USE OF A DISCRIMINATIVE AUDITORY CUE TO IMPROVE LANDING FLARE PERFORMANCE

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USE OF A DISCRIMINATIVE AUDITORY CUE TO IMPROVE LANDING FLARE PERFORMANCE

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TABLE OF CONTENTS

Chapter Page

III. DESIGN AND METHODOLOGY

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

One of the first obstacles that student pilots have to face is landing an aircraft. Perfect landings are the ambition of every pilot and landings are frequently used to evaluate pilot performance (Collins, 1981; Fowler, 1984; King, 1998). Failure to properly land the aircraft increases time to solo and may discourage students from pursuing the private pilot certificate. Yet, it is specifically the landing phase that most pilots struggle with (Balfour, 1988; Matson, 1973; Nagel, 1988). Figure 1 shows the breakdown of mean total and fatal accident-involved aircraft by first phase of operation for the years 1995, 1996, and 1997 (National Transportation Safety Board [NTSB], September 1998; NTSB, May 1999; NTSB, September 2000), and establishes the landing phase as the leading cause of all non-fatal aircraft accidents.

A special maneuver within the landing phase of operation is the flare. The flare is the transition from a controlled descent to actual contact with the landing surface (Federal Aviation Administration, Revised 1999; Grosz et al., 1995) and is also known as the flareout, roundout, or leveloff (Jeppesen, 1985).

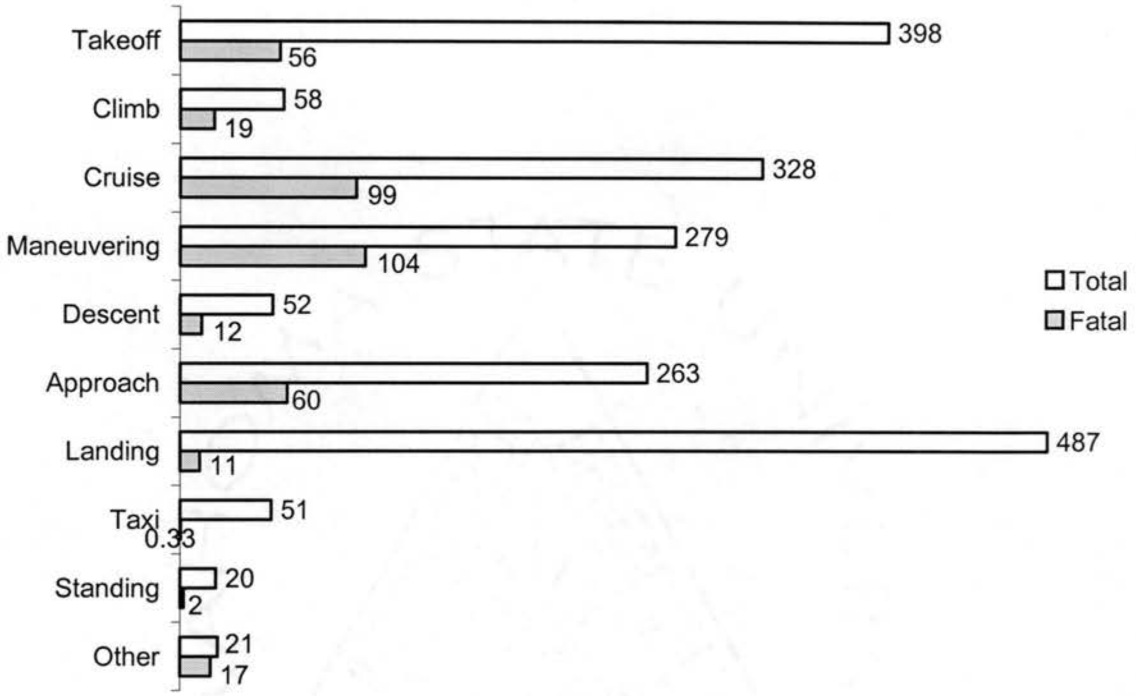

Figure 1. A Breakdown of Mean Total and Fatal Accident-Involved Aircraft by First Phase of Operation, 1995, 1996, and 1997.

Nature of the Problem

The ability to determine the aircraft altitude is critical to a successful flare (Love, 1995) and may distinguish between a proper and improper flare. The flare is tantamount to braking an automobile with the purpose of preventing a collision with a wall (Grosz et al., 1995). Whereas breaking too late would result in an unpleasant impact, breaking too early would stop the automobile before reaching the wall. Similarly, flaring an aircraft too late may result in an unpleasant impact with the runway surface (see Federal Aviation Administration, Revised 1999; Christy, 1991; Jeppesen, 1985; Kershner, 1981; Kershner, 1998; Love, 1995), bouncing (Kershner, 1998), or a “wheelbarrow” landing (Butcher, 1996; Love, 1995). Conversely, flaring too early (see Christy, 1991; Gleim, 1998; Jeppesen, 1985; Kershner, 1998; King, 1999; Quinlan, 1999) will not stop the aircraft in midair, but will lead to a stall and hard landing (Federal Aviation Administration, Revised 1999).

Recognizing the mechanism by which pilots determine the aircraft altitude Above Ground Level (AGL) is paramount to the success of any flare instruction. According to the title 14 Code of Federal Regulations (CFR), altimeter tolerance is set at 9.14 m (30 ft), but it is not uncommon for General Aviation (GA) altimeters to be off by as much as 22.86 m (75 ft). Obviously, GA pilots that initiate the flare 3.05 - 6.10 m (10 - 20 ft) AGL cannot rely on the altimeter and must resort to alternative cues. Such cues consist of ground effect, time-to-contact (see Grosz et al., 1995; Mulder, Pleijsant, van der Vaart, & van Wieringen, 2000), and kinesthetic information (Jeppesen, 1985; Menon, 1996). Nevertheless, it appears that pilots use vision more than any other tool to determine their altitude during the flare (Federal Aviation Administration, Revised 1999; Green, Muir, James, Gradwell, & Green, 1996; Jeppesen, 1985; Thom 1992). Specifically, pilots rely on monocular rather than binocular vision during the approach, landing, and flare (Benson, 1999; Bond, Bryan, Rigney, & Warren, 1962). An in-depth discussion of binocular and monocular vision is beyond the scope of this paper. Nevertheless, a distinction between the two is vital to the discrimination between effective and ineffective flare instructions.

Binocular (bi=two, ocular=eye) vision combines sensory information from both eyes. The disparate visual signals from each eye are fused to produce three-dimensional depth perceptions (see Goldstein, 1980). Fusion is also known as stereopsis and is thought of as “pure” three-dimensional vision. As Table 1 shows, the two other binocular cues are accommodation and convergence. Unlike binocular vision, monocular (mono=one, ocular=eye) vision does not require the use of both eyes (see Benson, 1999; Bond et al., 1962; Green, 1988; Kershner, 1981; Langewiesche, 1972; Peter, 1999; Reinhart, 1996; Reinhardt-Rutland, 1997; Riordan, 1974; Tredici, 1996), and generates depth perception from a two-dimensional environment (Hawkins, 1993; for an example see Nagel, 1988).

Table 1.

Description of Binocular Cues

1. **Accommodation**. The lenses protrude for close and flatten for distant objects.
2. **Convergence**. The eyes move inward for close and outward for distant objects.
3. **Stereopsis**. The fusion of signals from slightly disparate retinal points that result in a visual appreciation of three dimensions.

The subsequent distinction between binocular and monocular vision is fundamental to the success of flare instructions. Binocular depth perception may be an innate ability and certainly exists at a very early age (Reading, 1983; also see Fox, Aslin, Shea, & Dumais, 1980; Kalat, 1998; Reinecke & Simons, 1974). On the other hand, monocular depth perception must be learned over time (Benson, 1999; Bramson, 1982; Langewiesche, 1972; Love, 1995; Marieb,1995; Tredici, 1996) suggesting that the distinction between binocular and monocular vision is akin to the distinction between nature vs nurture.

Another principal distinction between binocular and monocular vision is operational range. Unlike monocular vision, binocular vision has a restricted range and is only dependable for short distances (Green, 1988; Langewiesche, 1972; Reinhardt-Rutland, 1997; Reinhart, 1982; Reinhart, 1996). For example, some birds have visual pathways that are specialized for binocular and monocular vision (Güntürkün, Miceli, & Watanabe, 1993). The tendency to alternate between the two pathways depends on the visual task at hand. Pigeons, eagles, and falcons use monocular vision to search for distant food or enemies, but switch to binocular vision to fixate on close objects when approaching a prey or pecking. This fundamental distinction negates the popular notion that pilots use stereoscopic vision during the landing phase of operation (Langewiesche, 1972), and stresses the importance of monocular cues during the flare.

Reliance on binocular cues may actually hinder pilots from acquiring the necessary skills for depth perception during the flare. For example, Liebermann and Goodman (1991) examined the effects of visual information on the ability to reduce impacts at touchdown from four height categories ranging from 5 - 95 cm (0.16 - 3.12 ft). To generate landing impacts, a horizontal free-fall device with a self-releasing mechanism was used. Participants were randomly assigned to vision and no-vision conditions. Participants in the no vision condition were allowed to see the height from which they would release themselves, as well as the landing surface prior to the free-fall. Liebermann and Goodman discovered that vision during flight did not aid participants in producing softer landings at touchdown. In fact, under certain conditions, higher impacts were registered when vision was available. Thus, Leibermann and Goodman concluded that two-dimensional recollections might have had an advantage over continuous visual guidance.

