:

Research Question 1: *After receiving the training, is there a significant increase in the level of agreement among different raters?*

The percentage of agreement for the pre-test control group, pre-test treatment group, post-test control group, and post-test treatment group were calculated and compared as a baseline reference.

In order to analyze the chance-corrected indication of inter-rater agreement, the Fleiss' Kappa values were calculated for each of the four groups. The Fleiss' Kappa values were then compared between and within groups and were referred to the matrix developed by Landis & Koch (1977), to determine the change in the level of agreement among different raters.

The hypothesis was an improvement in the level of agreement among different raters for the treatment group after the training workshop, as measured by the Fleiss' Kappa Statistic.

Research Question 2: *After receiving the training, is there a significant increase in the level of agreement between the raters and the referent standard?*

The percentage of agreement compared to the referent score for the pre-test control group, pre-test treatment group, post-test control group, and post-test treatment group were calculated as a baseline reference.

For each score given by the participants, the absolute deviation of that score from the referent score was calculated. The MAD was then analyzed for each participant.

An independent samples t-test was used to determine the statistical significance between pre-test control group and pre-test treatment group, as well as between post-test control group and post-test treatment group. In addition to the t-test, the Mann-Whitney U test was used as a non-parametric test to determine the statistical significance between the two groups.

A paired samples t-test was used to determine the statistical significance between pre-test control group and post-test control group, as well as between pre-test treatment group and post-test treatment group. In addition to the t-test, the Wilcoxon Signed-Rank Test and the Sign Test were conducted to determine the statistical significance within the groups.

The hypothesis was an improvement in the level of agreement between the raters and the referent standard for the treatment group after the training workshop, as measured by the MAD.

3.12 Threats to Internal and External Validity

There were several issues that must be addressed to reduce threats to internal validity and external validity. For the pre-test post-test control group design, potential issues must be identified, and care should be taken throughout the design and implementation phases, to minimize the threats to internal and external validity.

Internal validity is the ability of researchers to identify whether the independent variable created an effect on the dependent variable (Groebner, Shannon, & Smith, 2011). According to Campbell and Stanley (1963), potential threats to internal validity are: “History, Maturation, Testing, Instrumentation, Selection Bias, Statistical Regression, Mortality and Selection-Maturation Interaction” (p. 5).

External validity is the generalizability of treatment, or the observed relationships to the population outside of the experiment (Sani & Todman, 2008). There are also several important factors to be considered to ensure external validity, including "reactive or interaction effect of testing, interaction of selection bias and experimental variable, reactive effects of experimental arrangements, and multiple treatment interference" (Campbell and Stanley, 1963, p. 5-6).

3.12.1 History

History occurs when participants experience an external event not as part of the experiment, and that external event affects the post-test score (Kirk, 1982). For example, between the pre-test and post-test, the participant received additional rater training from outside sources. Researchers must ensure participants are not receiving treatments from other sources at the same time. The experiment should be conducted and finished in a timely manner, to limit the potential effects of external events. For this study, the pre-test, treatment, and post-test were completed on the same day, thus minimizing the adverse effect of history on internal validity.

3.12.2 Maturation

Dimitrov and Rumrill (2003) stated that maturation and history are the major threats to internal validity in pre-test post-test control group designs. Maturation is the physical or psychological change of participant characteristics over time, and that change can affect the post-test score (Campbell & Stanley, 1963). In contrast to history, maturation results from the internal changes that occur within the participants themselves, instead of changes caused by external events.

This study aimed to minimize maturation by reducing the overall time span of the experiment. As noted with history, the pre-test, treatment, and post-test were conducted in one day to reduce the threat from maturation. In addition, the FAA requires holders of the flight

instructor certificate to be at least 18 years of age (Eligibility Requirements, 2009). Only adults were eligible to participate in this study.

3.12.3 Testing

A pre-test may influence the outcome of a post-test (Christensen, Johnson, & Turner, 2015). The participant could memorize the questions used in the pre-test and apply that memory to the post-test. Careful design of the pre-test and post-test is essential to reduce the threats to validity from testing. For this study, researchers recorded two different sets of video scenarios. One set was used for the pre-test, while the other set was used for the post-test. Participants used the same grading scale to evaluate pilot performance in the videotapes for both pre-test and post-test. Repetition of the same videotapes was avoided, thus preventing participants from judging based on memory.

3.12.4 Instrumentation

If there is a change in the measurement instrument, or if there is a change in observers or grade sheets used during the experiment, there could be threats to internal validity (Campbell & Stanley, 1963). For this study, participants conducted the pre-test and post-test under the same set-up conditions, with the same evaluation standards and grading sheets.

3.12.5 Selection Bias

Selection bias occurs when participants in the control group and treatment group are not equivalent at the beginning of the study (Campbell & Stanley, 1963). Randomization is very important to reduce the threat from selection bias.

In this study, participants were randomly assigned into either the treatment or the control group, based on their instructional experience, with a ratio of 2:1.

3.12.6 Statistical Regression

There is a tendency for extreme scores to regress towards the mean between pre-test and post-test (Campbell & Stanley, 1963). For example, participants who scored very low in the pre-test may show an improved score on a post-test; however, participants who scored very high in the pre-test may show a decreased score on a post-test. A randomized assignment was necessary for this matter, to ensure participants were not grouped on the basis of extreme scores.

3.12.7 Mortality

When a participant drops out from a study, the sample size may be reduced, and the number of participants may be unbalanced between the control group and treatment group (Christensen et al., 2015). All subjects had the right to drop out from this study at any point of time, as they were voluntarily participating in the study. On the researcher's side, there were several ways to minimize the threat of mortality. First, the experiment was conducted on the subjects' best available times, to reduce the potential for participants to drop out, due to other duties at the same time. Second, the experiment was completed within a reasonable timeframe.

3.12.8 Selection-Maturation Interaction

In some instances, there can be an interaction between maturation and selection (Campbell & Stanley, 1963). The selection bias may cause specific groups to be different from another, and participants in these groups may be different in maturation. The interaction between the two may cause additional problems.

In this study, this interaction was minimized through the pre-test post-test control group design, the randomized selection, as well as a short overall time span of the experiment.

3.12.9 Reactive or Interaction Effect of Testing

A pre-test may influence the subjects' sensitivity to the dependent variable (Campbell & Stanley, 1963). The interaction of testing and the treatment may affect the final results of the treatment group. For example, participants who completed the pre-test may be more sensitive to the treatment, and may perform better in the post-test as a result. This result may not be generalizable to the population.

For this research, all participants were asked to complete the same pre-test. The pre-test was similar to what certified flight instructors accomplish in real life: observe student behaviors, assess student performance, and provide useful critique. Moreover, all participants completed both the pre-test and the post-test.

3.12.10 Interaction of Selection Bias and Experimental Variable

Due to the interaction of selection bias and the experimental variable, there is a possibility that the treatment effect could not be generalized to the larger population (Campbell & Stanley, 1963). For this study, a randomized assignment was conducted. In addition, all participants who volunteered in this study were part of a larger population.

3.12.11 Reactive Effects of Experimental Arrangements

For this study, subjects were aware that they were participating in research experiments. The experimental arrangements may affect the outcome of the pre-test and post-test (Campbell & Stanley, 1963). Researchers tried to simulate the grading process utilized in real-world situations.

3.12.12 Multiple Treatment Interference

When multiple treatments are being applied to the same subjects, multiple-treatment interference may occur (Campbell & Stanley, 1963). There was only one treatment in the design

of this study. Researchers also ensured that the participants did not accidentally receive additional treatments.

3.12.13 Reducing Participant Crosstalk

Edlund et al. (2009) conducted three experiments to identify and eliminate participant crosstalk in research studies. The first experiment showed that there was 2.8% confirmed crosstalk among the 809 participants (Edlund et al., 2009). The second experiment included a classroom treatment, as textbooks were modified to ask participants not to talk to other people about what happened in the laboratory. Also, this was reinforced by instructors throughout the semester. This treatment reduced the crosstalk to less than 1%; only 6 of the 631 students showed confirmed crosstalk. The third experiment further added an in-lab treatment. Participants were asked not to disclose any information regarding the experiment, and a verbal commitment was obtained from each participant. Only one (0.08%) of the nearly 1,250 participants showed clear evidence of cross-talk (Edlund et al., 2009). Results showed that a classroom treatment reminding students of the importance of non-disclosure, as well as an in-lab treatment asking students not to disclose any information, could eliminate the chance of crosstalk.

Several methods were used to reduce the chances of cross-talk among participants in this study. First, participants were not allowed to talk with each other during the pre-test and post-test. Second, participants were asked to sit as far apart as possible while doing the pre-test and post-test. Third, participants were asked not to discuss the video scenarios to anyone outside of the experiment.

3.13 Summary

This chapter described the methodology for this study. The research design, hypotheses, sampling approach, statistical error, grading scale, scenario events, experiment procedures, workshop design, variables, data analysis, and threats to internal and external validity were discussed.

CHAPTER 4. RESULTS

This study was designed to determine the effects of a training workshop on inter-rater agreement (IRA) and referent-rater agreement (RRA). Demographic information and statistical analysis will be discussed in the current chapter.

4.1 Demographic Information

After the recruitment process, a total of 31 candidates indicated interest in participation, and 29 participants showed up for the experiment sessions. To accommodate the participants' availability, two identical but independent sessions were held on different dates for the participants to select, and the participants could only enroll in one of the two dates. In the first experiment session, there were a total of 20 participants. In the second experiment session, there were a total of 9 participants. All of the 29 participants completed the entire experiment. Within each session, participants were asked about their total hours of flight instruction and were then randomly-assigned into the control group or the treatment group based on a ratio of 1:2. Table 4.1 shows the participants' total flight hours, Table 4.2 lists the participants' flight instructor background information, and Table 4.3 illustrates the participants' Phenom 100 course completion status.

Table 4.1 Participants' Flight Hours

Variables	Control Group Frequencies	Treatment Group Frequencies
Total Flight Hours		
≤ 200	1	1
200-399	4	5
400-599	2	7
600-799	2	3
800-999	0	3
≥ 1000	0	1
Total Hours as Flight Instructor		
≤ 49	3	4
50-99	1	3
100-199	1	2
200-499	4	7
500-999	0	4
Total Hours in a Flight Simulator		
≤ 49	1	0
50-99	6	11
100-149	2	8
≥ 150	0	1
Total Hours in the Phenom 100 Aircraft		
0	2	1
1-6	3	8
7-15	0	7
>15	4	4
Total (*n*)	**9**	**20**

Table 4.2 Flight Instructor Information

Variables	Control Group Frequencies	Treatment Group Frequencies
Initial CFI Checkride Year		
2015	0	1
2016	1	5
2017	5	11
2018	3	3
Types of CFI Certificates		
CFI only	7	14
CFI and CFI-I	2	5
CFI, CFI-I and MEI		1
Experience Teaching in a Flight Simulator		
Yes	6	14
No	3	6
Total (*n*)	**9**	**20**

Table 4.3 Phenom 100 Course Completion

Variables	Control Group Frequencies	Treatment Group Frequencies
AT395 (Phenom 100 Sim Course) Status		
Completed in Summer 2017 or before	4	13
Completed in Fall 2017	2	6
Enrolled in Spring 2018	3	1
AT396 (Phenom 100 Flight Course) Status		
Completed in Summer 2017 or before	2	6
Completed in Fall 2017	2	8
Enrolled in Spring 2018	2	5
Did Not Take	3	1
Total (*n*)	**9**	**20**

4.2 Emergency Evacuation Scenario

There was a large variation of scores on the post-test emergency evacuation scenario for all participants in the control group and the treatment group. The problem with this specific scenario event created an impact on the IRA and RRA analysis between and within the two groups. As a result, a separate analysis was conducted, to exclude the emergency evacuation scenario (five scenarios), in addition to the set including this scenario (six scenarios).

Several factors may have contributed to the large variation in scoring. First, Purdue University operates the Embraer Phenom 100 with two pilots (Purdue University, 2016) in spite of the fact that the jet is designed as a single-pilot aircraft (McClellan, 2009). The Phenom 100 emergency evacuation Quick Reference Handbook (QRH) checklist states that calling Air Traffic Control (ATC) is the third from last item to do, after the engine shutdown procedures. However, the QRH is designed by the aircraft manufacturer for single-pilot operations. Purdue

University operates the Phenom 100 within a multi-crew environment, and the Standard Operating Procedures (SOP) clearly states that “Just after the Captain calls for the emergency evacuation, the First Officer (F/O) may notify ATC. The order is maintained here in case of single pilot operation” (Purdue University, 2016, p. 80). However, even though the Emergency Evacuation SOP extract was given to the participants during the experiment, most participants were unaware of this paragraph in the SOP. During the training workshop, the delegation of “Calling ATC” task to the F/O was not emphasized.

Secondly, the emergency evacuation was conducted in the hypothetical scenario that both engines were on fire simultaneously. The pilots in the scenario decided to evacuate immediately. On the Phenom 100, there is only one fire extinguishing bottle for two engines. The engine fire extinguishing bottle is only able to discharge into one engine, even if both engines are on fire. In addition to the standard emergency evacuation QRH items, the crew in the scenario decided to discharge the fire extinguishing bottle as per the SOP and ordered evacuation to the left side only. Some participants considered it unacceptable to conduct this action because the emergency evacuation QRH did not specify this task.

For the reasons stated above, two separate sets of analyses were conducted and reported. One set of analyses included Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, Powerplant Failure during Takeoff, and Emergency Procedures - Emergency Evacuation, namely the “Six Video Scenarios Analysis”; the other set of analyses included Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, and Powerplant Failure during Takeoff, namely the “Five Video Scenarios Analysis”.

4.3 Descriptive Statistics of the Scenario Scores

Table 4.4 illustrates the mean, median, standard deviation, minimum and maximum scores given by the participants in the control group during pre-test. The referent standard scores are also listed for comparison.

Table 4.4 Descriptive Statistics for Pre-test Control Group

	Mean	Median	Standard Deviation	Minimum	Maximum	**Referent Score**
Scenario 1	3.11	3	0.33	3	4	**3**
Scenario 2	2.33	2	0.5	2	3	**2**
Scenario 3	2	2	0.87	1	3	**2**
Scenario 4	3.11	3	0.78	2	4	**3**
Scenario 5	3.22	3	0.67	2	4	**4**
Scenario 6	1.11	1	0.33	1	2	**1**

Table 4.5 illustrates the mean, median, standard deviation, minimum and maximum scores given by the participants in the treatment group during pre-test. The referent standard scores are also listed for comparison.

Table 4.5 Descriptive Statistics for Pre-test Treatment Group

	Mean	Median	Standard Deviation	Minimum	Maximum	**Referent Score**
Scenario 1	3.15	3	0.37	3	4	**3**
Scenario 2	2.65	3	0.75	1	4	**2**
Scenario 3	2.1	2	0.64	1	3	**2**
Scenario 4	3.1	3	0.64	2	4	**3**
Scenario 5	3.3	3	0.73	2	4	**4**
Scenario 6	1.25	1	0.44	1	2	**1**

Table 4.6 illustrates the mean, median, standard deviation, minimum and maximum scores given by the participants in the control group during post-test. The referent standard scores are also listed for comparison.

Table 4.6 Descriptive Statistics for Post-test Control Group

	Mean	Median	Standard Deviation	Minimum	Maximum	**Referent Score**
Scenario 1	1.89	2	0.78	1	3	**2**
Scenario 2	1.33	1	0.71	1	3	**1**
Scenario 3	3.33	3	0.71	2	4	**3**
Scenario 4	2.22	2	0.67	1	3	**2**
Scenario 5	2.78	3	0.67	2	4	**3**
Scenario 6	2.56	3	1.13	1	4	**4**

Table 4.7 illustrates the mean, median, standard deviation, minimum and maximum scores given by the participants in the treatment group during post-test. The referent standard scores are also listed for comparison.

Table 4.7 Descriptive Statistics for Post-test Treatment Group

	Mean	Median	Standard Deviation	Minimum	Maximum	**Referent Score**
Scenario 1	2	2	0	2	2	**2**
Scenario 2	1.05	1	0.22	1	2	**1**
Scenario 3	3.4	3	0.60	2	4	**3**
Scenario 4	2.05	2	0.51	1	3	**2**
Scenario 5	2.9	3	0.79	1	4	**3**
Scenario 6	3.1	3.5	1.07	1	4	**4**

4.4 Analysis of Inter-Rater Agreement

4.4.1 For Five Video Scenarios

For this set of analyses, only the pre-test and post-test data for Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, and Powerplant Failure during Takeoff were included. The percentage of agreement among the raters is reported in Table 4.8.

Table 4.8 Percentage of Agreement for Five Scenarios

	Pre-test	Post-test
Control Group	43.33%	38.33%
Treatment Group	45.37%	65.05%

To analyze the chance-corrected coefficient of IRA, the Fleiss' Kappa was utilized. A higher Fleiss' Kappa value indicates a higher level of agreement, with a maximum Kappa value of 1.0. The Kappa values are reported in Table 4.9.

Table 4.9 Fleiss' Kappa Values for Five Scenarios

	Pre-test	Post-test
Control Group	0.113	0.144
Treatment Group	0.132	0.507

For the pre-test score of the control group, the Fleiss' Kappa value was calculated as 0.113 ($z = 2.3$, $p < .05$). Since this Kappa value is between 0.01 and 0.20, it falls into the "None to Slight Agreement" category (Landis & Koch, 1977, p. 165).

For the pre-test score of the treatment group, the Fleiss' Kappa value was calculated as 0.132 ($z = 6.01$, $p < .01$). Since this Kappa value is between 0.01 and 0.20, it falls into the "None to Slight Agreement" category (Landis & Koch, 1977, p. 165).

For the post-test score of the control group, the Fleiss' Kappa value was calculated as 0.144 ($z = 3.16$, $p < .01$). Since this Kappa value is between 0.01 and 0.20, it falls into the "None to Slight Agreement" category (Landis & Koch, 1977, p. 165).

For the post-test score of the treatment group, the Fleiss' Kappa value was calculated as 0.507 ($z = 25.8$, $p < .01$). Since this Kappa value is between 0.41 and 0.60, it falls into the "Moderate Agreement" category (Landis & Koch, 1977, p. 165).

4.4.2 For Six Video Scenarios

For this set of analyses, the pre-test and post-test data for Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, Powerplant Failure during Takeoff, and Emergency Procedures - Emergency Evacuation were included. The percentage of agreement among the raters is reported in Table 4.10.

Table 4.10 Percentage of Agreement for Six Scenarios

	Pre-test	Post-test
Control Group	49.07%	34.72%
Treatment Group	47.89%	59.30%

To test inter-rater agreement, the Fleiss' Kappa was utilized. A higher Fleiss' Kappa value indicates a higher level of agreement, with a maximum Kappa value of 1.0. The Kappa values are reported in Table 4.11.

Table 4.11 Fleiss' Kappa Values for Six Scenarios

	Pre-test	Post-test
Control Group	0.275	0.101
Treatment Group	0.255	0.441

For the pre-test score of the control group, the Fleiss' Kappa value was calculated as 0.275 ($z = 6.64$, $p < .01$). Since this Kappa value is between 0.21 and 0.40, it falls into the "Fair Agreement" category (Landis & Koch, 1977, p. 165).

For the pre-test score of the treatment group, the Fleiss' Kappa value was calculated as 0.255 ($z = 14.2$, $p < .01$). Since this Kappa value is between 0.21 and 0.40, it falls into the "Fair Agreement" category (Landis & Koch, 1977, p. 165).

For the post-test score of the control group, the Fleiss' Kappa value was calculated as 0.101 ($z = 2.48$, $p < .02$). Since this Kappa value is between 0.01 and 0.20, it falls into the "None to Slight Agreement" category (Landis & Koch, 1977, p. 165).

For the post-test score of the treatment group, the Fleiss' Kappa value was calculated as 0.441 ($z = 25.2$, $p < .01$). Since this Kappa value is between 0.41 and 0.60, it falls into the "Moderate Agreement" category (Landis & Koch, 1977, p. 165).

4.5 Analysis of Referent-Rater Agreement

4.5.1 For Five Video Scenarios

For this set of analyses, only the pre-test and post-test data for Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, and Powerplant Failure during Takeoff were included. The percentage of agreement compared to the referent score is reported in Table 4.12.

Table 4.12 Percentage of Agreement Compared to the Referent Score for Five Scenarios

	Pre-test	Post-test
Control Group	53.33%	55.56%
Treatment Group	57%	75%

The mean absolute deviation (MAD) from the referent score is reported in Table 4.13.

Table 4.13 Mean Absolute Deviation From the Referent Score for Five Scenarios

	Pre-test	Post-test
Control Group	0.49	0.47
Treatment Group	0.48	0.26

For RRA, the MAD was calculated and used for comparison. Each grade given by the participants was transformed into an absolute deviation value from the gold standard score, and

the MAD value was calculated for each participant. These values were then compared for statistical significance.

Two bar charts are included in Appendix I, to illustrate and compare the differences of the MAD for each participant from pre-test to post-test. For the control group, two of the nine participants showed zero change in MAD from pre-test to post-test. Four of the control group participants showed a decrease in MAD from pre-test to post-test; while three of the participants showed an increase in MAD from pre-test to post-test. Control group participant #9 had the greatest decrease in MAD, from 0.80 to 0, while control group participant #4 had the greatest increase in MAD, from 0 to 0.40.

For the treatment group, three of the twenty participants showed no change in MAD from pre-test to post-test. Fourteen of the participants showed a decrease in MAD from pre-test to post-test; while only three of the participants showed an increase in MAD from pre-test to post-test. Treatment group participant #14 had the greatest decrease in MAD, from 1.00 to 0.20, while treatment group participant #5 had the greatest increase in MAD, from 0.40 to 0.60.

Before conducting an independent samples t-test, there are several assumptions that must be met (Laerd Statistics, 2018a). First, the data from each participant (observations) must be independent from each other. Independent observation is ensured by the design of this study. The participants completed their grading independently, without interaction with other participants.

Second, the data must be at least interval scale or higher (Laerd Statistics, 2018a). The MAD value is considered as interval scale, as the distance between the MAD values is consistent. Therefore, this assumption was met.

Third, an independent samples t-test requires the random sample to come from a normal distribution (Laerd Statistics, 2018a). Normality can be tested through the Shapiro-Wilk test. If

results of the Shapiro-Wilk test are not significant ($p > .05$), the data are believed to meet the normality assumption. After completion of the Shapiro-Wilk test, for the control group pre-test, $W(9) = 0.886$, $p > .05$; for the treatment group pre-test, $W(20) = 0.935$, $p > .05$; for the control group post-test, $W(9) = 0.883$, $p > .05$; and for the treatment group post-test, $W(20) = 0.879$, $p < .05$. All but the treatment group post-test met this assumption. However, the t-test is relatively robust to non-normal situations. The t-test results were reported, along with the non-parametric test results.

Finally, Levene's test was conducted to determine the Homogeneity of Variance (Laerd Statistics, 2018a). If the results of Levene's test are not significant ($p > .05$), the data are believed to meet the Homogeneity of Variance Assumption. The results showed that for the pre-test, $F(1, 27) = 0.245$, $p > .05$; for the post-test, $F(1, 27) = 0.005$, $p > .05$. Both the pre-test and post-test met the assumption of Homogeneity of Variance.

The independent samples t-test showed that there was no significant difference for the pre-test MAD between the control group ($M = 0.4889$) and the treatment group ($M = 0.48$), $t(27) = 0.078$, $p = .939$. There was a very small effect size ($d = 0.0307$).

For the post-test MAD between the control group ($M = 0.4667$) and the treatment group ($M = 0.26$), there was a significant difference between the two, $t(27) = 2.519$, $p = .018$. There was a large effect size ($d = 0.9836$).

To compare the differences between the two groups during the pre-test and during the post-test, a non-parametric test was also used. The Mann-Whitney U test can be used as a non-parametric test equivalent to the independent samples t-test (Mendonca, 2017).

There are four assumptions for the Mann-Whitney U test (Laerd Statistics, 2018b). First, the dependent variable must be on a continuous or ordinal level. Second, the independent

variable must include two different categorical groups. Third, the observations must be independent. Fourth, the Mann-Whitney U test can be utilized to compare the medians only when the distributions have a similar shape. If the distributions between two groups do not have a similar shape, only the mean ranks can be compared (Laerd Statistics, 2018b).

As part of the design of this study, the first three assumptions were already met. For the fourth assumption, through visual interpretations of histograms listed in Appendix H and Appendix I, the distributions of pre-test results and post-test results were not similar. Therefore, only the mean ranks were compared.

The results of the Mann-Whitney U test showed that for the pre-test, there was no significant difference between the treatment group MAD (Mean Rank = 14.80) and the control group MAD (Mean Rank = 15.44), $U = 86.000$, $p = .847$. However, for the post-test, the treatment group MAD (Mean Rank = 12.63) was significantly different from the control group MAD (Mean Rank = 20.28), $U = 42.500$, $p = .02$.

To compare the differences between pre-test and post-test within the same group, a paired samples t-test was conducted. There are several assumptions to be met in using this test (Laerd Statistics, 2018c).

First, the dependent variable must be on an interval scale or higher (Laerd Statistics, 2018c). This assumption was met, as MAD is considered to be on an interval level. Second, the independent variable must be two categorical, related groups (Laerd Statistics, 2018c). The subjects should be the same for both groups. This assumption was met through the design of this study, as the paired samples t-test is conducted to compare the differences within the same group between pre-test and post-test. Third, there should be no significant outliers in the differences

(Laerd Statistics, 2018c). According to a visual inspection of the boxplots in Appendix I, there were no significant outliers in the data.

Lastly, the differences between the groups must be approximately normally-distributed (Laerd Statistics, 2018c). For the control group, the differences between pre-test and post-test MADs were approximately normally-distributed through the Shapiro-Wilk test, $W(9) = 0.959$, $p > .05$; For the treatment group, the differences between pre-test and post-test MADs were also approximately normally-distributed, $W(20) = 0.923$, $p > .05$. As a result, this assumption was met.

The execution of a paired samples t-test showed that, for the control group, there was no significant difference between the pre-test MAD (M = 0.4889) and post-test MAD (M = 0.4667), $t(8) = 0.151$, $p = .884$. In comparison, for the treatment group, there was a significant difference between the pre-test MAD (M = 0.48) and post-test MAD (M = 0.26), $t(19) = 3.488$, $p = .002$.

The Wilcoxon Signed Rank Test, along with the Sign Test, is considered to be the non-parametric version of the paired samples t-test (Mendonca, 2017). There are three assumptions for the Wilcoxon Signed Rank Test. First, the data should be at least ordinal or higher. Second, the independent variable should be two categorical and related groups. These two assumptions have already been met. Third, there should be a symmetrical distribution of the differences between the two groups (Laerd Statistics, 2018d).

Through a visual inspection of the boxplots in Appendix I, only the treatment group had approximately symmetrical distribution. Therefore, the Wilcoxon Signed Rank Test was conducted for the treatment group only. Results showed that there was a significant difference between the post-test treatment group MAD and pre-test treatment group MAD ($z = -2.861$, $p = .004$).

A Sign Test was conducted to compare the differences before and after the workshop within both control group and treatment group. There are a total of four assumptions that must be met before conducting the Sign Test (Laerd Statistics, 2018e). First, the dependent variable must be on an ordinal or higher level. Second, the independent variable should consist of two categorical and related groups. Third, each observation should be independent. Fourth, the distribution of difference scores should be continuous (Laerd Statistics, 2018e). All four assumptions were met for this study.

For the control group, there were no significant differences between the pre-test and post-test ($p = 1.000$). For the treatment group, there was a statistically-significant difference between the pre-test and post-test ($p = .013$). Results showed that the training workshop did create a statistically-significant reduction of MAD for the treatment group, both between groups and within groups.

Table 4.14 illustrates the statistical test results, including t-test, Mann-Whitney U test, Wilcoxon Signed Rank Test and Sign Test.

Table 4.14 Statistical Test Results for Five Scenarios

	t-test	Mann-Whitney U Test	Wilcoxon Signed Rank Test	Sign Test
PreCtrl vs PostCtrl	$p = .884$	-	-	$p = 1.000$
PreTreat vs PostTreat	$p = .002$	-	$p = .004$	$p = .013$
PreCtrl vs PreTreat	$p = .939$	$p = .847$	-	-
PostCtrl vs PostTreat	$p = .018$	$p = .020$	-	-

An alternative-form reliability analysis was conducted on the two different versions of tests (pre-test and post-test), based on the MAD data from the control group. A Pearson product-

moment correlation was run to test the relationship between pre-test MADs and post-test MADs. Results showed r(7) = -.395, which is considered as medium negative correlation (Cohen, 1988), p = .293.

4.5.2 For Six Video Scenarios

For this set of analyses, the pre-test and post-test data for Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, Powerplant Failure during Takeoff, and Emergency Procedures - Emergency Evacuation were included. The percentage of agreement, compared to the referent score, is reported in Table 4.15.

Table 4.15 Percentage of Agreement Compared to the Referent Score for Six Scenarios

	Pre-test	Post-test
Control Group	59.26%	50%
Treatment Group	60%	70.83%

The MAD from the referent score is reported in Table 4.16.

Table 4.16 Mean Absolute Deviation From the Referent Score for Six Scenarios

	Pre-test	Post-test
Control Group	0.43	0.63
Treatment Group	0.44	0.37

Two bar charts are included in Appendix K, to illustrate and compare the differences of the MAD for each participant from pre-test to post-test. For the control group, two of the nine participants showed zero change from pre-test to post-test. Two of the participants showed a

decrease in MAD from pre-test to post-test; five of the participants showed an increase in MAD from pre-test to post-test. Control group participant #9 had the greatest decrease in MAD from 0.67 to 0.17, while control group participant #4 had the greatest increase in MAD from 0 to 0.83.

For the treatment group, eleven of the twenty participants showed a decrease in MAD from pre-test to post-test; nine of the participants showed an increase in MAD from pre-test to post-test. Treatment group participant #17 had the greatest decrease in MAD, from 0.83 to 0.30, while treatment group participant #18 had the greatest increase in MAD, from 0 to 0.62.

Before conducting the independent samples t-test, there are several assumptions that must be met (Laerd Statistics, 2018a). Similar to the 5 video scenarios analysis, the independent assumption, as well as the interval scale assumption, was met.