The contribution of monocular cues to smooth and safe landings led to a plethora of studies that isolated crucial cues. Frequent monocular cues that pilots use to determine altitude during the flare are presented in Appendix A (Benbassat & Abramson, in press, also see Langewiesche, 1972; Riordan, 1974; Tredici, 1996). Nevertheless, it seems that pilots use different cues or a combination of monocular cues and any attempt to determine the superiority of one cue over another is futile (Benbassat & Abramson, in press; Bond et al., 1962; Green, 1988; Riordan, 1974; Tiffin & Bromer, 1943; Warren & Owen, 1982). Moreover, it seems that awareness is not critical to the learning of monocular cues, and that pilots cannot explain how they use vision to determine altitude during the flare (Benbassat & Abramson, in press; Berbaum, Kennedy, &

Hettinger, 1991). These predicaments are reflected in current flare instructions. Overall, traditional flare instructions are inconsistent and ambiguous, and a review of the literature suggested that one flare instruction was not better than another.

In reference to the flare maneuver, the Airplane Flying Handbook (Federal Aviation Administration, Revised 1999) states that the flare should be started within "what appear to be" (p. 7-6) 3.05 - 6.10 m (10 - 20 ft) above the ground. Nevertheless, the handbook does not instruct pilots how to determine what "appears to be" the appropriate altitude, and what seems to one as a reasonable flare altitude may seem "ridiculous" to another (Bramson, 1982, p. 44). Certified Flight Instructors (CFIs) may also provide ambiguous instructions. Instructing pilots to initiate the flare at the height of a double decker bus (Bramson, 1982), hangar height (Kershner, 1998), or one-half of the aircraft wingspan (Christy, 1991) may prove difficult. Not everyone is familiar with a double deck bus, hangar dimensions are not consistent and not all runways have hangars adjacent to them, and using a measurement scale that is parallel to the ground may prove especially difficult. Regretfully, some instructors never really try to explain how to determine flare altitude and resolve to comment such as "just about now begin to flare" or "you're too high!" which only increases the frustration of not knowing when to initiate the flare (Bramson, 1982; Penglis, 1994).

Attempts to design alternative flare training instructions have only met with partial success. One such attempt suggested prolonged flares (Bramson, 1982; Kershner, 1981) or flying the aircraft at flare altitude down the runway. Prolonged flares were presumed to improve scanning techniques and allow pilots to appreciate the visual environment at flare altitude. Matson (1973) examined the effectiveness of prolonged flares as a teaching tool. He investigated the effects of prolonged flares on (a) attempts to land, (b) time-to-land, and (c) time to solo across instructional environments (i.e., aircraft type, instructors, and sequence of maneuvers). No significant differences were found among the students taught by the prolonged flares and those taught by traditional flare methods.

Another attempt incorporated a visual illusion prevalent during the flare (Penglis, 1994; also see Dempsey, 1993; Fowler, 1984). Throughout a normal approach the aircraft appears to be descending towards the ground, but as the aircraft transitions for landing the ground appears to rise toward the aircraft. Pilots should initiate the flare when the ground appears to rise and the nose of the aircraft is at level attitude with the far end of the runway. Placing the nose of the aircraft just under the end of the runway will compel pilots that tend to flare too high to continue their descent until they are able to place the nose just under the runway end. Conversely, pilots that flare too late will be required to initiate the flare earlier in order to achieve the desired visual reference. Nevertheless, a review of the literature and anecdotal evidence did not provide a critical evaluation of this method.

Regretfully, the flare is acknowledged as one of the most difficult maneuvers (Barnhart, as cited in Matson, 1973; Benbassat & Abramson, in press; Langewiesche, 1972; Love, 1995; Penglis, 1994) and landing flare accidents are relatively frequent (Benbassat & Abramson, in press). Yet, landing flare studies are sporadic and the contribution of proper flares to successful landings is traditionally ignored in the literature and aviation safety proceedings. Perhaps that is why "the one phase that can cause the majority of student pilots to question why they took up flying (and make their instructors wish they had stuck to golf) is the transition from approaching down the gentle glide path to that brief flit over the runway. . . " (Bramson, 1982, p. 44).

Statement of The Problem

A review of the literature suggests that flare instructions are not consistent and that no one method is better than another (also see Matson, 1973). Perhaps that is why "the reason no student knows where the ground begins is because the method we use to teach landings to students is wrong and does not work (Penglis, 1994, p. 91). Alternative flare instructions that challenge shortcomings addressed in this paper are desired. Of special interest are standardized behavioral flare instructions that allow pilots to associate proper flare altitude with appropriate cues in the airport visual environment.

Objectives of the Study

Primary

1. Assess the effectiveness of training method on quality of landing. Specific measures included,

- i. Flare altitude
- ii. Vertical Speed at touchdown (VStd)
- iii. Distance from aiming point (dist)
- iv. Velocity at touchdown (Vtd)
- v. Time to solo.

Secondary

1. Assess the effectiveness of training method on perceptions.
2. National Transportation Safety Board (NTSB) Accident Reports
   - i. Assess landing flare accidents rates for 1998 (most recent NTSB yearly report).

Tertiary

1. Assess ergonomics and safety of flare beacon prototype.

Significance of the Study

Failure to accurately determine the aircraft altitude may result in flaring the aircraft too high (Gleim, 1998; King, 1999; Quinlan, 1999) or too low above the runway (Christy, 1991; Kershner, 1981; Love, 1995). Such flares may lead to a stall and a hard landing, (Federal Aviation Administration, Revised 1999), bouncing (Federal Aviation Administration, Revised 1999; Kershner, 1998), or wheelbarrow landings (Butcher, 1996; Love, 1995) that contribute to increased payloads on the main landing gear tires and struts at impact. Improper flares also increase brake, nosewheel tire, and nosewheel shimmy dampener (on Cessnas) wear (Chrisy, 1991; Jorgensen & Schley, 1990).

The psychological consequences of improper flares are subtler. Since pilots strive for perfect landings, improper flares may affect pilot self-esteem and self-efficacy. For student pilots, improper flares may directly contribute to increase time to solo, training costs, and drop out rates. Referring to the landing phase of operations, the Flight Training Handbook determines that "if the student shows no progress at first, he may become discouraged and a severe mental handicap may develop" (as cited in Matson, 1973, p. 5).

Definition of Terms

AGL. Altitude above ground level.

Control Instructions. Flare instructions included CFI demonstrations and verbal instructions. The landing flare was compared to braking an automobile as it races towards a brick wall. Participants were also advised not to fixate their gaze during the approach and touchdown

Flare. The ability to determine altitude Above Ground Level (AGL) and arrest the aircraft descent in order to ensure a smooth and safe landing.

Experimental Instructions. In addition to CFI demonstrations and verbal instructions experimental participants learned to flare with the presentation of a four-dash auditory beacon. The beacon was presented at a constant altitude of 30 ft AGL.

KIAS. Indicated airspeed in knots.

MSL. Altitude above Mean Sea Level.

Normal Conditions. Optimal Visual Flight Rules (VFR) conditions (i.e., no wind, 10 miles visibility, and clear of clouds.).

Normal Vision. Distant vision of 20/20 corrected or uncorrected and near vision of 20/40 or better corrected or uncorrected (FAR - 67.103, Federal Aviation Administration, 2002).

Scope and Limitations

Microsoft Flight Simulator professional edition (FS2000) is an advanced flight simulator with detailed 3-D scenery. Nevertheless, it is not an approved Personal Computer Training Device (PCATD) by the Federal Aviation Administration (FAA) Flight Standards Service (AFS – 800 as of April 6, 2001). In addition, the limited field of view, lack of kinesthetic information such as sinking rate and ground effect, and reliance on the FS2000 landing analysis feature limits potential findings.

In addition, pilot perceptions were restricted to optimal conditions and lighter general aviation (GA) aircrafts. Whereas, it is possible that proper implementation of flares are hampered by conditions other than "normal", this study was restricted to lighter GA aircraft since many of the heavier airline aircraft utilize little or no flare landings (Collins, 1981).

CHAPTER II

REVIEW OF THE LITERATURE

The landing flare can be defined as the transition from a controlled descent to actual contact with the runway surface (Federal Aviation Administration, Revised 1999). The approach to landing is analogous to a car racing towards a brick wall. Just as drivers apply brakes in order to avoid an unpleasant impact, pilots flare the aircraft in order to avoid a collision with the runway surface (see Grosz et al., 1995). The purpose of this study was to test the effectiveness, ergonomics, and safety of a novel landing flare discriminative cue.

One of the first problems pilots face is determining when to initiate the flare, that is when to brake the descent rate (Langewiesche, 1972; Love, 1995). In fact, the ability to determine altitude above ground level (AGL) is crucial to a successful landing. The consequences of flaring the aircraft too high AGL may include an imminent stall and a hard landing (Gleim, 1998; Jeppesen, 1985). The consequences of flaring too low are more intuitive and resemble those of stopping a car too late as it races towards a wall. In addition to a hard landing, flaring too late may result in ballooning (Kershner, 1998; King, 1999) or bouncing (Kershner, 1998). Both low and high flares may lead to structural damage

(Christy, 1991; Jorgensen & Schley, 1990) and adversely affect pilot confidence and self-efficacy (Flight Training Handbook, as cited in Matson, 1973, p. 5).

Pilots acknowledge that the landing phase of operation is the leading cause of all non-fatal aircraft accidents (Balfour, 1998, Nagel, 1988). In a recent groundbreaking study, Benassat & Abramson (in press) reported that 18.33% of all landing accidents in 1995, 1996, and 1997 were flare related accidents. Preliminary investigation by the authors into most recently available National Transportation Safety Board (NTSB) accident reports suggest that the trend had not changed in 1998. The ability to determine altitude AGL and initiate the flare or leveloff will be discussed next. That ability is crucial to proper flares (Grosz et al., 1995) and may provide clues to the relatively high flare accident rates.