In order to test the normality assumption, the Shapiro-Wilk test was conducted (Laerd Statistics, 2018a). Results showed that for the control group pre-test, $W(9) = 0.899$, $p > .05$; for the treatment group pre-test, $W(20) = 0.917$, $p > .05$; for the control group post-test, $W(9) = 0.951$, $p > .05$; for the treatment group post-test, $W(20) = 0.919$, $p > .05$. The normality assumption was met.

Lastly, the Levene's test was conducted to determine the Homogeneity of Variance assumption (Laerd Statistics, 2018a). The results showed that for the pre-test, $F(1, 27) = 0.035$, $p > .05$; for the post-test, $F(1, 27) = 0.121$, $p > .05$. Both the pre-test and post-test data met this assumption.

The independent samples t-test showed that there was no significant difference for the pre-test MAD between the control group ($M = 0.4259$) and the treatment group ($M = 0.4417$), $t(27) = -0.159$, $p = .874$. There was a very small effect size ($d = 0.0649$).

For the post-test MAD between the control group (M = 0.6296) and the treatment group (M = 0.3667), there was a significant difference between the two, t(27) = 2.538, p = .017. The effect size (d = 1.0157) was large.

To compare the differences between the two groups during the pre-test and during the post-test, the Mann-Whitney U test was conducted. As part of the design of this study, the first three assumptions (ordinal level or higher, two groups, independent observations) for the Mann-Whitney U test (Laerd Statistics, 2018b) were met. For the fourth assumption (similar-shaped distributions), through visual interpretations of histograms in Appendix J and Appendix K, the distributions of pre-test results and post-test results were judged to be not similar. Therefore, only the mean ranks were compared, and the median ranks were not compared.

The results of the Mann-Whitney U test showed that for the pre-test, there was no significant difference between the treatment group MAD (Mean Rank = 15.05) and the control group MAD (Mean Rank = 14.89), U = 89.000, p = .961. However, for the post-test, the treatment group MAD (Mean Rank = 12.58) was significantly different from the control group MAD (Mean Rank = 20.39), U = 41.500, p = .02.

To compare the differences between pre-test and post-test within the same group, a paired samples t-test was conducted. There are several assumptions to be met before using this test (Laerd Statistics, 2018c).

First, the dependent variable must be on an interval scale or higher (Laerd Statistics, 2018c). This assumption is met, as MAD is considered to be on an interval level. Second, the independent variable must be two categorical, related groups (Laerd Statistics, 2018c). The subjects should be the same for both groups. This assumption was met through the design of this study, as the paired samples t-test was conducted to compare the differences within the same

group between pre-test and post-test. Third, there should be no significant outliers in the differences (Laerd Statistics, 2018c). According to a visual inspection of the boxplots in Appendix K, there were no significant outliers in the data.

The results of the paired samples t-test showed that, for the control group, there was no significant difference between the pre-test MAD (M = 0.4259) and post-test MAD (M = 0.6296), t(8) = -1.301, p = .230. For the treatment group, there was also no significant difference between the pre-test MAD (M = 0.4417) and post-test MAD (M = 0.3667), t(19) = 0.975, p = .342.

The Wilcoxon Signed Rank Test and the Sign Test are considered to be the non-parametric version of the paired samples t-test (Mendonca, 2017). In order to conduct the Wilcoxon Signed Rank Test, first, the data should be at least ordinal or higher. Second, the independent variable should be two categorical and related groups. These two assumptions were met. Third, there should be a symmetrical distribution of the differences between the two groups (Laerd Statistics, 2018d).

Through a visual inspection of the boxplots in Appendix K, both groups did not have a symmetrical distribution. A Wilcoxon Signed Rank Test could not be conducted, because the differences were not approximately symmetrical for either the control group or the treatment group.

The Sign Test was conducted to compare the differences before and after the workshop for both control group and treatment group. There are four assumptions for the Sign Test (Laerd Statistics, 2018e). First, the dependent variable must be on an ordinal or higher level. Second, the independent variable must include two categorical and related groups. Third, each observation should be independent. Fourth, the distribution of the difference scores must be continuous (Laerd Statistics, 2018e). All four assumptions were met for this study.

The researcher conducted a Sign Test to compare the differences before and after the workshop, for both the control group and the treatment group. For the control group, there was no significant difference between the pre-test and post-test (p = .453). For the treatment group, there was also no significant difference between the pre-test and post-test (p = .238).

Table 4.17 illustrates the statistical test results, including t-test, Mann-Whitney U test, Wilcoxon Signed Rank Test and Sign Test.

Table 4.17 Statistical Test Results for Six Scenarios

	t-test	Mann-Whitney U Test	Wilcoxon Signed Rank Test	Sign Test
PreCtrl vs PostCtrl	p = .230	-	-	p = .453
PreTreat vs PostTreat	p = .342	-	-	p = .238
PreCtrl vs PreTreat	p = .874	p = .961	-	-
PostCtrl vs PostTreat	p = .017	p = .020	-	-

An alternative forms reliability analysis was conducted on the two different versions of the tests (pre-test and post-test), based on the MAD data from the control group. A Pearson product-moment correlation was run to test the relationship between pre-test MADs and post-test MADs. Results showed r(7) = -.780, which is considered as large negative correlation (Cohen, 1988), p = .013.

4.6 Summary

Chapter 4 presented the results of this study. The demographics information and the analyses for both inter-rater and referent-rater agreement were discussed.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Study

This study aimed to improve inter-rater and referent-rater agreement of pilot performance evaluation conducted by instructors and evaluators (i.e., raters). An interactive training workshop was developed, with focus on Behavioral-Observation Training, Performance-Dimension Training, and Frame-of-Reference Training.

The pre-test and post-test included the following pre-scripted video scenarios: Steep Turn, Approach to Landing Stall, Precision Approach, Landing from a Precision Approach, Engine Failure After Takeoff, and Emergency Evacuation. One set of six video scenarios was created for pre-test, and a different set of six video scenarios was created for post-test. Each video script was designed based on a gold standard score (referent score). The video scripts were brainstormed, developed, and validated by a board of SMEs using the Delphi Method. Researchers completed the videotaping process on an Embraer Phenom 100 Flight Training Device (FTD), based on the script.

An Institutional Review Board (IRB) approval was obtained through Purdue University's Human Research Protection Program (HRPP), under the expedited category. Participants were then recruited using several methods, including emails, classroom visits, and campus posters. To better facilitate the participants' schedule, two identical experiment sessions were conducted. A total of 31 participants signed up for the experiment. In the first session, there were 20 participants. In the second session, there were nine participants. As a result, there were 29 participants who completed the entire experiment.

Participants were randomly-assigned into two groups, within their blocks of similar instructional experience. All participants completed a background survey, followed by the pre-

test. Participants watched and graded a total of six video scenarios during the pre-test on their individual PC stations. After completing the pre-test, all participants were given a 10-minute break. Participants in the control group then completed the post-test. Participants in the treatment group went through the interactive training workshop in a separate classroom, followed by another 10-minute break. During the post-test, all participants watched and graded a different set of 6 video scenarios on their individual PC stations. After completion of the post-test, the experiment ended, and all participants were given gift cards for their participation.

The data were de-identified and analyzed. Due to issues with the post-test Emergency Evacuation video scenario, two independent sets of analyses were conducted. One set of analyses included Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, Powerplant Failure during Takeoff, and Emergency Procedures - Emergency Evacuation, namely the "Six Video Scenarios Analysis"; the other set of analyses included Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, and Powerplant Failure during Takeoff, namely the "Five Video Scenarios Analysis".

First, the descriptive statistic was presented for each scenario and for each group. An analysis of inter-rater and referent-rater agreement was conducted. For inter-rater agreement (IRA), the percentage of agreement was presented. The Fleiss' Kappa statistic was used and benchmarked with the matrix defined by Landis and Koch (1977). For referent-rater agreement (RRA), the percentage of agreement between the raters and the referent score was reported. The mean absolute deviation (MAD) from the standard score was calculated, and the result was compared for statistical significance between and within groups by parametric and non-parametric tests. IBM SPSS 24 Statistics 24, R: A Language and Environment for Statistical

Computing 3.4.2, ReCal3 (Freelon, 2010) and Microsoft Excel 2016 were used for quantitative analyses.

5.2 Results and Conclusions

An analysis was conducted to test for improvement in inter-rater and referent-rater agreement between and within groups. Data for the five video scenarios and the six video scenarios were analyzed separately.

In terms of IRA, when analyzing five video scenarios (Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, and Powerplant Failure during Takeoff) per test:

1. The Kappa value of pre-test control group (κ = 0.113), pre-test treatment group (κ = 0.132), and post-test control group (κ = 0.144) were similar and were all in the "None to Slight Agreement" category. The Kappa values were at a consistent low level for pre-test control group, pre-test treatment group and post-test control group.
2. For the post-test treatment group, the Kappa value increased by approximately 0.4 and was in the "Moderate Agreement" category (κ = 0.507).
3. The Kappa value went up by two category levels for the treatment group after the training workshop, indicating the training was effective in improving inter-rater agreement. There was no improvement for the control group, based on the pre-test and post-test Kappa values.

In terms of IRA, when analyzing six video scenarios (Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, Powerplant Failure during Takeoff, and Emergency Procedures - Emergency Evacuation) per test:

1. Both the pre-test control group ($\kappa = 0.275$) and pre-test treatment group ($\kappa = 0.255$) had a similar Kappa value and were in the "Fair Agreement" category. The Kappa values were consistent across the pre-test control group and pre-test treatment group.
2. Due to the disruption of the sixth video scenario, the post-test control group Kappa value went down one category level ($\kappa = 0.101$) and was in the "None to Slight Agreement" category.
3. Despite the disruption, the post-test treatment group's Kappa value still showed an improvement ($\kappa = 0.441$) and was in the "Moderate Agreement" category.
4. When comparing between groups, the Kappa value for post-test treatment group moved up two category levels, compared to the post-test control group; when comparing within groups, the Kappa value for post-test treatment group moved up one category level, compared to the pre-test treatment group.
5. The results indicated that the training was effective in improving inter-rater agreement when compared between and within groups.

In terms of RRA, for each video scenario, each person's absolute deviation from the standard referent score was calculated and the MAD was analyzed. Parametric and non-parametric tests were conducted to test for statistical significance.

When analyzing five video scenarios (Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, and Powerplant Failure during Takeoff) per test:

1. There was no significant difference ($p > .05$) for the MAD between pre-test control group (M = 0.49) and pre-test treatment group (M = 0.48). This result was determined using the independent samples t-test and Mann-Whitney U Test.

2. The difference for the MAD between post-test control group (M = 0.47) and post-test treatment group (M = 0.26) was statistically significant ($p < .05$). This result was determined using the independent samples t-test and Mann-Whitney U Test. There was a large effect size of 0.98.
3. There was no significant difference ($p > .05$) for the MAD between pre-test control group (M = 0.49) and post-test control group (M = 0.47). This result was determined using the paired samples t-test and Sign Test.
4. The difference for the MAD between pre-test treatment group (M = 0.48) and post-test treatment group (M = 0.26) was statistically significant ($p < .05$). This result was determined using the paired samples t-test, the Wilcoxon Signed Rank Test and Sign Test.

When analyzing six video scenarios (Steep Turns, Approaches to Stalls and Stall Recovery, Precision Approaches - Hand Flown, Landing from a Precision Approach, Powerplant Failure during Takeoff, and Emergency Procedures - Emergency Evacuation) per test:

1. There was no significant difference ($p > .05$) for the MAD between the pre-test control group (M = 0.43) and pre-test treatment group (M = 0.44). This result was determined using the independent samples t-test and Mann-Whitney U Test.
2. The difference for the MAD between the post-test treatment group (M = 0.37) and post-test control group (M = 0.63) was statistically significant ($p < .05$). This result was determined using the independent samples t-test and Mann-Whitney U Test. There was a large effect size of 1.02.

3. There was no significant difference ($p > .05$) for the MAD between the pre-test control group (M = 0.43) and the post-test control group (M = 0.63). This result was determined using both paired samples t-test and Sign Test.
4. There was no significant difference ($p > .05$) for the MAD between the pre-test treatment group (M = 0.44) and the post-test treatment group (M = 0.37). This result was determined using both the paired samples t-test and Sign Test.

In conclusion, in terms of IRA for both five video scenarios and six video scenarios analyses, the Fleiss' Kappa values were at a higher category level after the treatment. Therefore, there was a significant increase in the level of agreement among different raters after the training. However, the Fleiss' Kappa coefficient only reached "Moderate Agreement" level after the treatment and did not reach "Substantial Agreement" or "Almost Perfect Agreement" level.

In terms of RRA, for five video scenarios per test, the MAD was at a significantly lower level after the treatment workshop between and within groups. For six video scenarios per test, the MAD was at a significantly lower level when comparing the post-test control group with the post-test treatment group. Therefore, after receiving the training, there was a significant increase in the level of agreement between the raters and the referent standard.

Overall, there was an improvement when comparing the inter-rater and referent-rater agreement between and within groups after the treatment. This suggests that the utilization of a focused rater training workshop could significantly affect rater agreement of pilot performance evaluation conducted by instructors and evaluators (i.e., raters). Participants also expressed generally positive feedback on the training workshop. See Appendix G for the comments from participants.

5.3 Limitations of the Study

There were several limitations in this study. First, the video scenarios were pre-scripted, and the participants had a relatively controlled environment when watching the videos. However, in "real life" situations, instructors may be performing other duties at the same time, such as acting as ATC or simulator operator. The additional tasks were not considered during this experiment.

There were six Areas of Operation covered in this experiment, compared to a total of 32 Areas of Operation in the FAA ATP PTS (2008) for airplane multi-engine land. In real training situations, instructors must evaluate all the items required in the FAA ATP PTS. The additional events/maneuvers may add complexity to the grading process, as each Area of Operation has its unique challenges. Additional training may be required for each individual Area of Operation, and the training workshop may take significantly longer.

One of the other limitations is the aircraft itself. The Embraer Phenom 100 is designed as a single-pilot aircraft (McClellan, 2009). All the manuals and procedures from Embraer were designed, based on single-pilot operations. However, Purdue University operates the Phenom 100 under a multi-crew environment (Purdue University, 2016). As a result, the Purdue-specific SOP was developed, based on a multi-crew environment. Pilots are required to refer to documents developed from the aircraft manufacturer and the air operator at the same time. Some confusion existed during the experiment, as seen in the emergency evacuation scenario. Additional research should be done to examine the impact of utilizing multi-person crews on aircraft designed to be flown by a single pilot. Furthermore, the grades in this study were only given to the pilot flying in the left seat. No grades were established for the pilot monitoring in the right seat.

During the experiment, the researcher attempted to assign instructors to two groups, based on instructional experience. However, due to the unequal number of participants during the two different sessions, the number of more-experienced instructors and less-experienced instructors was not evenly-distributed between the two groups. The varied instructional experience among different instructors remained as one of the limitations for this study.

This study tested only the effect of a one-time training workshop. Due to constraints in time and resources, there was no subsequent recurrent training or testing. In real flight training situations, recurrent training may be essential for instructors and evaluators.

5.4 Recommendations for Practice

Rather than only grading a candidate as pass or fail, it is recommended to grade a student, based on a 4-point scale, to more precisely reflect the candidate's performance. This grading process is also promoted by the FAA under AQP, as well as the grading scale used by Transport Canada for all flight tests. Rater training is essential to standardized training and operations. Based on the results from this study, it is a recommended practice for airlines and flight training organizations to conduct rater training workshops. Behavior-Observation Training, Performance-Dimension Training, as well as Frame-of-Reference Training, are recommended to be included in the workshop. Through this experiment, Frame-of-Reference Training was found to be the most engaging and positive element of the workshop.

The findings from this study could apply to several situations. First, the findings in this research could help FAR Part 121 and Part 135 air carriers to develop or improve their rater training programs, especially when providing initial training to new instructors and evaluators.

Second, the findings from this research could help collegiate aviation programs develop or improve their instructor training programs. The evolution of AQP at air carriers has changed

the training process for airline pilots. However, most FAR Part 61 and Part 141 pilot training providers are still following the procedures and practices established decades ago. Currently, only a few flight schools and colleges have a clearly-defined grading rubric. With the large turnovers of flight instructors and inadequate training, different instructors may provide scores, based on different standards, leading to deficiencies in training. It is recommended to conduct training workshops on student grading for all new and experienced instructors. The findings from this study could help collegiate programs to develop and revise their own training programs and scoring standards, thus improving the quality of training.

No matter whether the organization is an air carrier or a flight school, the ultimate goal of rater training is to improve aviation safety. If instructors are well-trained, the students will become better and safer pilots. It is vital for instructors to effectively assess the student's performance, and thereby help to ensure a safe aviation industry.

Even if some participants may not become evaluators in the future, it is beneficial for all pilots to assess the performance of other pilots (Mavin, Roth & Dekker, 2012). This research should be beneficial for all participants involved, as learning about the assessment model and evaluating a peer's performance could further reinforce the individual's learning.

The findings from this study can be used not only for pilot training, but also in other sectors in aviation, such as cabin crew training. Subjective judgments are usually required in the fields of sports, medicine, and education. The findings herein may also be helpful and provide insights for IRA/RRA issues in other industries.

5.5 Future Research Recommendations

Even though this research showed a positive influence of the rater training workshop on inter-rater and referent-rater agreement, additional research is needed, and further studies are required to reveal the unknown.

IRA and RRA were both investigated in this study. RRA requires a referent score to be established for each case scenario, which may not be practical during real-world operations. IRA, on the other hand, does not require a common referent score to be established for the specific case scenario. During this research, both IRA and RRA showed an improvement after the training workshop. However, additional research can be done to investigate whether IRA or RRA is a more-preferred method to evaluate instructors.

This study consisted only of quantitative analysis. Even though participants may give the exact same score, the reasons behind his/her grading may be completely different (Weber et al., 2013). Further qualitative research should be conducted to discover the reasons behind each person's grading.

During this study, only the pilot flying in the left seat was graded by the participants. Similarly, the FAA ATP PTS (2008) is based on grading one individual at a time. With the evolution of flight training and the focus on multi-crew operations, CRM is becoming an increasingly crucial element of safe flight operations. With this in mind, additional research should be conducted to test whether it is a better practice to grade the entire crew, or to grade each pilot individually.

Pilots at FAR Part 121 and Part 135 air carriers are required to conduct recurrent training within a certain time interval. Instructors will need to go through recurrent training, as well. Additional research can be conducted to determine the effect of memory lapse and the best interval for instructor recurrent training.

Flying is a dynamic environment, and every decision made by pilots may result in completely different outcomes. The pre-scripted scenarios utilized in this study could not represent every scenario that would happen during real-world operations. In some cases, the real-world situations may be more complex than what was exposed during the study. During these complex scenarios, it may be more difficult for the instructor to grade the student, especially when they involve multiple issues with non-technical skills. Future research can be conducted to study and define the standards for non-technical skills.

In conclusion, this research has shown the positive impact of a rater training workshop on inter-rater and referent-rater agreement. After the training, there was a significant increase in the level of agreement among different raters. Similarly, there was a significant increase in the level of agreement between the raters and the referent standard. The researcher hopes this study will contribute to the on-going study of inter-rater and referent-rater agreement.

APPENDIX A. INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

PURDUE UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	THOMAS CARNEY HAMP
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	03/05/2018
Committee Action:	**Expedited Approval - Category**(7)
IRB Approval Date	03/05/2018
IRB Protocol #	1802020272
Study Title	Assessing and Improving Inter-Rater & Referent-Rater Agreement of Pilot Performance Evaluation
Expiration Date	03/04/2019
Subjects Approved:	

The above-referenced protocol has been approved by the Purdue IRB. This approval permits the recruitment of subjects up to the number indicated on the application and the conduct of the research as it is approved.

The IRB approved and dated consent, assent, and information form(s) for this protocol are in the Attachments section of this protocol in CoeusLite. Subjects who sign a consent form must be given a signed copy to take home with them. Information forms should not be signed.

Record Keeping: The PI is responsible for keeping all regulated documents, including IRB correspondence such as this letter, approved study documents, and signed consent forms for at least three (3) years following protocol closure for audit purposes. Documents regulated by HIPAA, such as Authorizations, must be maintained for six (6) years. If the PI leaves Purdue during this time, a copy of the regulatory file must be left with a designated records custodian, and the identity of this custodian must be communicated to the IRB.

Change of Institutions: If the PI leaves Purdue, the study must be closed or the PI must be replaced on the study through the Amendment process. If the PI wants to transfer the study to another institution, please contact the IRB to make arrangements for the transfer.

Changes to the approved protocol: A change to any aspect of this protocol must be approved by the IRB before it is implemented, except when necessary to eliminate apparent immediate hazards to the subject. In such situations, the IRB should be notified immediately. To request a change, submit an Amendment to the IRB through CoeusLite.

Continuing Review/Study Closure: No human subject research may be conducted without IRB approval. IRB approval for this study expires on the expiration date set out above. The study must be close or re-reviewed (aka continuing review) and approved by the IRB before the expiration date passes. Both Continuing Review and Closure may be requested through CoeusLite.

Unanticipated Problems/Adverse Events: Unanticipated problems involving risks to subjects or others, serious adverse events, and serious noncompliance with the approved protocol must be reported to the IRB immediately through CoeusLite. All other adverse events and minor protocol deviations should be reported at the time of Continuing Review.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911

APPENDIX B. INVITATION EMAIL

Dear Prospective Participant,

You are invited to participate in a research study, aiming to improve inter-rater agreement among flight instructors. In this research study, you will be invited to watch videos of a pilot flying several maneuvers in the Phenom 100 FTD, and be asked to assign grades to the performance of the pilot in each video. You may be asked to participate in a rater training workshop as part of the experiment.

Your identity will remain completely anonymous except to the researchers, and your participation is completely voluntary. If you choose, you may opt out of the study at any time, without any negative consequences.

You are eligible to participate in this study if you hold an FAA Certified Flight Instructor (CFI) certificate, and are currently enrolled or have completed AT395 (Turbine Flight Simulations Lab Course).

You will be compensated with a $45 Amazon.com gift card, if you complete the entire study.

If you are interested in this study, please visit (weblink) and submit your email address. A member of the research team will establish contact with you shortly.

If you have any questions, or are interested in learning more, please contact Allen Xie at (contact), or Dr. Thomas Carney at (contact).

Thank you in advance for your consideration.

Sincerely,

Dr. Thomas Carney, Principal Investigator

APPENDIX C. CONSENT FORM

Purdue IRB Protocol #: 1802020272 - Expires on: 04-MAR-2019

RESEARCH PARTICIPANT CONSENT FORM

Assessing and Improving Inter-Rater & Referent-Rater Agreement
of Pilot Performance Evaluation

Thomas Q. Carney, Ph.D.
School of Aviation and Transportation Technology
Purdue University

What is the purpose of this study?

The purpose of this research project is to assess and improve inter-rater agreement and referent-rater agreement of pilot performance evaluation conducted by instructors and evaluators (i.e., raters). You are being asked to participate in this study because you hold a Certified Flight Instructor (CFI) certificate, and you are currently enrolled or have completed AT395 (Turbine Aircraft Simulations Lab Course). The results of this study may provide positive contribution to flight training and aviation safety.

What will I do if I choose to be in this study?

You will be assigned a random ID number if you decide to participate in this study.
You will be asked to complete a short background questionnaire. You will be randomly-assigned to either a control group (the group of participants who will only grade the videos) or a workshop group (the group of participants who will receive a rater training workshop in addition to grading the videos). You have a 33.33% chance of being in the control group, and 66.66% chance of being in the workshop group.
You will complete an electronic pre-test. The pre-test experiment contains six videos that are pre-recorded in the Phenom 100 FTD. The six videos contain different scenarios and reflect different levels of student performance. You will be asked to watch and grade the pilots in each video with a 4-point grading scale, and list the strengths/weakness/problems you observed in each video. These data will be collected for future analysis. The pre-test process will take approximately 30 to 45 minutes.
After the pre-test, there will be a 10-minute break for all participants. If you are assigned to the control group, you will proceed directly to the post-test. If you are assigned to the workshop group, you will go to a classroom to attend a rater training workshop. The training will take approximately 60 minutes.

The post-test will contain a different set of six videos that are pre-recorded in the Phenom 100 FTD. You will be asked to watch and grade the pilots in each video with a 4-point grading scale, and list the strengths/weakness/problems you observed in each video. These data will be collected for future analysis. The post-test process will take approximately 30 to 45 minutes.
After the post-test, you will be asked to complete a survey, focusing on your feedback and comments on the experiment process.

How long will I be in the study?

Each participant is expected to go through the process listed above. The entire duration of participation, including training, completing the scenarios, and filling out the survey, is expected to take approximately 1 to 3 hours for most participants, and should not exceed 4 hours in duration. Actual time may vary, depending on your group assignment. The entire process will be done in a single day.

What are the possible risks or discomforts?

There is always a risk in any research study. However, the risk or discomfort in this study is minimal: no more risk exists than the amount encountered in everyday activities. You will be sitting in front of a personal computer during the pre-test and post-test. The rater workshop will be conducted under normal classroom settings. Thus, there should be minimal risks involved in this study. However, you may experience minor fatigue. Care will be taken to minimize the risk of breach of confidentiality, as you should be anonymous in this experiment. Please keep in mind that you are free to stop at any time during the experiment without further consequence. In this case, please notify the researcher, and your participation in the experiment will be stopped.

Are there any potential benefits?

You may gain experience in pilot performance evaluation on the Embraer Phenom 100.
You may become a better instructor, by learning how to observe a behavior, and how to effectively give grades to certain behaviors.
You may enjoy the process of watching and grading the videotaped scenarios.
The results from this study may be beneficial to the aviation industry, as better instructors and evaluators may train safer pilots, and safer pilots may improve aviation safety.

Will I receive payment or other incentive?

Complimentary pizza and refreshments will be provided before the pre-test.

You will be compensated with a physical $45 Amazon.com Gift Card after completion of the post-test survey.

Will information about me and my participation be kept confidential?

The project's research records may be reviewed by the researchers and by departments at Purdue University responsible for regulatory and research oversight. The data collected will be the grades you gave to each video, the errors/problems/strengths you identified and described for each video, and the surveys you took. All data collected in this study will be de-identified. You will be assigned a random ID number, and this ID number will be used for data analysis. The data will be stored with encryption, and all identifying information will be separately stored by the principle investigator in a locked cabinet and destroyed one year after the day of experiment. Electronic data may be securely copied to password-protected computers of the study team members. Identifying information will not be used in the data analysis or any subsequent document or presentation. Your signed consent forms will be stored in a locked cabinet in the principle investigator's office, and destroyed one year after the day of experiment. Findings from this research study may be published and presented in the future.

What are my rights if I take part in this study?

Your participation in this study is completely voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty. Your participation or non-participation will not affect any of your class standing, or employability.

Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, you can talk to one of the researchers. Please contact Dr. Thomas Carney at 765-494-9954 or Allen Xie at 765-491-0868 (first contact). If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please contact the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:
Human Research Protection Program - Purdue University
Ernest C. Young Hall, Room 1032
155 S. Grant St.,
West Lafayette, IN 47907-2114

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. My signature also affirms that I am at least 18 years of age. I will be offered a copy of this consent form after I sign it.

_____ _____

Participant's Signature Date

_____

Participant's Name

_____ _____

Researcher's Signature Date

APPENDIX D. SME QUESTIONNAIRE

Phenom 100 Grading Scenarios

Brainstorming Questionnaire

Scenario 1: Steep Turn

Please refer to Page 2 & 3 of the Scenario PTS & SOP Packet,

-What behaviors and/or tolerances do you think that would result in a score of 2?

-What behaviors and/or tolerances do you think that would result in a score of 1?

Scenario 2: Approach to Landing Stall

Please refer to Page 4 & 5 of the Scenario PTS & SOP Packet,

-What behaviors and/or tolerances do you think that would result in a score of 2?

-What behaviors and/or tolerances do you think that would result in a score of 1?

Scenario 3: Precision Approach

Please refer to Page 6 & 7 of the Scenario PTS & SOP Packet,

-What behaviors and/or tolerances do you think that would result in a score of 3?

-What behaviors and/or tolerances do you think that would result in a score of 2?

Scenario 4: Landing from a Precision Approach

Please refer to Page 8 & 9 of the Scenario PTS & SOP Packet,

-What behaviors and/or tolerances do you think that would result in a score of 3?

-What behaviors and/or tolerances do you think that would result in a score of 2?

Scenario 5: Engine failure during takeoff (V1-Cut)

Please refer to Page 10 & 11 of the Scenario PTS & SOP Packet,

-What behaviors and/or tolerances do you think that would result in a score of 4?

-What behaviors and/or tolerances do you think that would result in a score of 3?

Scenario 6: Emergency Evacuation

Please refer to Page 12 & 13 of the Scenario PTS & SOP Packet,

-What behaviors and/or tolerances do you think that would result in a score of 4?

-What behaviors and/or tolerances do you think that would result in a score of 1?