When automobile drivers approach a stationary car at an intersection they apply breaks in order to stop at a reasonable and safe distance. Nevertheless, they may not be able to explain how they determine distance from the stationary car. Likewise, pilots and certified flight instructors (CFIs) are unable to explain how they determine altitude AGL as they approach the runway (Benbassat & Abramson, in press; Hasbrook, August, 1971). Experts agree that pilots use various cues such as monocular cues, sinking rate, and time-to-contact (Denker, 1995; Jeppesen, 1985). Whereas it appears that monocular cues are the predominant depth perception cues on approach and landing (Benson, 1999; Reinhardt-Rutland, 1997), experts cannot agree which cues are more important then others. In fact, it appears that pilots use different cues or combination of cues (Berbaum, Kennedy, & Hettinger, 1991; Mulder, Pleijsant, van der Vaart, & van Wieringen, 2000; Riordan, 1974).

Since comments such as: "just about now begin to flare" increase the frustration of not knowing how to determine altitude AGL, student pilots must learn from experience (Benson, 1999; Thom, 1992). But, experience is the single ingredient that all student pilots lack. In fact, a 5000 hrs total time pilot only has about 8 hrs of flare time (King, 1998), and novice, intermediate, and expert pilots all have attested to the difficulty of the flare maneuver (Benbassat & Abramson, in press). Penglis (1994) echoed pilot sentiments by saying: "you have no idea where the air ends and the ground begins. The closer you get to the ground, the less you are aware where it begins" (p. 90).

As mentioned, the task of determining altitude AGL is critical to a successful flare, and requires pilots to engage in a process of altitude discrimination. Initially, pilots flare the aircraft at different altitudes AGL, but with time pilots restrict the flare to altitudes that will ensure smooth and safe landings. Behaviorists have successfully demonstrated that organisms respond to cues that signal the presentation of reinforcement and ignore cues not associated with reinforcement (see Houston, 1991). The visual cues that pilots use to determine altitude AGL appear different as the aircraft descends towards the runway and experienced pilots use that information in order to initiate the flare at a safe altitude. With time, the cues that represent appropriate flare altitude AGL become a signal to initiate the flare because they are followed by reinforcement. In the case of landing an aircraft, reinforcements may consist of reduced tension as the flare is initiated, smooth and safe landings, and complimentary evaluation from passengers.

The difficulty aviators encounter during the landing flare is tantamount to that encountered by musicians. Accurate intonation is crucial to a successful musical performance and is one of the first difficulty music students face (Salzberg, 1980; Smith, 1995). Like altitude AGL, intonation is arranged on a continuum and pitch discrimination improves with experience (Elliot, 1974). According to Welch (1985), musicians use different cues or combination of "meaningful" (p.147) cues to determine their intonation. Those external cues provide objective feedback of pitch accuracy and allow the musician to detect intonation deviations. With time, musicians "internalize" (Welch, 1985, p. 148) the external cues and perform accurately without them. An additional advantage of the external feedback is that it provides accurate intonation information regardless of the musical skills and knowledge of the instructor.

In reference to intonation, studies found that contingent feedback was found to be more effective than verbal feedback alone (Welch, Howard, & Rush, 1989; also see Smith, 1995) or model performance (Salzberg, 1980). It was further found that meaningful cues were more effective than continuous visual information in string players (Salzberg, 1980; Smith, 1985, 1987; for a related study see Liebermann & Goodman, 1991). Unlike musicians that use feedback to determine the discrepancy between the actual and intended pitch, aviation instructions must contend with safety issues. Specifically, aviation flare instructions should incorporate errorless discrimination learning (see Terrace, 1963a, 1963b) in which pilots never respond to inappropriate flare altitudes AGL.

Thus, it is believed that an external discriminative cue will facilitate the task of discriminating altitude AGL as the aircraft descends towards the runway. With such a cue, pilots will consistently initiate the flare at an ideal flare altitude and associate that altitude with appropriate depth perception cues. In addition, an external beacon will provide standardized discriminative information regardless of the knowledge or expertise of the flight instructor. Eventually, it is believed that pilots will be able to initiate the flare at an appropriate altitude without the external cue.

In light of flare accident rates and flaws in traditional flare instruction (Benbassat & Abramson, 2002) the authors considered an alternative. The present study compared the quality of simulated landings between traditional landing flare instructions and instructions that included a novel discriminative cue.

CHAPTER III

DESIGN AND METHODOLOGY

Participants

Participants were 26 undergraduate students from Oklahoma State University with normal vision and no prior aviation experience. They were asked to commit to three 60 min block sessions on three consecutive days and were randomly assigned to a control (males = 6, females = 7;
mean age = 19.62) or experimental (males = 8, females = 5; mean age =21.31) condition. Thus, each condition included 13 participants.

According to Federal Aviation Regulations (FARs) participants were required to avoid consumption of alcohol at least 8-hrs prior to their simulated flights (FAR - 91.17, Federal Aviation Administration, 2002). Participation was voluntary and anonymous with the exception of demographic information that included gender and age.

Research Instrument

Flight Simulator. Microsoft Flight Simulator 2000 (FS2000) professional edition was a technologically advanced and detailed personal flight simulator program with more than 20,000 airports and 14 aircraft. FS2000 also provided detailed 3D scenery with 16-bit color based on true elevation data. FS2000 ran on a Pentium 500 (Dell computer OptiPlex GX1P) with a 1024 x 768 resolution for optimal graphics quality and instrument panel readability.

For the purpose of this study, the FS2000 simulated the controls, performance, and cockpit of a Cessna Skylane (Cessna 182S). The Cessna 182S is a high performance general aviation aircraft with a seating capacity of four. The aircraft scenery and instrument controls were projected (sanyo ProEx multimedia projector, model PLC-8810N; Chatsworth, CA) onto a 2.04 x 1.524 m (6.85 x 5.00 ft) screen, 2.337 m (7.800 ft) away from the participant. A CH Products flight simulator yoke (CH71 USB LE Flight Sim Yoke, FSY208LE; Vista, CA) was used to control the elevators, ailerons, throttle, flaps, elevator trim, and landing gear brakes.

Flare Beacon. The approach and touchdown phases overload the visual sensory modality as pilots attend to instrument approach gauges, monitor pattern traffic, check aircrafts or objects on active and incursion runways, and attempt to determine altitude AGL. Furthermore, need to transition from scanning instruments inside the cockpit to visual scanning of the airport environment is especially crucial during the approach and touchdown phases. Thus, an auditory discriminative cue that allows pilots to continually scan the airport environment without adding an additional visual task was used.

Proper landing flares depend on the ability to discriminate altitude AGL. The discriminative cue in this study alerted participants when the aircraft reached an ideal flare altitude. The auditory alert cue was referred to as the flare beacon and consisted of a four-dash tone (FS2000 outer marker sound file "outermk.wav"). The WAV file was opened with a Microsoft Window Media Player and the playback option was set to loop twice (View > Options > Playback > Play).

In addition to reducing the visual overload and eliminating the need to gaze in a particular direction, auditory signals have faster reaction times associated with them. Indeed, current warning and advisory aircraft signals are auditory (Doll & Folds, 1986; Lyons, Gillingham, Teas, Ercoline, & Oakley, 1990; Van Laer, Galanter, & Klein, 1960).

<u>Perception Questionnaire</u>. Portions of the Pilots Perception Questionnaire (Benbassat & Abramson, in press) were used. Participants first rated the various maneuvers they practiced for level of difficulty (1 = extremely easy, 7 = extremely difficult). The maneuvers included holding airspeed, lowering flaps, aligning with RWY centerline, flaring the aircraft, aiming for touchdown point, and holding glide altitude.

Next, participants rated the task of determining the aircraft altitude AGL during the flare (1 = very easy, 7 = very difficult). In item 3, participants imagined that they were transitioning for landing and rated how confident they were that the aircraft was at flare altitude (1 = low confident, 7 = high confidence). Participants were asked if there was a need for improved flare training methods in item 4 (1 = definitely yes, 7 = definitely no), and to rate their landings in item 5 (1 = very good, 7 = very poor). Finally, participants rated their potential of becoming pilots (1 = very good, 7 = very poor) in item 6.

Procedure

Volunteers with no prior ground or flight time were trained to land in a Microsoft Flight Simulator 2000 (FS2000) Professional Edition located at the Department of Psychology at Oklahoma State University.

Participants were randomly assigned to a control or experimental condition. Both groups received identical landing training with the exception of flare instructions. Participants in the control group received traditional flare instructions. The instructions included CFI demonstrations and verbal descriptions of when to initiate the flare in order to ensure a smooth and safe landing. Those in the experimental condition learned to flare with an additional aid in the form of a four-dash beacon (FS2000 outer marker sound file “outermk.wav”). The beacon was triggered when the aircraft was at a constant altitude of 9.14 m (30 ft) AGL, and participants were instructed to initiate the flare in response to the beacon.

The first session (time = 60 min) consisted of elementary aircraft instrument and performance familiarization instructions from a certified pilot (the experimenter). Instructions included introduction to the FS2000 airspeed indicator, attitude indicator, altimeter, turn coordinator, heading indicator, and vertical speed indicator. Following cockpit familiarization, the flight instructor departed from runway (RWY) 17 in Stillwater Municipal (SWO) airport in a westerly heading (270°) and climbed to 3000 ft MSL. After leveling off at the assigned altitude, participants were introduced to and performed shallow banks, climbs, descends, and approach to landing stalls. Those maneuvers were deemed important for the purpose of this study. Session one ended with landing instructions and two simulated landings to RWY 12 (dimension = 2926 x 61m [9600 x 200 ft], elevation = 2790 ft) in Mojave airport (MHV). The simulated scenario placed the aircraft on a long final approach at 4680 ft and a heading of 122°. The automatic wing leveler was activated in order to keep the participants from over rolling the aircraft and reduce the workload on the participants. Thus, participants were only required to perform one shallow left bank and control the aircraft pitch, flaps, elevator trim, and brakes.