APPENDIX E. VIDEO SCENARIOS SCRIPT

	Steep Turn - A Score of 3	**Expected Duration: 1:00**
Event	PF Actions	PM Actions
	Starting Position: 15 nm north of KLAF, heading 360; Starting Altitude & Speed: 10,000ft and 180KIAS; Autopilot & FD On, ALT & HDG Mode, Bug 180 KIAS; Flaps Up, Gear Up, IMC Weather;	
1	**"Autopilot off, Flight Director off"**	
2		Turns off Autopilot and Flight Director
3	Adds 4-5% N1, smoothly roll into a turn to the left	
4	Stablizes at 45 degrees bank	
5	Pitch up a little and gain 60ft: 10,060ft	
6	Correct back to 10,020ft	
7	Start reducing the bank angle at 020 degree	
8	End up at +5 degrees during rollout	
9	Maintain speed ±6 kts throughout the maneuver	
10	**"Heading Mode, Altitude Hold, Autopilot On"**	
11		Heading mode, Altitude mode, autopilot on

	Steep Turn - A Score of 2	**Expected Duration: 1:00**
Event	PF Actions	PM Actions
	Starting Position: 15 nm north of KLAF, heading 360; Starting Altitude & Speed: 10,000ft and 180KIAS; Autopilot & FD On, ALT & HDG Mode, Bug 180 KIAS; Flaps Up, Gear Up, IMC Weather;	
1	**"Autopilot off, Flight Director off"**	
2		Turns off Autopilot and Flight Director
3	Adds 4-5% N1, smoothly roll into a turn to the left	
4	Turns into a 50 degrees bank, then corrected back to 45 degrees	
5	Did not pitch the nose up and lost 140ft: 9,860ft	
6	Promptly corrected back to 10,000ft	
7	Start reducing the bank angle at 010 degree	
8	End up at +8 degrees during rollout	
9	Maintain speed ±10 kts throuhout the maneuver	
10	**"Heading Mode, Altitude Hold, Autopilot On"**	
11		Heading mode, Altitude mode, Autopilot on

	Approach to Landing Stall - A score of 2	**Expected Duration: 1:30**
Event	PF Actions	PM Actions
	Starting Position: 15 nm north of KLAF, heading 360; Starting Altitude & Speed: 10,000ft and 160KIAS; Autopilot & FD On, ALT & HDG Mode, Bug 160 KIAS; Flaps Up, Gear Up, IMC Weather; Power 60%	
1	**"Flaps 1"**	
2		**"Checks, Flaps 1"**, Set Flaps 1
3	**"Gear Down"**	
4		Puts gear down
5	**"Flaps 3"**	
6		Set Flaps 3
7	**"Flaps Full"**	Set Flaps Full
8	Set power idle	
9	At the **"Stall, Stall"** aural warning:	
10	Pitch the nose down and add power	
11	**"Flaps 2"**	
12	(Leaves the flight director on)	Sets flaps 2
13	Did not pitch down enough, resulting in a new "Stall, stall" warning, but corrected promptly	
14		**"Positive Rate"**
15	**"Gear Up"**	Selects gear up
16	As the aircraft is accelerating… At 140kts	
17		**"Would you like Flaps 0?"**
18	**"Oh yes, Flaps 0"**	
19	**Goes above the original altitude, then correct back**	
20	**"Heading Mode, Alititude Hold, Autopilot On"**	Turns autopilot on

	Approach to Landing Stall - A score of 1	**Expected Duration: 1:30**
Event	PF Actions	PM Actions
	Starting Position: 15 nm north of KLAF, heading 360; Starting Altitude & Speed: 10,000ft and 160KIAS; Autopilot & FD On, ALT & HDG Mode, Bug 160 KIAS; Flaps Up, Gear Up, IMC Weather; Power 60%	
1	**"Gear Down"**	
2		Puts gear down
3	**"Flaps 1"**	
4		**"Checks, Flaps 1"**, Set Flaps 1
5	**"Flaps Full"**	
6		Set Flaps Full
7	Set power idle	
8	At the **"Stall, Stall"** aural warning:	
9	Add full power but pulled control backwards	
10	Enters multiple secondary stalls	
11	**"Flaps 0"**	
12		Sets flaps 0
13	Forgets to put gear up	
14		
15	**"Heading Mode, Alititude Hold, Autopilot On"**	Turns autopilot on

	ILS - A score of 2	**Expected Duration: 2:30**
Event	PF Actions	PM Actions
	Start Position: 3 miles from EARLE on ILS10, 2300ft, Flaps 1, 150KIAS, Hand Flown with Flight Director	
		"Glideslope Alive"
1	**(Does nothing when GS alive)**	
2	EARLE inbound	**"EARLE Inbound"**
3	**"Oh, gear down, flaps 3, bug Vref+5"**	
4		Did all three items at the same time
5	**"Flaps full"**	
6	Speed fluctuating between Vref and Vref+10	
7	Oscillate left and right half a dot back and forth	
8		**"1000ft above"**
9	**"Stabilized"**	
10	**"… Landing checklist, set missed approach altitude"**	Completes checklist, set missed approach altitude
11		**"200 above"**
12		**"100 above"**
13	**"Runway insight, landing"**	

	ILS - A score of 3	**Expected Duration: 2:30**
Event	PF Actions	PM Actions
	Start Position: 3 miles from EARLE on ILS10, 2300ft, Flaps 1, 150KIAS, Hand flown with FD	
1	**"Glideslope alive, gear down"**	Sets gear down
2	When gear is down: **"Flaps 3, bug Vref+5"**	
3	When flap is 3: **"Flaps full, set missed approach altitude, before landing checklist"**	
4	Speed fluctuating between Vref and Vref+5	
5	Left on course 1/4 dot then corrected, small glideslope deviation 1/2 dot then corrected	
6		**"1000ft above"**
7	**"Stabilized"**	
8		**"200 above"**
9		**"100 above"**
10	**"Runway insight, landing"**	

	Landing from a Precision Approach - Score of 3	**Expected Duration: 1:00**
Event	PF Actions	PM Actions
	Starting Position: 250' AGL on ILS10@KLAF, Heading 100, Speed Vref+5; Autopilot off, FD on, Bug Vref+5; Flaps Full, Gear Down, VMC Weather	
1	**"Runway in sight, Landing"**	
2	Glideslope deviates 1/4 dot	
3	PAPI shows 2 white 2 red	
4	Maintains Vref+5 above the runway threshold	
5	Left of centerline, but the centerline remains within main landing gear width	
6	Started flare and touched down at Vref-5	
7	Main landing gear touches down first.	
8	Land at touch down zone 1000' markers at +200ft	
9	Applies heavy braking (but evenly) trying to make B taxiway	

	Landing from a Precision Approach - Score of 2	**Expected Duration: 1:00**
Event	PF Actions	PM Actions
	Starting Position: 250' AGL on ILS10@KLAF, Heading 100, Speed Vref+5; Autopilot off, FD on, Bug Vref+5; Flaps Full, Gear Down, VMC Weather	
1	**"Runway in sight, Landing"**	
2	Stayed high, glideslope deviates 1/2 dot	
3	PAPI shows 3 white 1 red, little corrections made for that	
4	Maintains Vref above the runway threshold	
5	The aircraft is left of centerline, and the right gear is left of the centerline	
6	Started flare and touched down at Vref-5	
7	Main landing gear touches down first at a slightly harder touch down rate.	
8	Land at touch down zone 1000' markers at +500ft	
9	Used rudder and differential braking to correct back to centerline	
10	Oscilatted left and right of centerline due to inproper brake usage, until below 40kts.	

	Emergency Evacuation - Score of 4	**Expected Duration: 1:00**
Event	PF Actions	PM Actions
	Starting Position: After touchdown, rolling on Runway 10@KLAF, Heading 100, Speed 30kts; Flaps Full, Gear Down, VMC Weather	
1	Fire, Fire, Fire on both engines	
2	**"Silence the warning, and we are going to evacuate as we stop"**	
3		**"I will call ATC"**
4		**"Mayday Mayday Mayday, Phenom 100PU, both engines on fire, evacuating to the left side"**
5	Thrust Levers, Idle	
6	Emergency/Parking Brake, Set	
7	Start Stop Knobs Stop	
8	Shutoff 1 & 2 Buttons, Push in	
9	Fire Bottle Select	
10	Pressurization Mode Switch - Manual	
11	Dump - Push in	
12	ATC - notified	**"Notified"**
13	Evacuation - Perform	
14	"Evacuate via the main doors only!"	
15	**BATT 1 & 2 switches - off**	

	Emergency Evacuation - Score of 4	**Expected Duration: 1:00**
Event	PF Actions	PM Actions
	Starting Position: After touchdown, rolling on Runway 10@KLAF, Heading 100, Speed 30kts; Flaps Full, Gear Down, VMC Weather	
1	Fire, Fire, Fire on both engines	
2	**"Silence the warning, and we are going to evacuate as we stop"**	
3		**"I will call ATC"**
4		**"Mayday Mayday Mayday, Phenom 100PU, both engines on fire, evacuating to the left side"**
5	Thrust Levers, Idle	
6	Emergency/Parking Brake, Set	
7	Start Stop Knobs Stop	
8	Shutoff 1 & 2 Buttons, Push in	
9	Pressurization Mode Switch - Manual	
10	Dump - Push in	
11	ATC - notified	**"Notified"**
12	Evacuation - Perform	
13	"Evacuate via the main doors only!"	
14	**BATT 1 & 2 switches - off**	

	Emergency Evacuation - Score of 1	**Expected Duration: 1:00**
Event	PF Actions	PM Actions
	Starting Position: After touchdown, rolling on Runway 10@KLAF, Heading 100, Speed 30kts; Flaps Full, Gear Down, VMC Weather	
1	**Fire, Fire, Fire on both engines**	
2	**Did not silence the fire warning**	
3	Stopped the aircraft and did nothing	
4	Did not announce anything, started the evacuation checklist by memory	
5	Start/Stop Knobs - Stop	
6	**"Hey can you pull out the QRH?"**	
7		**"I am going to pull out the QRH"**
8		(Spends the next minute looking for the pages)
9	Pressurization Mode Switch - Manual	
10	Dump - Push in	
11	Did not notify ATC	
12	**"Evacuate!!! Go go go go!"**	
13	Did not shut of BATT 1 & 2	

	V1 Cut - Score of 4	**Expected Duration: 2:30**
Event	PF Actions	PM Actions
	Starting Position: Runway 10, Heading mode, TO mode, aircraft configured for takeoff	
1	TOGA: **"Thrust Set"**	
2	When ATR armed…	**"ATR armed"**
3	When airspeed alive…	**"Airspeed Alive"**
4	At 70 knots…	**"70 knots"**
5	**"Checked"**	
6	At V1…	**"V1, Rotate"**
7	(Lose Engine 1)	**"Engine failure"**
8	Maintain directional control using rudder	
9		**"Positive Rate"**
10	**"Gear Up"**	
11		Pulls the gear up
12	**"Flight Level Change, Bug V2"**	
13		Bug V2 speed, FLC switch
14		**"Mayday Mayday Mayday, Phenom 100PU, Engine failure, departing**
15	1000ft: **"Autopilot On, Bug Vfs"**	
16		Turn on autopilot and bug Vfs
17	Aircraft accelerates…	
18	Right before Vfs: **"Flaps Zero"**	
19		Sets flaps to 0
20	Set thrust to CON/CLB	
21	**"I have control and communication"**	
22	**"Engine 1 Failure Checklist"**	

	V1 Cut - Score of 3	**Expected Duration: 2:30**
Event	PF Actions	PM Actions
	Starting Position: Runway 10, heading mode, TO, aircraft configured for takeoff	
1	TOGA: **"Thrust Set"**	
2	When ATR armed…	**"ATR armed"**
3	When airspeed alive…	**"Airspeed Alive"**
4	At 70 knots…	**"70 knots"**
5	**"Checked"**	
6	At V1…	**"V1, Rotate"**
7	(Lose Engine 1)	**"Engine failure"**
8	Lost directional control to the left for 8 degrees	
9		**"Positive Rate"**
10	**"Gear Up"**	
11		Pulls the gear up
12	**"Flight Level Change, Bug V2"**	
13	Slightly uncoordinated	Bug V2 speed, FLC switch
14		**"Mayday Mayday Mayday, Phenom 100PU, Engine failure, departing**
15	Maintain V2+8kts for climb…	
16	1000ft: **"Autopilot On, Bug Vfs"**	
17		Turn on autopilot and bug Vfs
18	Aircraft accelerates…	
19	After reaching Vfs: **"Flaps Zero"**	
20		Sets flaps to 0
21	Set thrust to CON/CLB	
22	**"I have control and communication"**	
23	**"Engine 1 Failure Checklist"**	

APPENDIX F. PARTICIPANT DEMOGRAPHICS SURVEY

Please enter your **participant ID number**.

What is your **total flight time**?

- <200
- 200-399
- 400-599
- 600-799
- 800-999
- >1000

What are your total hours as a **flight instructor** (dual given)?

- 0-49
- 50-99
- 100-199
- 200-499
- 500-999
- >1000

What is your total flight time in a **flight simulator**? (Include PCATD/BATD/AATD/FTD/FFS)

- 0-49
- 50-99
- 100-149
- >150

Select all the types of **CFI certificates/ratings** you hold.

- CFI
- CFI-I
- MEI
- Gold Seal CFI

Approximately what time did you take your initial CFI checkride? (e.g. Fall 2015, Summer 2016)

How many students have you taught as a **flight instructor**? (Include students you are currently teaching; only include students you have trained for more than 5 hours; Include all simulator students)

- 0
- 1-3
- 3-6
- 6-12
- >12

Do you have any experience **teaching in a flight simulator**?

- Yes
- No

How many hours do you have on the **ACTUAL Phenom 100** aircraft?

- 0
- 1-6
- 7-15
- >15

What is your status for the **AT395** (Phenom 100 **Simulator** Course)?

- Enrolled this semester
- Completed during Fall 2017
- Completed during Summer 2017 or before
- Did not take

What is your status for the **AT396** (Phenom 100 **Flight** Course)?

- Enrolled this semester
- Completed during Fall 2017
- Completed during Summer 2017 or before
- Did not take

APPENDIX G. SUGGESTIONS AND COMMENTS FROM PARTICIPANTS

It was good to show a variety of different maneuvers and skill levels. However, most of us as CFIs instruct in smaller GA planes, not the Phenom or Phenom sim. Maybe it would be good to do this experiment with maneuvers in the Cirrus or Frasca sims, representing small GA aircraft that most of us do CFI in?
I think that this was a good experience, however it would help to know the level of student being evaluated, as expectations would differ for someone who is entering the course and then towards the end of completing it.
Near the end of the pre-test session, i felt rushed as more and more people left the computer lab. This changed how detailed i was with my responses and analysis of the scenarios. Had all of the participants stayed in the room until everyone was complete, i feel i would have taken more time to analyze the laws two videos.
clearer video quality needed wider/multiple views of instrumentation (esp. nav dats on MFD during ILS)
There was a lot of paper used and distributed for this project. Some of the material probably could have been presented electronically (for example, the PTS/SOP packet could have been opened in another window as a PDF) to keep waste down. I liked the experiment and the way it was conducted overall.

Implementation of the workshop into the Hangar 6 standardization would greatly improve grading. It is many instructor's first time instructing and they are worried more about the student not killing them then they are giving them a grade. this is a very simple and straight forward grading procedure that i think would be beneficial to all grading flight operations.
I had briefly gone over the 1-4 grading system with my instructor for 396 so had an idea how the system worked going into the first set of videos. After the workshop I had a deeper understanding of the grading system and used my knew knowledge to the best of my abilities to grade the students. I do believe however that my grades from the first set of videos are likely similar to the second set of videos only because my understanding of the grading system before hand. I do believe that I may have graded harder before my understanding after the work shop. All in all in was a great experience for me to get some more practice and understanding of different teaching and grading methods.
Incorporating more borderline scenarios to lead to a discussion. It would be necessary to have one correct standard answer to provide after the discussion.
Have the group who attended the workshop do the second round of grading without the training packet in front of them as they grade. In the real world it will be unlikely they will carry this with them as they are grading students. Another suggestion is to only

Make airspeed and glideslope more visible on some of the videos - was hard to read and thus grade as a result (mostly the landing video).
This was great, and I really hope to see something like this implemented in the future. It takes a LARGE amount of subjectivity out of the grading process and makes it more streamlined and sets a more recognizable goal for both students and instructors alike to reach. Hearing that this is used in the industry only furthers my hope that this becomes standard practice in America.
The presentation diagram was very helpful to help with the grading. Allen did an excellent job explaining the problems and challenges that instructors face and applying it to our daily flight. I believe that this SHOULD be mandatory for all instructors. It would help me be less random with the grading of my students especially at H6.
This was awesome Allen. I think all CFI's should go through the workshop for Purdue Aviation and University.
Kind of hard to judge the flights because it was hard to tell what the airspeeds and other indications were. made it slightly difficulty to be picky with airspeeds but overall was a good study and I feel I will be taking a lot away from it.
none that i can think of
Excellent workshop. I hope we transition to this grading system and use this training during Stan week

APPENDIX H. PRE-TEST ANALYSIS FOR FIVE SCENARIOS

Fleiss' Kappa for Pre-test Control Group

Fleiss' Kappa for m Raters
Pre-test Control Group

Subjects = 5

Raters = 9

Kappa = 0.113

z = 2.3
p-value = 0.0215

Fleiss' Kappa for Pre-test Treatment Group

Fleiss' Kappa for m Raters
Pre-test Treatment Group

Subjects = 5

Raters = 20

Kappa = 0.132

z = 6.01
p-value = 1.87e-09

Descriptive Statistics for Pre-test Control Group MAD

Descriptives

			Statistic	Std. Error
PreControl	Mean		.4889	.10062
	95% Confidence Interval for Mean	Lower Bound	.2569	
		Upper Bound	.7209	
	5% Trimmed Mean		.4988	
	Median		.6000	
	Variance		.091	
	Std. Deviation		.30185	
	Minimum		.00	
	Maximum		.80	
	Range		.80	
	Interquartile Range		.60	
	Skewness		-.425	.717
	Kurtosis		-1.360	1.400

Normality Tests for Pre-test Control Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PreControl	.199	9	.200*	.886	9	.180

Note. *. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Descriptive Statistics for Pre-test Treatment Group MAD

Descriptives

			Statistic	Std. Error
PreTreatment	Mean		.4800	.06224
	95% Confidence Interval for Mean	Lower Bound	.3497	
		Upper Bound	.6103	
	5% Trimmed Mean		.4778	
	Median		.4000	
	Variance		.077	
	Std. Deviation		.27834	
	Minimum		.00	
	Maximum		1.00	
	Range		1.00	
	Interquartile Range		.40	
	Skewness		.359	.512
	Kurtosis		-.503	.992

Normality Tests for Pre-test Treatment Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PreTreatment	.163	20	.171	.935	20	.191

Note. a. Lilliefors Significance Correction

Group Statistics for Pre-test MAD

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
PreTest	1.00	9	.4889	.30185	.10062
	2.00	20	.4800	.27834	.06224

Levene's Test for Pre-Test MAD

Test of Homogeneity of Variances

PreTest

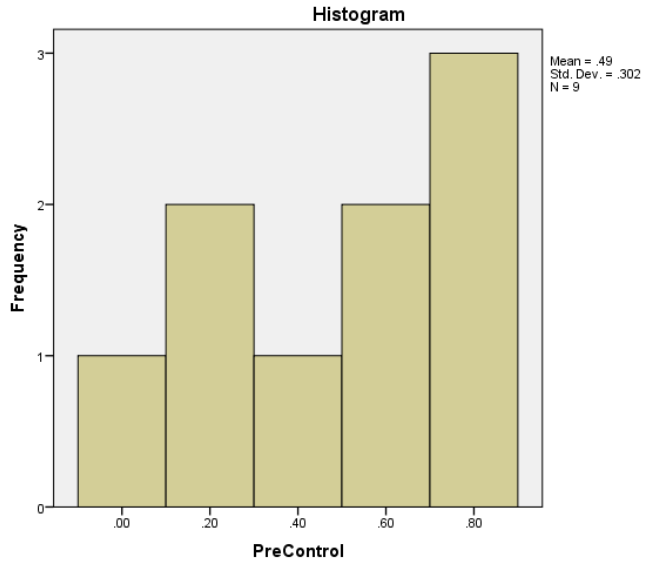
Levene Statistic	df1	df2	Sig.
.245	1	27	.625

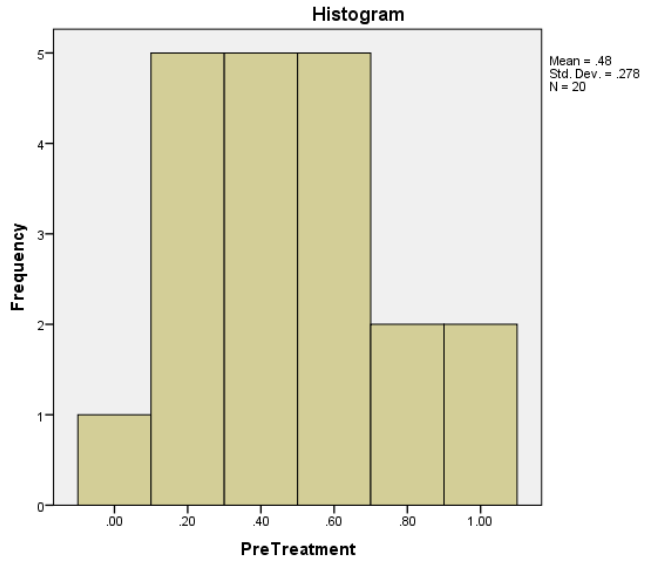
Independent samples T-Test for Pre-test MAD

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PreTest	Equal variances assumed	.078	27	.939	.00889	.11460	-.22625	.24403
	Equal variances not assumed	.075	14.406	.941	.00889	.11831	-.24419	.26197

Mann-Whitney U Test for Pre-test MAD





Ranks

	Group	N	Mean Rank	Sum of Ranks
PreTest	1.00	9	15.44	139.00
	2.00	20	14.80	296.00
	Total	29		

Test Statistics[a]

	PreTest
Mann-Whitney U	86.000
Wilcoxon W	296.000
Z	-.193
Asymp. Sig. (2-tailed)	.847
Exact Sig. [2*(1-tailed Sig.)]	.871[b]

Note. a. Grouping Variable: Group

b. Not corrected for ties.

APPENDIX I. POST-TEST ANALYSIS FOR FIVE SCENARIOS

Fleiss' Kappa for Post-test Control Group

Fleiss' Kappa for m Raters
Post-test Control Group

Subjects = 5

Raters = 9

Kappa = 0.144

z = 3.16
p-value = 0.00156

Fleiss' Kappa for Post-test Treatment Group

Fleiss' Kappa for m Raters
Post-test Treatment Group

Subjects = 5

Raters = 20

Kappa = 0.507

z = 25.8
p-value = 0

Descriptive Statistics for Post-test Control Group MAD

Descriptives

			Statistic	Std. Error
PostControl	Mean		.4667	.07454
	95% Confidence Interval for Mean	Lower Bound	.2948	
		Upper Bound	.6385	
	5% Trimmed Mean		.4741	
	Median		.4000	
	Variance		.050	
	Std. Deviation		.22361	
	Minimum		.00	
	Maximum		.80	
	Range		.80	
	Interquartile Range		.20	
	Skewness		-.843	.717
	Kurtosis		1.943	1.400

Normality Tests for Post-test Control Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PostControl	.272	9	.054	.883	9	.170

Note. a. Lilliefors Significance Correction

Descriptive Statistics for Post-test Treatment Group MAD

Descriptives

			Statistic	Std. Error
PostTreatment	Mean		.2600	.04377
	95% Confidence Interval for Mean	Lower Bound	.1684	
		Upper Bound	.3516	
	5% Trimmed Mean		.2556	
	Median		.2000	
	Variance		.038	
	Std. Deviation		.19574	
	Minimum		.00	
	Maximum		.60	
	Range		.60	
	Interquartile Range		.35	
	Skewness		.067	.512
	Kurtosis		-.964	.992

Normality Tests for Post-test Treatment Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PostTreatment	.213	20	.018	.879	20	.017

Note. a. Lilliefors Significance Correction

Group Statistics for Post-test MAD

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
PostTest	1.00	9	.4667	.22361	.07454
	2.00	20	.2600	.19574	.04377

Levene's Test for Post-Test MAD

Test of Homogeneity of Variances

PostTest

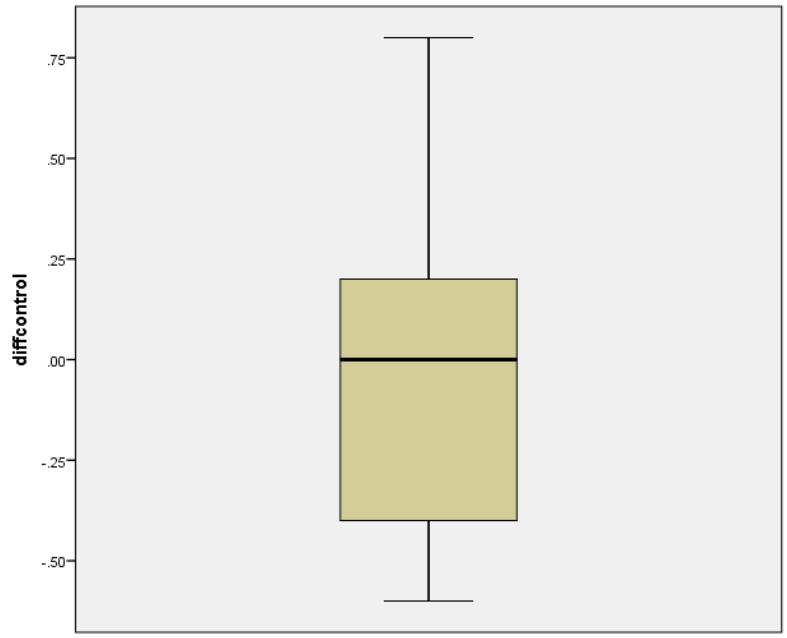
Levene Statistic	df1	df2	Sig.
.005	1	27	.947

Independent samples T-Test for Post-test MAD

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PostTest	Equal variances assumed	2.519	27	.018	.20667	.08204	.03833	.37500
	Equal variances not assumed	2.391	13.779	.032	.20667	.08644	.02100	.39233

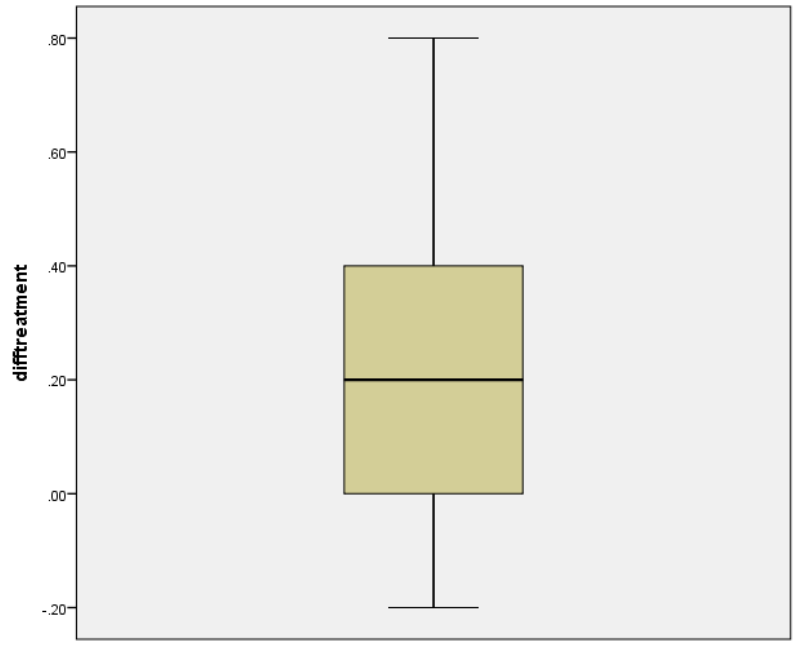
Paired Samples T-Test for Control Group MAD



Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
PreControl - PostControl	.02222	.44096	.14699	-.31673	.36117	.151	8	.884

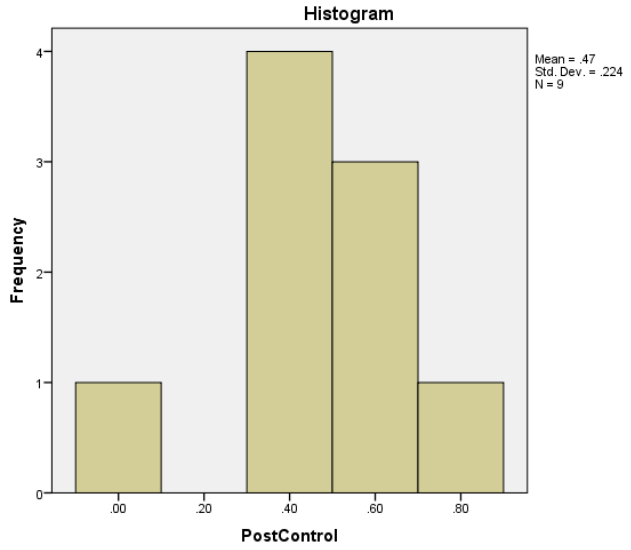
Paired Samples T-Test for Treatment Group MAD

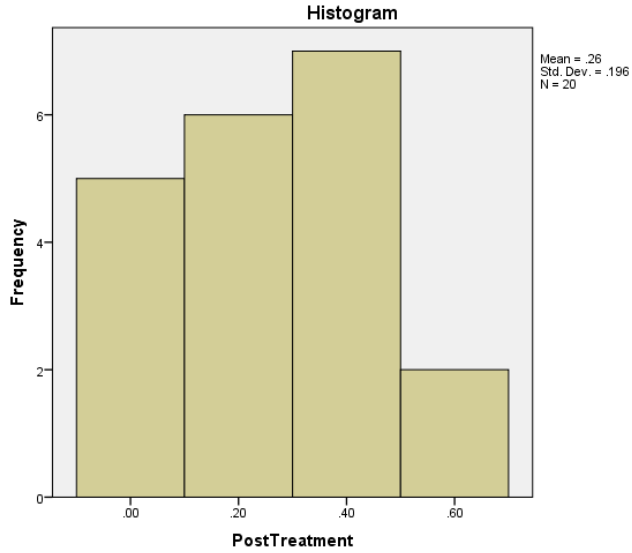


Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
			Std. Error	95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Mean	Lower	Upper			
PreTreatment - PostTreatment	.22000	.28210	.06308	.08797	.35203	3.488	19	.002

Mann-Whitney U Test for Post-test MAD





Ranks

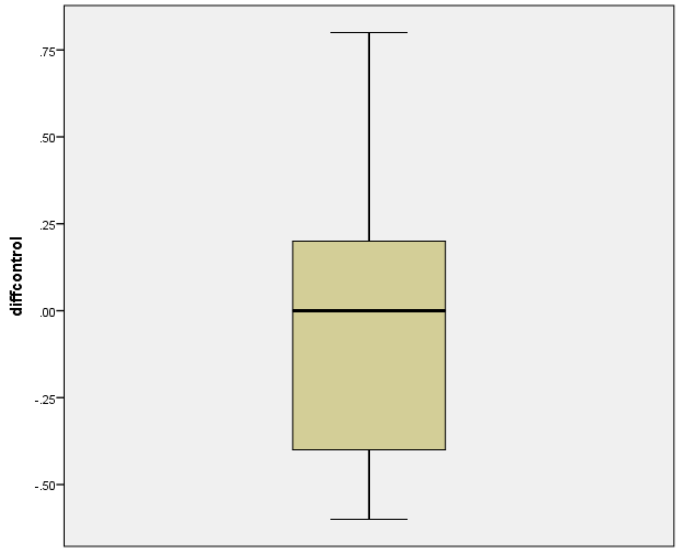
	Group	N	Mean Rank	Sum of Ranks
PostTest	1.00	9	20.28	182.50
	2.00	20	12.63	252.50
	Total	29		

Test Statistics[a]

	PostTest
Mann-Whitney U	42.500
Wilcoxon W	252.500
Z	-2.330
Asymp. Sig. (2-tailed)	.020
Exact Sig. [2*(1-tailed Sig.)]	.023[b]

Note. a. Grouping Variable: Group
b. Not corrected for ties.