Before starting the FS2000 scenario (Tutorial 7, Situation 3) participants used the game controllers (in Windows 98 click on Start > Settings > Control Panel) function to ensure the flight controls (CH Flight Sim Yoke LE) were free and correct. After pressing the Test tab, participants moved the yoke to all extremes and confirmed that the "+" followed the movements of the yoke handle. Participants also verified that the throttle lever and elevator trim, landing breaks, and flaps setting buttons were responsive. Participants then reset the altimeter to 29.92 inches of mercury to ensure real elevation data (4680 ft), lowered full flaps, idled the throttle, and set the elevator trim for landing.

Participants started the simulation after completing the "before starting" simulation checklist. FS2000 Tutorial 7, Situation 3 placed the aircraft on a high (1659.96 ft AGL) 3.551 km (2.206 mi) final approach for RWY 12. The scenario was chosen because the aircraft could clear the runway threshold with full flap settings and idled throttle, thus eliminating the need to manipulate those controls. Landing procedure standardization was further guaranteed as evident from

Appendix B and Appendix C.

Pilots were instructed to pitch for 70 KIAS after starting the simulation and maintain that airspeed until the landing flare. Figure 2 shows that participants were instructed to aim for the incursion of RWY 4-22 with RWY 17. Traditionally, the active RWY numbers are the preferred aiming point during a normal landing. However, the incursion of RWY 4-22 was perceived as a notable landmark and was preferred in order to ensure a standardized aiming point.

Figure 2. Landing Aiming Point (RWY 4-22)

As noted, the FS2000 landing scenario placed the aircraft on a high final approach to RWY 12 with an indicated heading of 122°. This configuration necessitated a shallow bank correction in order to maintain RWY centerline alignment. As a consequence, participants were instructed to execute one full left aileron deflection at 3500 ft AGL. The wing leveler prevented an excessive correction and ensured an appropriate shallow turn for RWY alignment.

The standardized approach and descent was maintained until the landing flare. Participants in the control instruction condition were instructed to determine the aircraft altitude and initiate the flare at a safe altitude AGL. The flight instructor advised the participants when flaring too high or too low and demonstrated when appropriate. In fact, each control and experimental session started with the flight instructor at the controls and a demonstration of three landings. The landing flare was also compared to braking an automobile before impacting a wall in order to help participants determine altitude AGL. Finally, the inability of the altimeter to accurately gauge low altitudes AGL was disclosed and participants were advised not to fixate their gaze during the approach and touchdown.

In addition to CFI demonstrations and verbal instructions, participants in the experimental condition were instructed to flare the aircraft with the presentation of the flare beacon (2820 ft). Appendix D shows that the ideal landing flare altitude (30 ft) was determined from the analysis of 180 landings from 6 altitude categories (10 ft, 20 ft, 30 ft, 40 ft, 50 ft, 60 ft) and the results are presented in Figure 3.

Participants were instructed to maintain a flare attitude of 12° until touchdown in order to ensure standardized operations. Instructing participants to apply full brakes immediately after touchdown completed the touchdown phase and participants reset the simulated landing scenario. The standardized landing procedures were practiced in session two (landings, n=10; time = 50 min) until participants were able to land the aircraft without the assistance of the flight instructor. During the last session (time = 45 min), participants performed three dual landings and five solo landings without the aid of the instructor or the beacon (for the experimental group). Landing analysis measures that consisted of flare altitude (ft), vertical speed at touchdown (ft/min), distance from aiming point (dist), and velocity at touchdown (kts) were collected during the five solo landings. In addition, participants completed a brief perception questionnaire (see Appendix E).

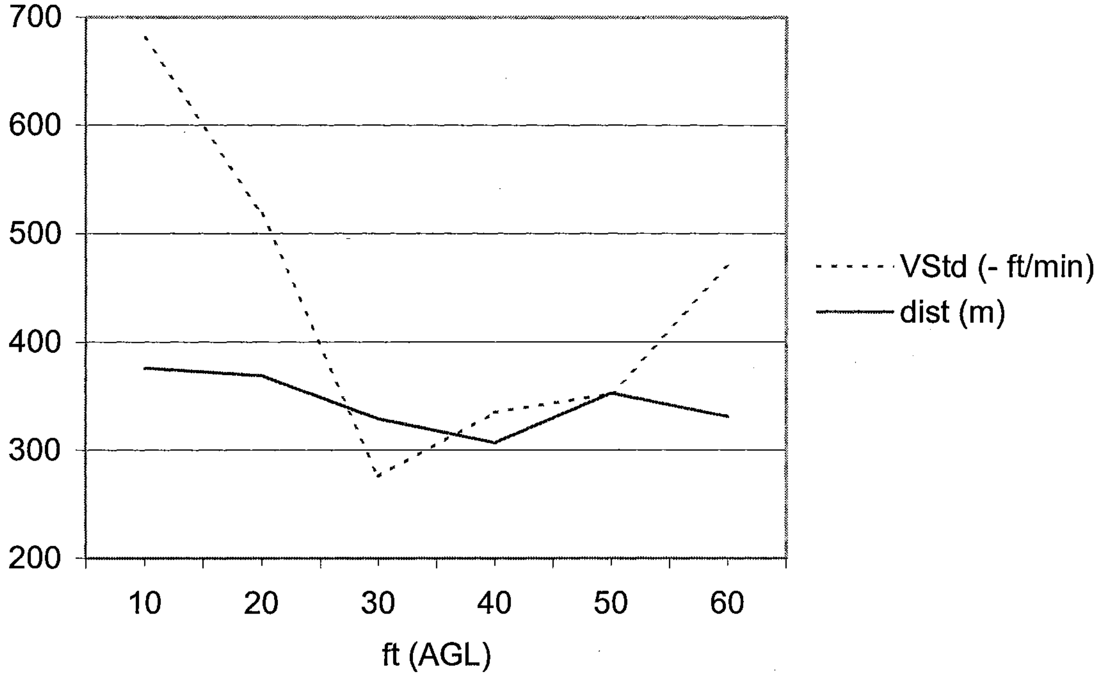

Figure 3. Vertical Speed at Touchdown (VStd) and Distance (dist) from Aiming Point

Measures

Flight Simulator. Participants were cleared to solo after three consecutive landings that included proper pitch for aiming point, RWY centerline alignment, pitch configuration during the flare, and proper brake application. Landing analysis measures consisted of flare altitude (ft), VStd (ft/min), dist (km), and Vtd (kts).

Before each solo flight the flight instructor selected the MS2000 Landing Analysis (Options > Flight Performance > Landing Analysis) and Flight Video (Options > Flight Video > Record New) features from his vantage point 2.438 m (8 ft) posterior to the participant. While vertical velocity at touchdown (VStd) data were obtained from the landing analysis feature, actual flare altitude, distance from aiming point (dist) and velocity at touchdown (Vtd) were obtained from the flight video analysis.

Perception Questionnaire. The questionnaire was presented after participants completed their solo flights.

National Transportation Safety Board Accident Reports. Reports produced by the National Transportation Safety Board (NTSB) were analyzed. The NTSB is an independent federal agency that investigates every civil aviation accident in the United States. The accident database compiled by the NTSB is open to the public and contains information about civil aviation accidents within the United States, its territories and possessions, and in international waters. For the purpose of this study, only final descriptions of accident reports and probable causes were used. In a landmark study, Benbassat and Abramson (in press) analyzed 6676 NTSB accident reports from 1995, 1996, and 1997 and concluded that landing flare accident rates were relatively high. This study continued the analysis and determined flare accident rates for 1998. Each narrative was read and analyzed. An accident report was labeled as a flare accident if the NTSB determined the probable cause to be a flare accident, or if there were definitive clues within the narrative that implicated a flare accident.

Design

Flight Simulator. As Table 2 shows, most flight simulator measures were moderately correlated. Therefore, the four measures were regarded as related measures of the "quality of landing" construct.

Table 2

Correlation Matrix for Flight Simulator Measures

		VStd	Flare ALT	Vtd
Flare ALT	Pearson Correlation	-.727**		
	Sig. (2-tailed)	.000		
	N	26		
	r^2	.530		
Vtd	Pearson Correlation	-.622**	-.496**	
	Sig. (2-tailed)	.001	.010	
	N	26	26	
	r^2	.390	.250	
dist	Pearson Correlation	-.395*	.224	-.301
	Sig. (2-tailed)	.046	.272	.135
	N	26	26	26
	r^2	.160	.050	.090

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

As mentioned, landing analysis was produced for each solo landing. Based on the assumption that pilots determine altitude AGL in a trial-and-error fashion, one would expect larger flare altitude variability in the control group. Hence, it was hypothesized that,

H_0 $\sigma c = \sigma e$

Where:

σc = control flare altitude variance

σe = experimental flare altitude variance

The second set of hypotheses related to differences in mean performance. Private-pilot students traditionally perform three consecutive solo landings and CFIs determine quality of landing based on the "average" of the three. Furthermore, solo landings are not considered practice landings and pilots are only allowed to solo after performing consistently good landings. Hence, variability in quality of landing among individual solo flights was expected to be small and averaging the performance of solo flights was deemed sensible. An analysis of flare altitude standard deviation (STDEV) for solo flights per participant supported the notion that the performance of each participant was stable across solo flights (T6 was an exception and was treated as a case study).

Hence, multivariate analysis was used to determine effects of training method on quality of landing and univariate analyses of means were conducted to determine effects of training method on each flight measure. Therefore, it was hypothesized that,

$$H_0 \quad \begin{bmatrix} \mu 11 \\ \mu 21 \\ \mu 31 \\ \mu 41 \end{bmatrix} = \begin{bmatrix} \mu 12 \\ \mu 22 \\ \mu 32 \\ \mu 42 \end{bmatrix}$$

Where:

μ_1 = population mean vector for control participants

μ_2 = population mean vector for experimental participants

CHAPTER IV

RESULTS

Flight Simulator Measures

Flight simulator data consisted of flare altitude, vertical velocity at touchdown (VStd), distance from aiming point (dist), and velocity at touchdown (Vtd) measures. Whereas flare altitude was directly manipulated, VStd, Vtd and dist were byproduct measures of flare altitude.

The first set of hypotheses tested for significant differences in dispersion of flare altitudes between the control and experimental groups. The notion that pilots determine altitude AGL in a trial-and-error fashion supported the expectation for larger flare altitude variability in the control condition.

The second set of hypotheses tested for significant differences in mean performance among the control and experimental groups. Performance was compared for each measure and flare altitude was of primary importance. The notion that pilots traditionally tend to execute high flares supported the expectation for higher flares in the control condition. Results are presented next.

Analysis of Variance

Hypothesis. $H_0 \ \sigma c = \sigma e$

Where,

σc = control flare altitude variance

σe = experimental flare altitude variance

Levene's test for homogeneity of variance was performed and led to rejection of the null hypothesis regarding flare altitude variability between the control and experimental groups, F(24) = 14.298, p = .001. As Figure 4 illustrates the flare altitude STDEV for the control condition (SD = 11.8460) was significantly higher than that of the experimental condition (SD = 4.6702). The tendency of control participants to determine altitude AGL in a trial-and-error fashion becomes apparent when considering Figure 5.

Further Levene's tests for homogeneity of variance revealed no significant differences between the control and experimental conditions for VStd, F(24) = 2.002, p = .170; Vtd, F(24) = 1.112, p = .302; and dist, F(24) = 1.459, p = .239.

Analysis of Means

$$H_0 \quad \begin{bmatrix} \mu 11 \\ \mu 21 \\ \mu 31 \\ \mu 41 \end{bmatrix} = \begin{bmatrix} \mu 12 \\ \mu 22 \\ \mu 32 \\ \mu 42 \end{bmatrix}$$

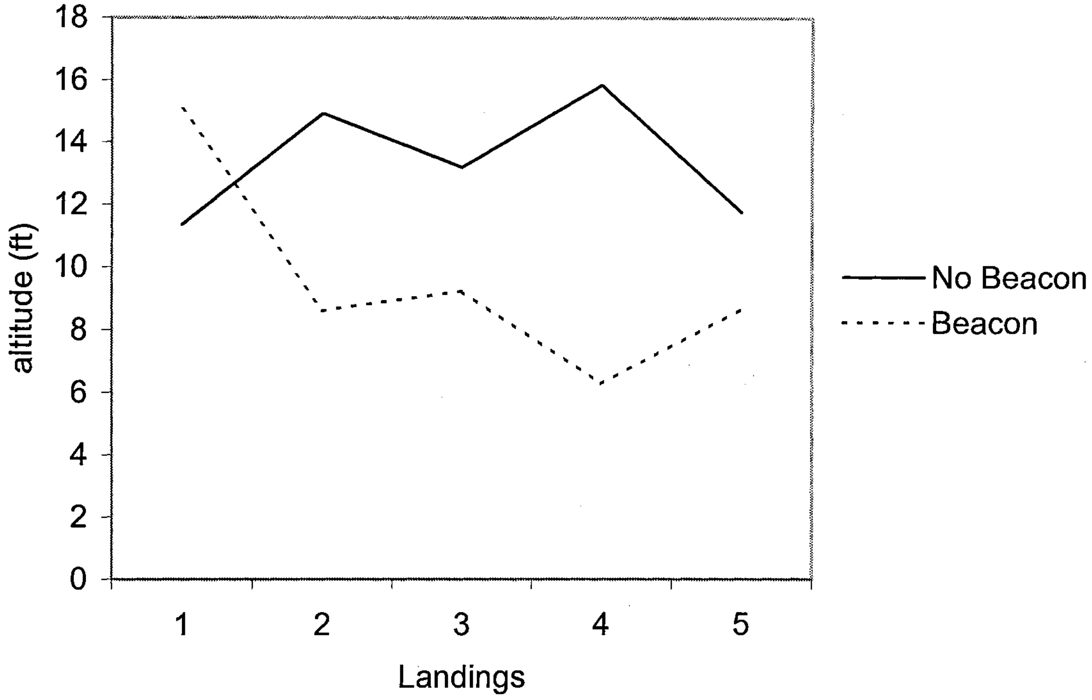

Figure 4. Control and Experimental Flare Altitude STDEV Across Five Solo Landings

Where:

μ_1 = vector for control participants

μ_2 = vector for experimental participants

A multivariate analysis of variance was performed to determine the effect of training method (control, experimental) on quality of landing as measured by flare altitude, vertical velocity at touchdown (VStd), distance from aiming point (dist), and velocity at touchdown (Vtd). Results indicated that there was a significant effect of training method on quality of landing, F = 7.2446, p = .001 (eta^2 = .580, power = .983).

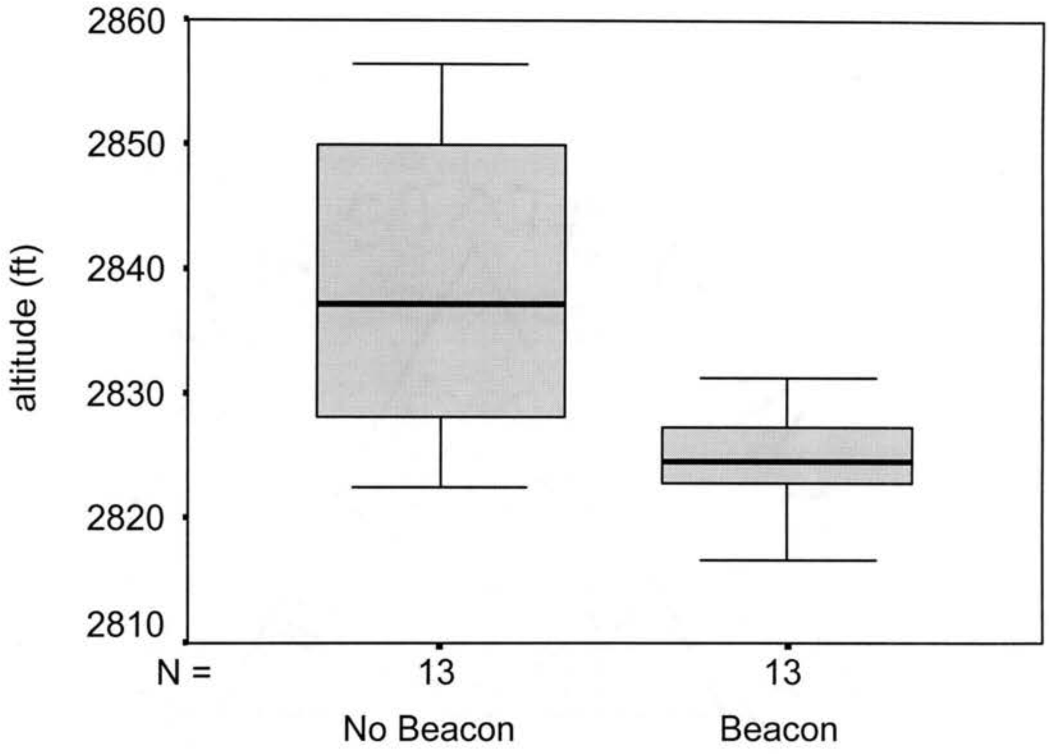

Figure 5. Control and Experimental boxplot

Following the significant multivariate test, univariate analyses were conducted to determine the effect of training method on each landing measure. The Bonferroni procedure produced a modified alpha level of .0125 in order to safeguard against Type I error across the univariate tests.

Effect of training method on flare altitude (ft) with significant variance estimates were significant, F(1,15.642) = 14.594, p = .001 ($eta^2 = .378$, power = .956). Figure 6 shows that participants in the control condition (M = 2838.5529) flared higher than participants in the experimental condition (M = 2825.0615) by 3.08 to 23.90 ft. Similarly, effects of training methods on VStd (ft/min) were significant, F(1,24) = 27.144, p = .0001 ($eta^2 = .531$, power = .999). Impact at touchdown was greater for the control condition (M = -448.3077) than the experimental condition (M = -286.9846) by –247.93 to –74.72 ft/min.

There was no effect of training method on Vtd (kts), F(1,24) = 4.429, p = .046 among the control (M = -48.8000) and experimental (M = 50.4461) conditions, or dist (km), F(1,24) = .360, p > .05 among control (M = .3052) and experimental (M = .2997) conditions. Finally, training method had no effect on time-to-solo (number of landings) among control (M = 10.2308) and experimental (M = 9.3077) participants, t (24) = 1.368, p > .05.