Wilcoxon Signed Rank Test for Control Group MAD



Ranks

		N	Mean Rank	Sum of Ranks
PostControl - PreControl	Negative Ranks	4[a]	3.50	14.00
	Positive Ranks	3[b]	4.67	14.00
	Ties	2[c]		
	Total	9		

Note. a. PostControl < PreControl
b. PostControl > PreControl
c. PostControl = PreControl

Test Statistics[a]

	PostControl - PreControl
Z	.000[b]
Asymp. Sig. (2-tailed)	1.000

Note. a. Wilcoxon Signed Ranks Test
b. The sum of negative ranks equals the sum of positive ranks.

Sign Test for Control Group MAD

Frequencies

		N
PostControl - PreControl	Negative Differences[a]	4
	Positive Differences[b]	3
	Ties[c]	2
	Total	9

Note. a. PostControl < PreControl
b. PostControl > PreControl
c. PostControl = PreControl

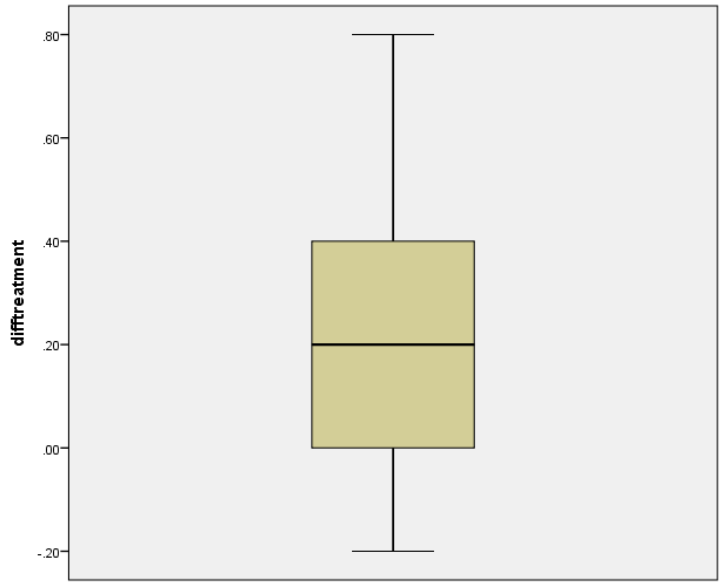
Test Statistics[a]

	PostControl - PreControl
Exact Sig. (2-tailed)	1.000[b]

Note. a. Sign Test

b. Binomial distribution used.

Wilcoxon Signed Rank Test for Treatment Group MAD



Ranks

		N	Mean Rank	Sum of Ranks
PostTreatment - PreTreatment	Negative Ranks	14[a]	9.64	135.00
	Positive Ranks	3[b]	6.00	18.00
	Ties	3[c]		
	Total	20		

Note. a. PostTreatment < PreTreatment

b. PostTreatment > PreTreatment

c. PostTreatment = PreTreatment

Test Statistics[a]

	PostTreatment - PreTreatment
Z	-2.861[b]
Asymp. Sig. (2-tailed)	.004

Note. a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.

Sign Test for Treatment Group MAD

Frequencies

		N
PostTreatment - PreTreatment	Negative Differences[a]	14
	Positive Differences[b]	3
	Ties[c]	3
	Total	20

Note. a. PostTreatment < PreTreatment
b. PostTreatment > PreTreatment
c. PostTreatment = PreTreatment

Test Statistics[a]

	PostTreatment - PreTreatment
Exact Sig. (2-tailed)	.013[b]

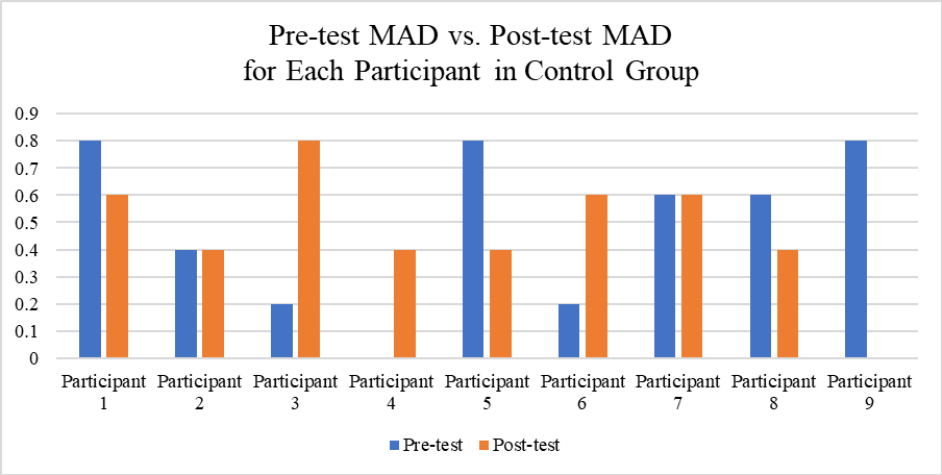
Note. a. Sign Test
b. Binomial distribution used.

Pearson Product-moment Correlation

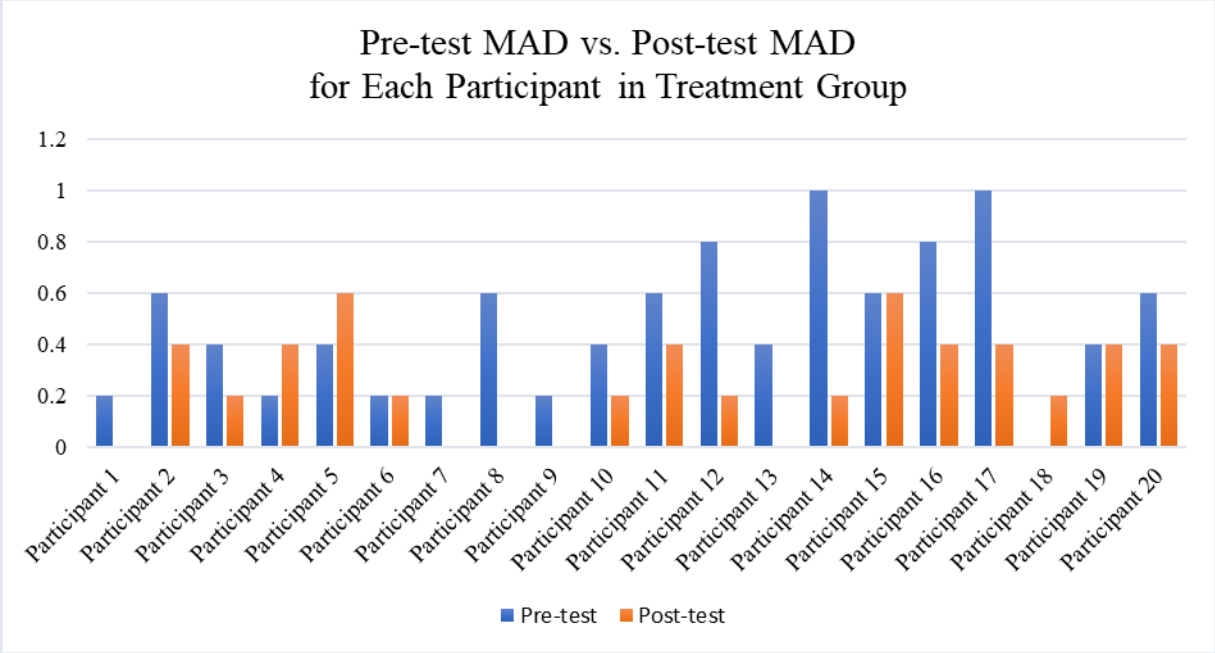
Correlations

		Pre-test	Post-test
Pre-test	Pearson Correlation	1	-.395
	Sig. (2-tailed)		.293
	N	9	9
Post-test	Pearson Correlation	-.395	1
	Sig. (2-tailed)	.293	
	N	9	9

Pre-test MAD vs. Post-test MAD for Each Participant in Control Group



Pre-test MAD vs. Post-test MAD for Each Participant in Treatment Group



APPENDIX J. PRE-TEST ANALYSIS FOR SIX SCENARIOS

Fleiss' Kappa for Pre-test Control Group

Fleiss' Kappa for m Raters
Pre-test Control Group

Subjects = 6

Raters = 9

Kappa = 0.275

z = 6.64
p-value = 3.12e-11

Fleiss' Kappa for Pre-test Treatment Group

Fleiss' Kappa for m Raters
Pre-test Treatment Group

Subjects = 6

Raters = 20

Kappa = 0.255

z = 14.2
p-value = 0

Descriptive Statistics for Pre-test Control Group MAD

Descriptives

			Statistic	Std. Error
PreControl6	Mean		.4259	.07911
	95% Confidence Interval for Mean	Lower Bound	.2435	
		Upper Bound	.6084	
	5% Trimmed Mean		.4362	
	Median		.5000	
	Variance		.056	
	Std. Deviation		.23733	
	Minimum		.00	
	Maximum		.67	
	Range		.67	
	Interquartile Range		.42	
	Skewness		-.645	.717
	Kurtosis		-.543	1.400

Normality Tests for Pre-test Control Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PreControl6	.178	9	.200*	.899	9	.246

Note. *. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Descriptive Statistics for Pre-test Treatment Group MAD

Descriptives

			Statistic	Std. Error
PreTreatment6	Mean		.4417	.05577
	95% Confidence Interval for Mean	Lower Bound	.3249	
		Upper Bound	.5584	
	5% Trimmed Mean		.4444	
	Median		.5000	
	Variance		.062	
	Std. Deviation		.24941	
	Minimum		.00	
	Maximum		.83	
	Range		.83	
	Interquartile Range		.46	
	Skewness		.044	.512
	Kurtosis		-.875	.992

Normality Tests for Pre-test Treatment Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PreTreatment6	.192	20	.051	.917	20	.088

Note. a. Lilliefors Significance Correction

Group Statistic for Pre-test MAD

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
PreTest6	1.00	9	.4259	.23733	.07911
	2.00	20	.4417	.24941	.05577

Levene's Test for Pre-Test MAD

Test of Homogeneity of Variances

PreTest6

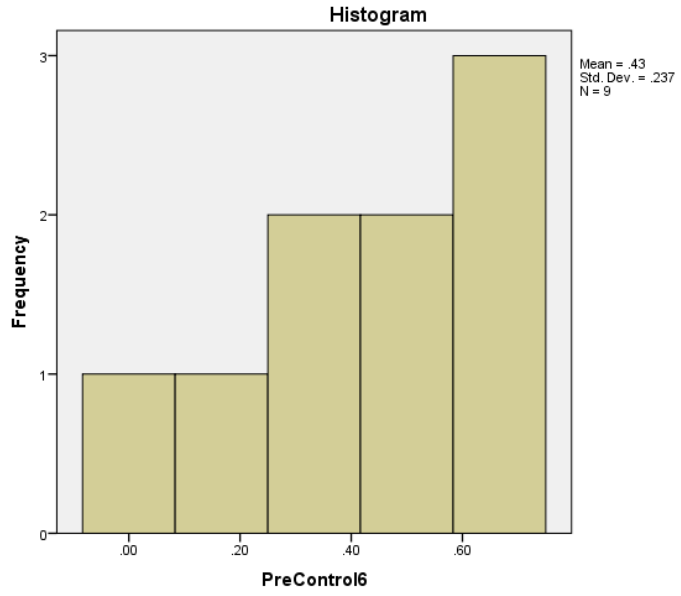
Levene Statistic	df1	df2	Sig.
.035	1	27	.853

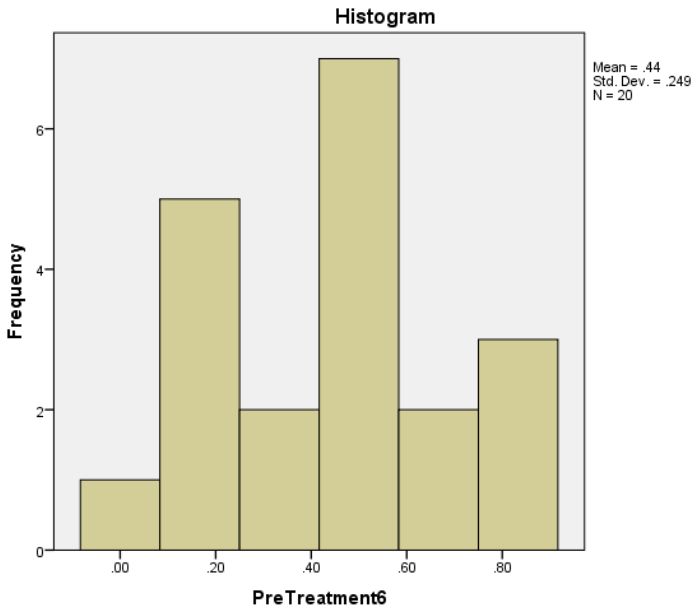
Independent samples T-Test for Pre-test MAD

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PreTest6	Equal variances assumed	-.159	27	.874	-.01574	.09870	-.21826	.1867
	Equal variances not assumed	-.163	16.239	.873	-.01574	.09679	-.22069	.1892

Mann-Whitney U Test for Pre-test MAD





Ranks

	Group	N	Mean Rank	Sum of Ranks
PreTest6	1.00	9	14.89	134.00
	2.00	20	15.05	301.00
	Total	29		

Test Statistics[a]

	PreTest6
Mann-Whitney U	89.000
Wilcoxon W	134.000
Z	-.048
Asymp. Sig. (2-tailed)	.961
Exact Sig. [2*(1-tailed Sig.)]	.982[b]

Note. a. Grouping Variable: Group

b. Not corrected for ties.