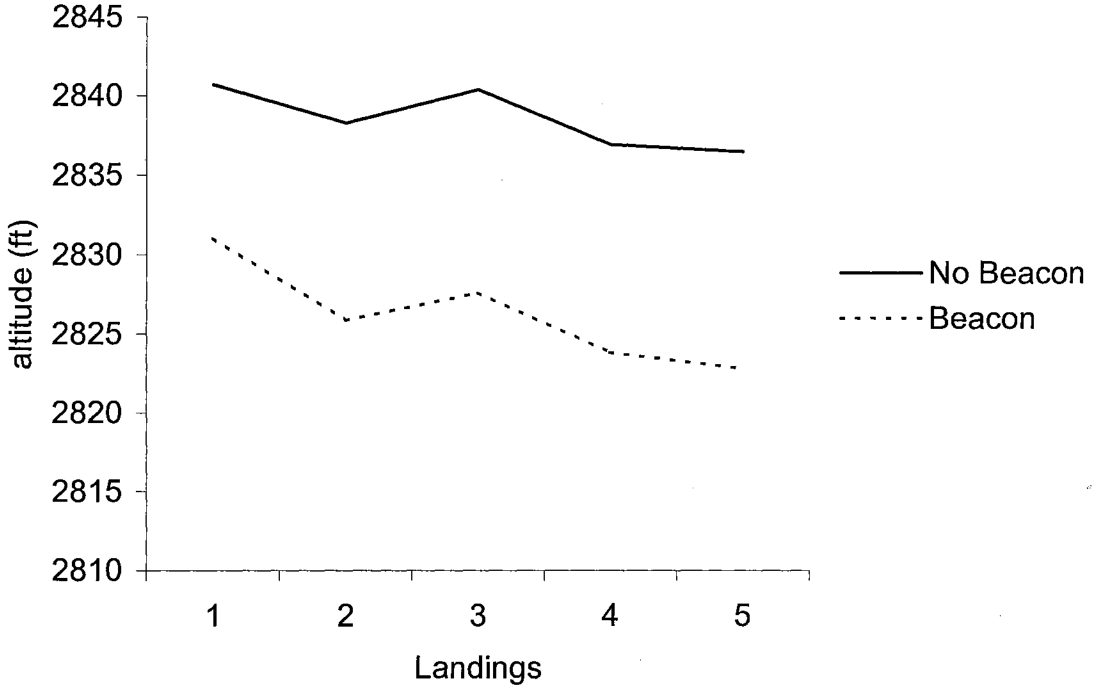

Figure 6. Control and Experimental Mean Flare Altitude Across Five Solo Landings

Perception Questionnaire

The following section presents findings from the pilot perception questionnaire. Whereas the simulator data provided an index of pilot quantitative performance, the following data provides a qualitative index of performance or a subjective indicator of how pilots felt about their performance.

Part I

Benbassat & Abramson (in press) found that pilots from three different flight schools and level of expertise (novice, intermediate, experts) found the flare maneuver to be more difficult than nine other standard flight maneuvers. In an attempt to replicate these findings, participants in the control and experimental conditions were asked to rate the six maneuvers they practiced for level of difficulty (1=extremely easy, 7=extremely difficult). It was hypothesized that pilots would perceive the flare maneuver to be more difficult than the other five maneuvers. Hence,

h_o $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6$

h_1 Not h_o. At least one maneuver will be significantly different.

As evident from Figure 7, a one-way analysis of variance suggested that there was a significant effect of maneuver type on pilot perceptions at the .01 level, F (5, 150) = 20.658, p=.0001 (effect size "eta^2" = .408, power = 1.00). Note that despite a failure to meet homogeneity of variance assumptions, the Fmax ratio did not exceed three and a stringent alpha level was adopted (see Kepple, 1991). A Tukey Honestly Significant Difference (HSD) Post hoc analysis conducted at the .01 level suggested that pilots perceived the flare maneuver (M = 4.192, SD = 1.414) to be more difficult than holding airspeed (M = 1.653, SD = .628), lowering flaps (M = 1.307, SD = .617), aligning with centerline (M = 2.615, SD = 1.601), aiming for touchdown point (M = 2.653, SD = 1.354), and maintaining a standard approach glide (M = 2.038, SD = .823).

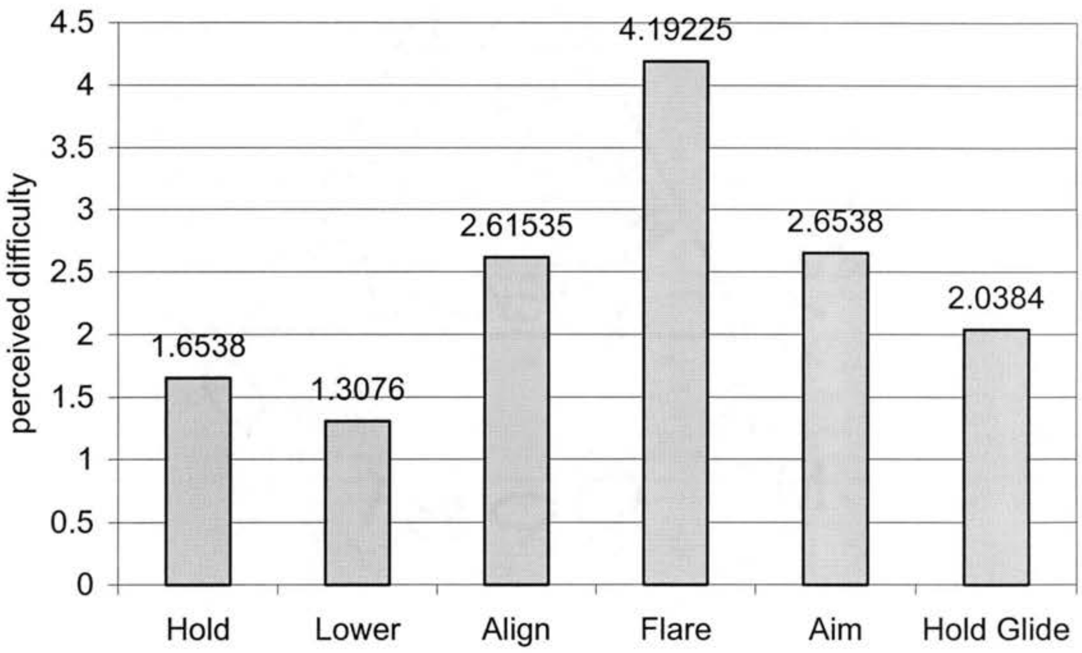

Figure 7. Perceptions of Flare Maneuver Difficulty

Further analysis proceeded to examine for effects of training method (control, experimental) on perceived flare difficulty, hence,

h_o $\mu_{control} = \mu_{experimental}$

h_1 $\mu_{control} \neq \mu_{experimental}$

Findings suggested that control (M = 4.153, SD = 1.675) and experimental (M = 4.230, SD = 1.165) participants perceived the flare maneuver to be as difficult, t (24) = -.136, p > .05.

Part II

The following findings represent qualitative data from five additional pilot perception items. Regression analysis suggested that the items were independent and results are presented in Table 3. Hence, the effects of training method (control, experimental) on pilot perceptions were analyzed for each individual item. It was hypothesized that there would be a significant difference in mean perceptions among the control and experimental conditions,

Table 3

Pearson Correlation of Perception items

		Item 2	Item 3	Item 4	Item 5	Item 6
Item 2	P					
	Sig.					
	N					
Item 3	P	- .521**				
	Sig.	.006				
	N	26				
Item 4	P	- .276	.053			
	Sig.	.172	.798			
	N	26	26			
Item 5	P	- .048	.016	-.113		
	Sig.	.817	.937	.584		
	N	26	26	26		
Item 6	P	- .124	.067	.080	.378	
	Sig.	.547	.744	.698	.057	
	N	26	26	26	26	

**correlation significant at the 0.01 level hence,

$h_o\ \mu_{control} = \mu_{experimental}$

$h_1\ \mu_{control} \neq \mu_{experimental}$

Table 4 illustrates that even though mean differences met expectations, there was no significant effect of training method on perceptions regarding the aircraft altitude AGL during the flare (item 2), confidence that the aircraft was at flare altitude (item 3), need for improved flare training methods (item 4), and potential of becoming a pilot (item 6).

The effect of training method on landing ratings (item 5) was significant, t(24) = -2.245, p = .037. Participants in the control condition perceived their landings to be better.

Table 4

Effect of Training Method on Perceptions

		N	Mean	t value	sig	
Item 2	con	13	4.6154	1.177	.251	1=easy
	exp	13	3.9231			7=difficult
Item 3	con	13	3.4615	-.813	.424	1=low
	exp	13	3.8462			7=high
Item 4	con	13	2.3077	-.568	.576	1=yes
	exp	13	2.6154			7=no
Item 5	con	13	3.0000	-2.245	.037*	1=good
	exp	13	3.7692			7=poor
Item 6	con	13	3.0000	-.716	.481	1=good
	exp	13	3.3846			7=poor

*significant at .05.

National Transportation Safety Board

Accident Reports

The National Transportation Safety Board (NTSB) has been including flare accidents in the landing phase of operation category. Hence, the magnitude of flare accident rates has not been apparent. Benbassat & Abramson (in press) analyzed 6676 accident reports produced by the NTSB flare accident rates. Results indicated that the NTSB investigated an average of 7.44 (SD = 3.91, mode=8) flare accidents per month across the years 1995 (M = 6.50, SD = 3.32), 1996

(M = 9.08, SD = 4.48), and 1997 (M = 6.75, SD = 3.62).

This study continued the analysis of flare accident rates and presents findings from the most recent NTSB yearly publication. Overall, 2282 accident reports from 1998 were scrutinized for flare accident rates. It was found that the NTSB investigated an average of 7.17 (SD = 2.33) flare accidents per month in 1998.

As shown in Figure 8, flare accident rates across the years 1996, 1997, and 1998 were not significantly different, $F(2, 33) = 1.444$, $p > .05$. It was found that the NTSB investigated an average of 7.67 (median = 7.50) flare accidents per month across the three years. Figure 9 shows the frequencies of flare accidents by month and year. The apparent increase in flare accident rates during the warmer months is a trend found across phases of operations. The reason may include increased operations in VFR weather as well as the expert pilots that operate aircraft under IFR conditions.

Flare accident rates by aircraft type was also analyzed. Overall, across the years 1996, 1997, and 1998, 82.97% of all aircraft involved in flare accidents were single engine aircraft. Helicopter flare accident frequencies constituted 6.88% of all flare accidents, multi-engine 5.80%, Jet engine 2.17%, glider 1.45%, and gyroplane 0.72%. Similar frequency ratios are reflected in accident by aircraft type data for total aircraft accidents published by the National Transportation Safety Board. Inclusive accident rates by year and aircraft type are presented in Appendix F.

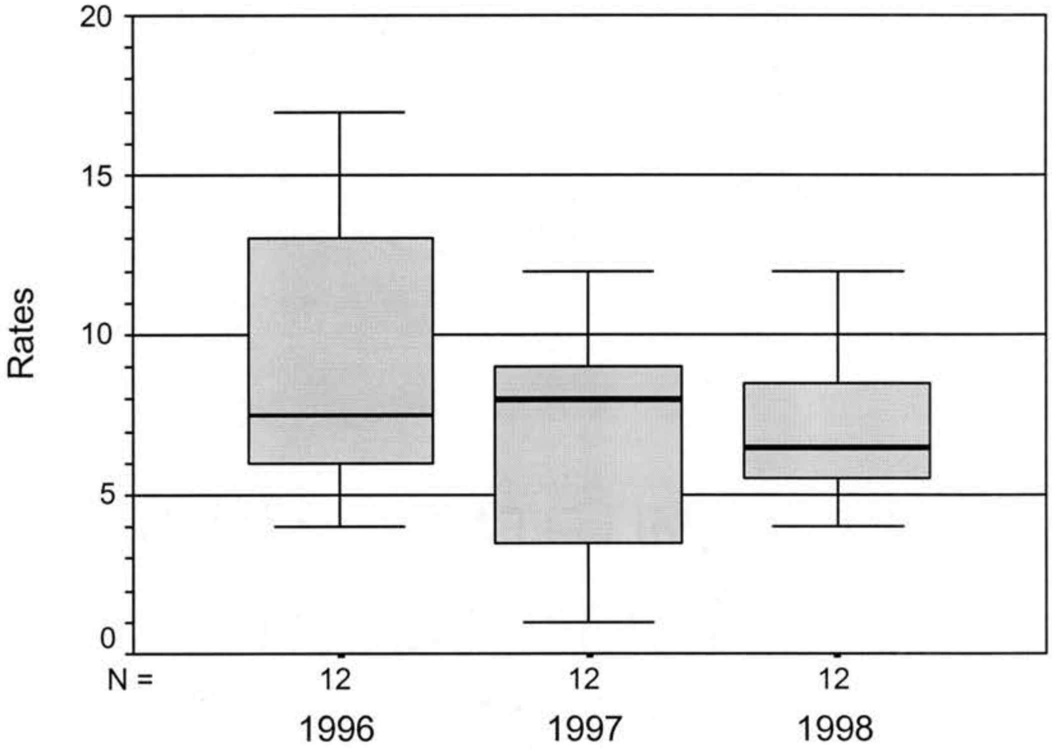

Figure 8. Boxplot of Flare Accident Rates by Year

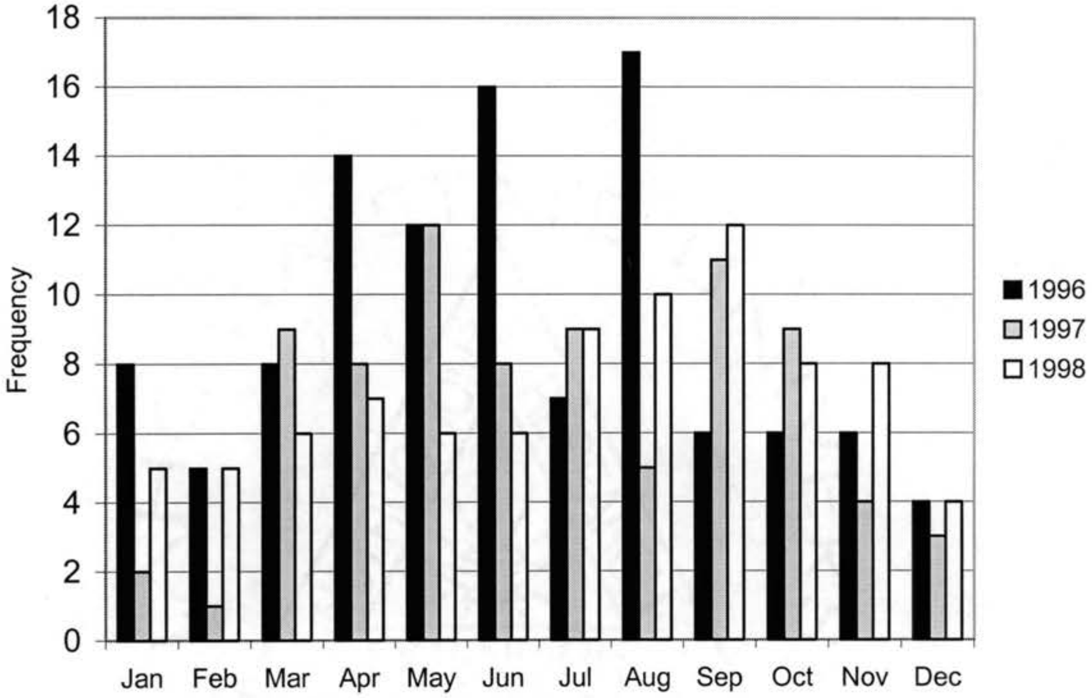

Figure 9. Flare Accident Frequencies by Month and Year

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Pilots recognize the landing phase of operations as the leading cause of all non fatal accidents. That recognition is supported by accident reports published by the National Transportation Safety Board (NTSB). Nevertheless, whereas many pilots intuitively recognize the landing flare as a particularly difficult maneuver, flare accident rates are not readily available.

The difficulty of the flare maneuver is not readily supported by NTSB accident reports because flare accident rates are included within the landing phase of operation. An analysis of flare accident rates for 1995, 1996, and 1997 (Benbassat & Abramson, in press) revealed that 18.33% of all landing accidents reported by the NTSB were flare related accidents.

This study provided further support to the difficulty of the flare maneuver by analyzing NTSB flare accident rates for 1998 and studying participant perceptions. The relatively high trend of flare accident rates continued in 1998 and findings suggested that seven to eight flare accidents could be expected on any given month.

Previously, Benbassat and Abramson (in press) reported that pilots testified to the difficulty of the landing flare by rating it more difficult than nine other standard flight maneuvers. The landing flare was rated most difficult regardless of pilot experience (novice, intermediate, expert). Similarly, findings from this study indicated that participants found the flare maneuver to be more difficult than the five other standard flight maneuvers they practiced.

The discussion now turns to the flight simulator data. By standardizing all maneuvers and procedures this study isolated the approach and touchdown phases from the flare maneuver. Moreover, this study isolated two phases within the landing flare maneuver itself. Specifically, the ability to determine altitude AGL and level off the aircraft was isolated from the roundout in which pilots increase the angle of attack in order to allow the aircraft to settle on its main landing gear. Thus, the ability to determine altitude AGL and level off the aircraft in order to initiate the flare was studied.

Flight simulator measures were gathered from control (no beacon) and experimental (beacon) solo flights and analyzed for quality of landing. The first analysis regarded significant differences in mean flare altitude between the control and experimental groups. Findings suggested that experimental flares ($\underline{M}$ = 2825.06 ft) were initiated in proximal distance to the ideal flare altitude ($\underline{M}$ = 2820 ft). On the other hand, control participants initiated their flare significantly higher then the ideal flare altitude ($\underline{M}$ = 2838.55 ft). As a consequence, the impact that control aircraft sustained (M = -448.31 ft/min) during landings were significantly higher then those sustained (M = -286.98 ft/min) by experimental aircraft.

The second analysis regarded significant differences in dispersion of flare altitude around group means between the control and experimental conditions. This analysis directly hinted at a flaw in current flare instructions. As mentioned, proper flares depend on experience and certified flight instructor (CFI) instructions. Nevertheless, despite commitment and ambition, student pilots lack experience and CFIs cannot explain how to determine altitude above ground level (AGL). Hence, it is likely that student pilots learn to flare in a trial-and-error fashion.

Learning by trial-and-error would imply that pilots flare high at times and low at other. Hence, subsequent landing flares are improved through a trial-and-error fashion. Needless to say, learning to flare through trial-and-error increases the likelihood of flare accidents or aircraft structural damage, requires more flare practice time, which increases training costs, and may add to pilot frustration and feelings of low self-efficacy.

Findings from this study supported the notion that student pilots learn to determine altitude AGL in a trial-and-error fashion. Results indicated that the dispersion of flare altitudes around the mean for the control group was significantly higher (11.85 ft) than the dispersion of flare altitudes for the experimental group (4.67 ft). Hence, the ability of experimental participants to initiate flares at consistent altitudes may be a reflection of their ability and confidence in determining altitude AGL.

Conclusions and Recommendations

This study addressed limitations in the ability to determine altitude above ground level (AGL) and flaws in traditional flare instructions by testing the effectiveness of a novel discriminative cue. The effectiveness and distinct advantages that resulted from the use of the discriminative cue are discussed next.

First and foremost, the discriminative cue was effective in teaching participants how to determine altitude AGL. Experimental participants were able to determine altitude AGL and initiate proper flares in a consistent manner. Furthermore, the discriminative cue proved to be a thrifty mode of instruction in terms of both time and money. Note that experimental participants learned to execute significantly better flares after only 15 simulated landings.