APPENDIX K. POST-TEST ANALYSIS FOR SIX SCENARIOS

Fleiss' Kappa for Post-test Control Group

Fleiss' Kappa for m Raters
Post-test Control Group

Subjects = 6

Raters = 9

Kappa = 0.101

z = 2.48
p-value = 0.0132

Fleiss' Kappa for Post-test Treatment Group

Fleiss' Kappa for m Raters
Post-test Treatment Group

Subjects = 6

Raters = 20

Kappa = 0.441

z = 25.2
p-value = 0

Descriptive Statistics for Post-test Control Group MAD

Descriptives

			Statistic	Std. Error
PostControl6	Mean		.6296	.08686
	95% Confidence Interval for Mean	Lower Bound	.4293	
		Upper Bound	.8299	
	5% Trimmed Mean		.6348	
	Median		.6667	
	Variance		.068	
	Std. Deviation		.26058	
	Minimum		.17	
	Maximum		1.00	
	Range		.83	
	Interquartile Range		.42	
	Skewness		-.541	.717
	Kurtosis		-.145	1.400

Normality Tests for Post-test Control Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PostControl6	.223	9	.200*	.951	9	.701

Note. *. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Descriptive Statistics for Post-test Treatment Group MAD

Descriptives

			Statistic	Std. Error
PostTreatment6	Mean		.3667	.05748
	95% Confidence Interval for Mean	Lower Bound	.2464	
		Upper Bound	.4870	
	5% Trimmed Mean		.3611	
	Median		.4167	
	Variance		.066	
	Std. Deviation		.25706	
	Minimum		.00	
	Maximum		.83	
	Range		.83	
	Interquartile Range		.33	
	Skewness		-.084	.512
	Kurtosis		-1.046	.992

Normality Tests for Post-test Treatment Group MAD

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PostTreatment6	.198	20	.039	.919	20	.094

Note. a. Lilliefors Significance Correction

Group Statistic for Pre-test MAD

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
PostTest6	1.00	9	.6296	.26058	.08686
	2.00	20	.3667	.25706	.05748

Levene's Test for Post-Test MAD

Test of Homogeneity of Variances

PostTest6

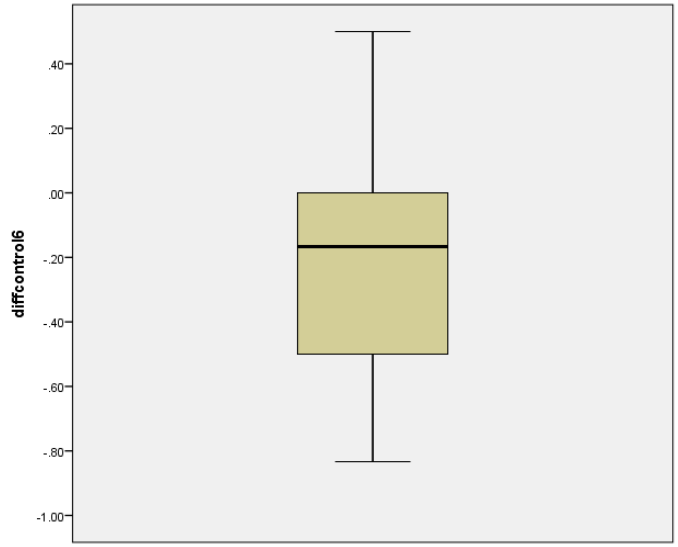
Levene Statistic	df1	df2	Sig.
.121	1	27	.731

Independent samples T-Test for Post-test MAD

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PostTest6	Equal variances assumed	2.538	27	.017	.26296	.10360	.05039	.47554
	Equal variances not assumed	2.525	15.305	.023	.26296	.10416	.04134	.48458

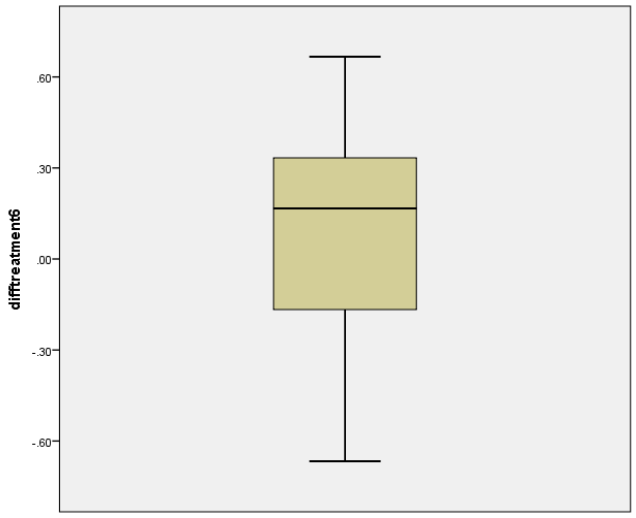
Paired Samples T-Test for Control Group MAD



Paired Samples Test

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
PreControl6 - PostControl6	-.20370	.46976	.15659	-.56480	.15739	-1.301	8	.230

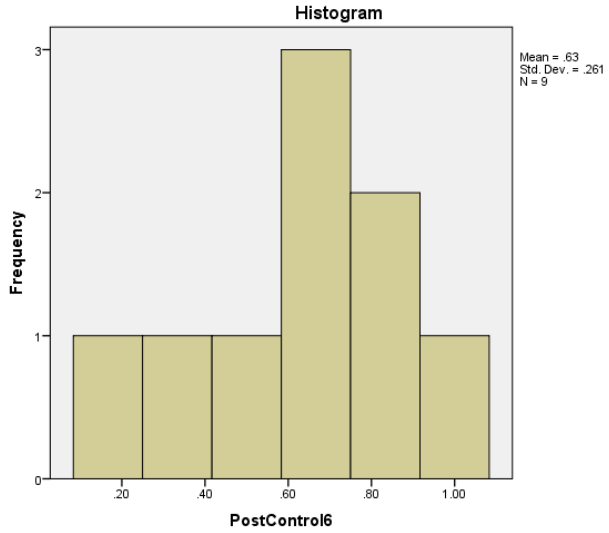
Paired Samples T-Test for Treatment Group MAD

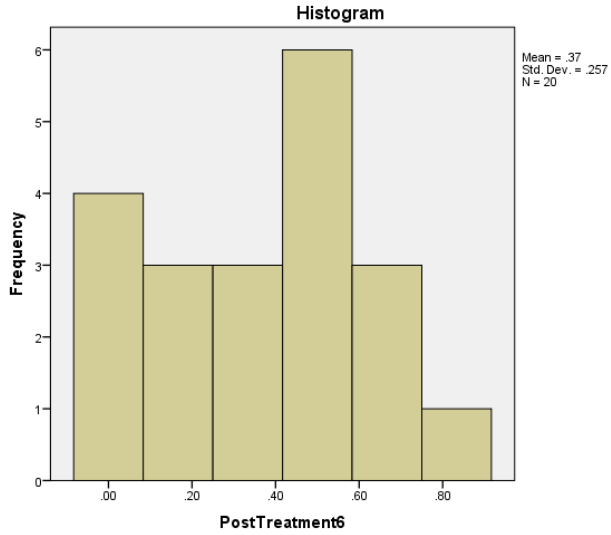


Paired Samples Test

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
PreTreatment6 - PostTreatment6	.07500	.34402	.07692	-.08601	.23601	.975	19	.342

Mann-Whitney U Test for Post-test MAD





Ranks

	Group	N	Mean Rank	Sum of Ranks
PostTest6	1.00	9	20.39	183.50
	2.00	20	12.58	251.50
	Total	29		

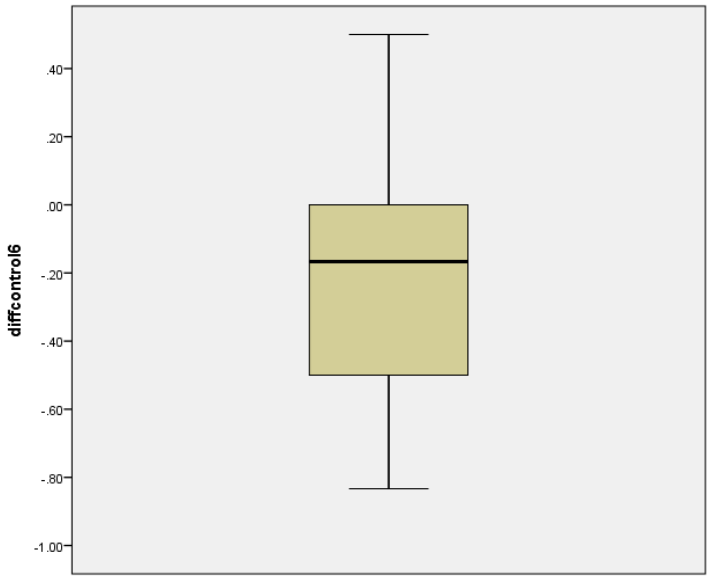
Test Statistics[a]

	PostTest6
Mann-Whitney U	41.500
Wilcoxon W	251.500
Z	-2.322
Asymp. Sig. (2-tailed)	.020
Exact Sig. [2*(1-tailed Sig.)]	.020[b]

Note. a. Grouping Variable: Group

b. Not corrected for ties.

Wilcoxon Signed Rank Test for Control Group MAD



Ranks

		N	Mean Rank	Sum of Ranks
PostControl6 - PreControl6	Negative Ranks	2[a]	3.50	7.00
	Positive Ranks	5[b]	4.20	21.00
	Ties	2[c]		
	Total	9		

Note. a. PostControl6 < PreControl6

b. PostControl6 > PreControl6

c. PostControl6 = PreControl6

Test Statistics[a]

	PostControl6 - PreControl6
Z	-1.190[b]
Asymp. Sig. (2-tailed)	.234

Note. a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Sign Test for Control Group MAD

Frequencies

		N
PostControl6 - PreControl6	Negative Differences[a]	2
	Positive Differences[b]	5
	Ties[c]	2
	Total	9

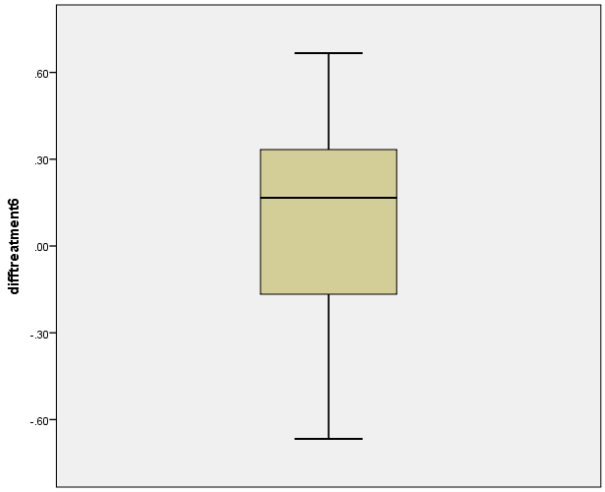
Note. a. PostControl6 < PreControl6
b. PostControl6 > PreControl6
c. PostControl6 = PreControl6

Test Statistics[a]

	PostControl6 - PreControl6
Exact Sig. (2-tailed)	.453[b]

Note. a. Sign Test
b. Binomial distribution used.

Wilcoxon Signed Rank Test for Treatment Group MAD



Ranks

		N	Mean Rank	Sum of Ranks
PostTreatment6 - PreTreatment6	Negative Ranks	12[a]	9.04	108.50
	Positive Ranks	6[b]	10.42	62.50
	Ties	2[c]		
	Total	20		

Note. a. PostTreatment6 < PreTreatment6
b. PostTreatment6 > PreTreatment6
c. PostTreatment6 = PreTreatment6

Test Statistics[a]

	PostTreatment6 - PreTreatment6
Z	-1.013[b]
Asymp. Sig. (2-tailed)	.311

Note. a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.

Sign Test for Treatment Group MAD

Frequencies

		N
PostTreatment6 - PreTreatment6	Negative Differences[a]	12
	Positive Differences[b]	6
	Ties[c]	2
	Total	20

Note. a. PostTreatment6 < PreTreatment6
b. PostTreatment6 > PreTreatment6
c. PostTreatment6 = PreTreatment6

Test Statistics[a]

	PostTreatment6 - PreTreatment6
Exact Sig. (2-tailed)	.238[b]

Note. a. Sign Test
b. Binomial distribution used.

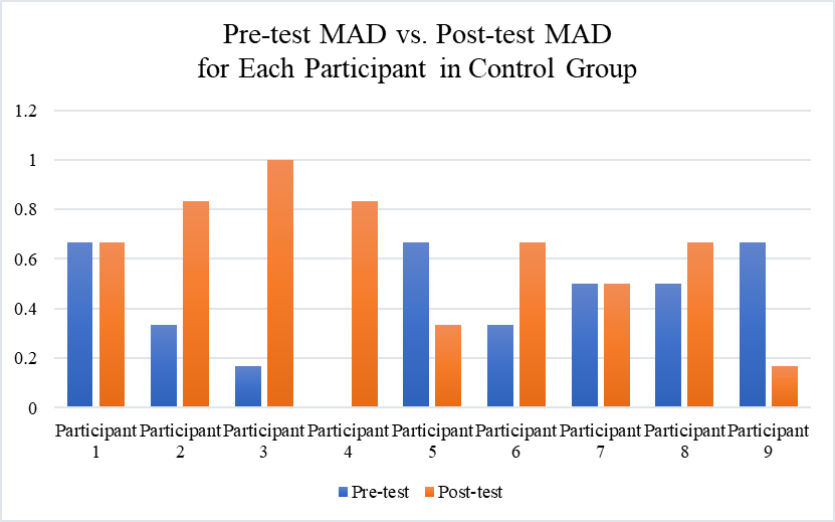
Pearson Product-moment Correlation

Correlations

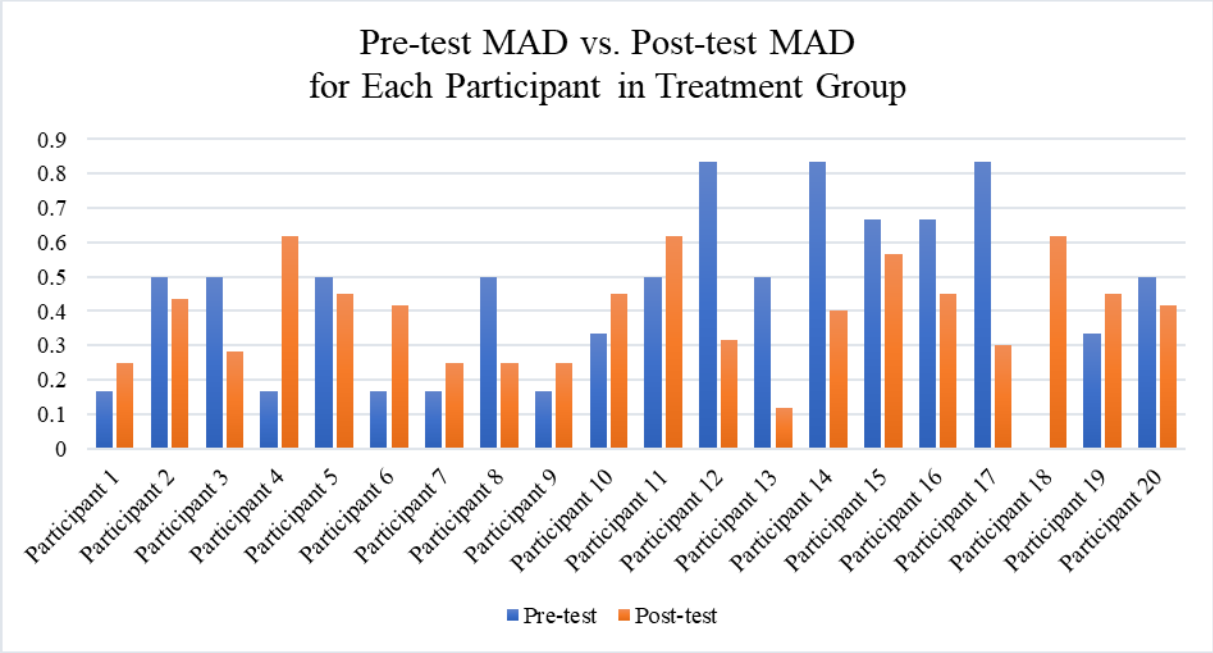
		Pre-test	Post-test
Pre-test	Pearson Correlation	1	-.780*
	Sig. (2-tailed)		.013
	N	9	9
Post-test	Pearson Correlation	-.780*	1
	Sig. (2-tailed)	.013	
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

Pre-test MAD vs. Post-test MAD for Each Participant in Control Group



Pre-test MAD vs. Post-test MAD for Each Participant in Treatment Group



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