The inherent characteristics of an automated discriminative cue provide further benefits to general aviation flare instructions. Teaching to determine altitude AGL with an automated discriminative cue or flare beacon ensures consistent and objective instructions. Thus, the pilot is advised when to flare the aircraft on each and every landing at an exact altitude AGL. In addition to providing standardized instructions, the discriminative cue alleviates CFI burden during the landing. Certified flight instructors are not required to explain what they themselves do not know and granted the leisure to concentrate on safety during the landing.

Finally, recall that the discriminative cue signals the presence of appropriate altitude cues. Hence, the flare beacon represents an individualized training approach that permits pilots to incorporate various appropriate altitude cues or combination of cues. As discussed earlier, pilots determine altitude AGL through the use of cues such as monocular cues, sinking rate, and time-to-contact. Whereas experts agree that monocular cues are of utmost importance, it is unclear which monocular cues are most important and it appears that pilots use different cues or combination of cues.

Imagine a flight instructor that routinely advises her student pilot to flare at the height of the local hangar. Now imagine the student pilot on his first solo cross-country flight to an airport without hangars. The discriminative cue is a powerful conditioning tool because all relevant appropriate altitude cues (monocular and other) are associated with an ideal altitude AGL. Thus, through individualized instruction, the ability to determine altitude AGL generalizes to different airport environments and terrains.

The discussion now turns to possible limitations and criticisms. Participants in this study were trained to land a Cessna 182S Skylane and advised when to flare based on that particular aircraft weight and balance. The argument that flare altitude changes as a function of aircraft weight challenges the effectiveness of the flare beacon method. Nevertheless, student pilots that train for the private pilot certificate typically spend 40 - 60 hours in a light general aviation aircraft such as a Cessna 152 Aerobat or a Piper PA-28 Cherokee.

Thus, transitioning from a Cessna 152 to a Piper PA-28 would not significantly hinder the ability to determine altitude above ground level (AGL). However, transitioning from a Cessna 152 to a twin Beech 76 Dutchess would.

Learning to flare higher as aircraft weight and subsequent speed increases requires experience. Nevertheless, pilots previously trained with a discriminative cue will have a flare altitude reference point that would allow them to appreciate what it means to flare higher. As a consequence, the ability to discriminate altitude and flare higher should be facilitated by previous training with the flare beacon. Finally, the flare beacon may also be used as an instruction modality on heavier aircraft.

In conclusion, this study tested the effectiveness, ergonomics, and safety of the flare beacon as an instruction modality. The benefits of the flare beacon in determining altitude AGL that were discussed earlier were supported by two case studies. Recall that simulator flight measures were collected while participants performed five solo landings. With the exception of two experimental participants, each participant flared at approximately the same altitude AGL on each landing.

Nevertheless, the behavior of two experimental participants hinted at the compelling advantages of the flare beacon. The most dramatic case was that of T7 which flared too high on the first solo landing. Immediately following the high flare T7 uttered: “felt like I flared high.” There are many reasons why T7 flared high on the first landing, but more importantly was the fact that T7 was able to recognize the high flare. In fact, T7 verbalized that recognition even though T7 was the only occupant in the mock cockpit. Furthermore, T7 not only recognized the high flare, but dramatically improved the subsequent flare on the second landing from 2837.91 ft to 2823.14 ft.

In reference to ergonomics and safety, recall that participants were presented with an auditory tone so that it would not interfere with the demanding visual tasks present on approach and touchdown. An auditory modality was also chosen in order to differentiate it from the visual task of identifying monocular cues (for similar modality concurrent tasks see Logie, Gilhooly, & Wynn, 1994). Pilots were not only able to hear and react to the tone, but were not distracted or alarmed by the tone. Thus, taken as a whole, findings from this study support future studies with a discriminative cue in-vivo. Accurate and inexpensive vertical altitude measures are currently available and can easily be adapted to a training aircraft without a significant impact to the aircraft weight-and-balance.

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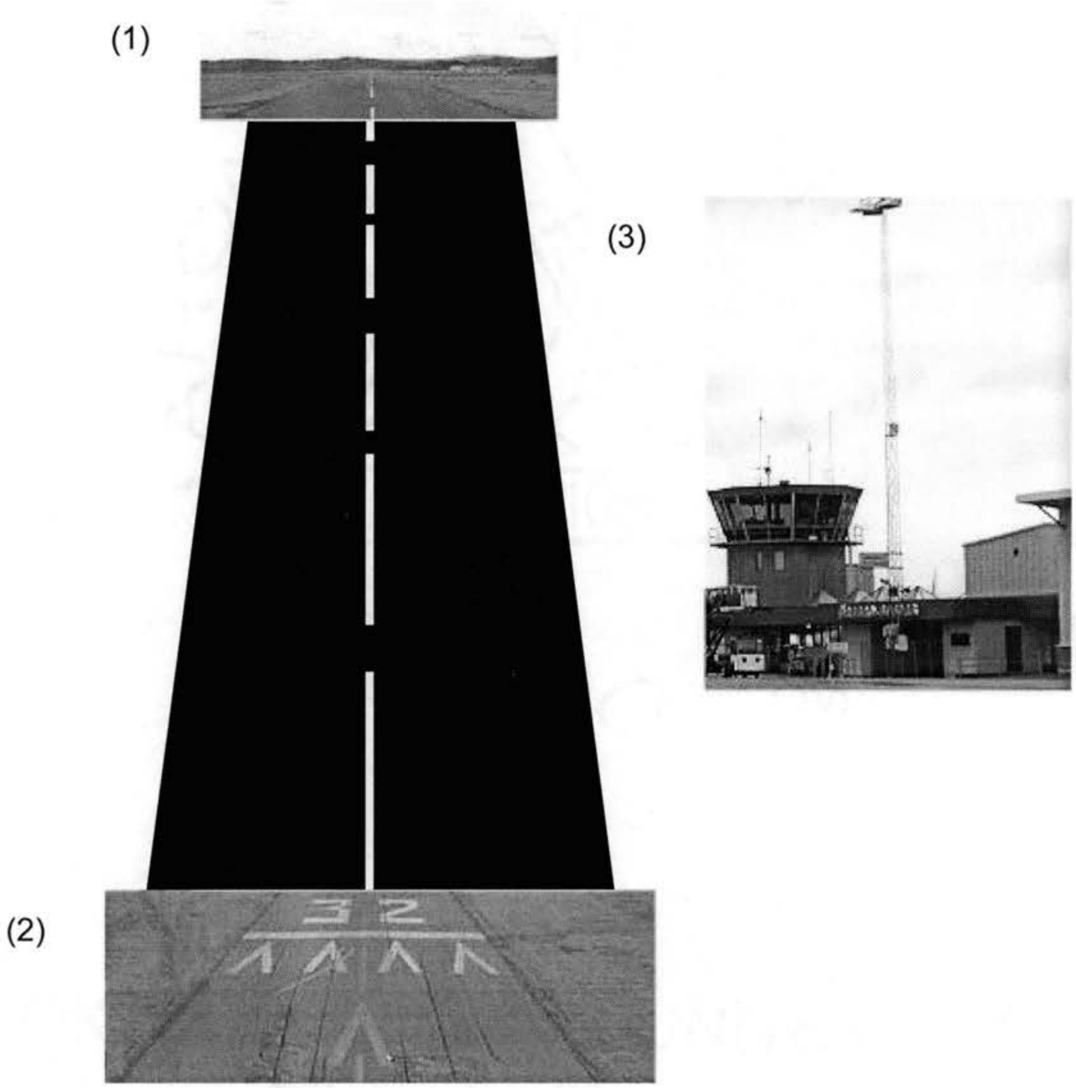
APPENDIXES

APPENDIX A

MONOCULAR CUES EMPLOYED DURING THE LANDING FLARE



(1) The horizon / end of runway

(2) Shape of runway / runway markings

(3) Familiar objects / size of retinal image

APPENDIX B

LANDING CHECKLIST

LANDING PROCEDURES

BEFORE STARTING SIMULATION

(1) Flight Controls -- **FREE and CORRECT**
(2) Altimeter -- **SET**
(3) Wing Flaps -- **FULL**
(4) Mixture -- **RICH**
(5) Prop -- **HIGH RPM**
(6) Throttle -- **IDLE**
(7) Elevator Trim -- **LANDING**

START SIMULATION

(1) Pitch for **70 KIAS**
(2) Aim for **RWY 4-22**
(3) Bank left at **3500 ft** to align with centerline
(4) Pith **12°** for flare
(5) Apply breaks at touchdown

NOTE: This checklist was customized for use with FS2000 and the aircraft simulator study.

APPENDIX C

PILOT LOG

DATE 2001	AIRCRAFT MAKE & MODEL	POINT OF DEPARTURE & ARRIVAL		REMARKS, PROCEDURES, MANEUVERS	NO. LDG	TOTAL DURATION OF FLIGHT (MIN)
		FROM	TO			
	C182S	SWO/SWO	MHV/MHV	normal tko, shallow turns, climbs, desc, ldg stalls	2	60
	C182S	MHV	MHV	normal ldg, pre-solo work	10	50
	C182S	MHV	MHV	normal ldg, solo (5 solo ldg)	8	45
PILOT'S SIGNATURE (N2)____________________				PAGE TOTAL	20	155

APPENDIX D

LANDING FLARE MEASURES

	Alt AGL (ft) (ELEV=2790 ft)					
	10	**20**	**30**	**40**	**50**	**60**
VStd (ft/min)						
Mean	-680.27	-518.57	-275.47	-334.97	-351.87	-469.20
Median	-717.50	-568.00	-273.00	-344.50	-365.00	-478.00
STEV	200.17	146.54	46.68	70.36	79.81	58.15
Dist (km)						
Mean	.376	.369	.329	.307	.353	.331
Median	.372	.376	.333	.314	.345	.336
STEV	.056	.029	.039	.025	.046	.032
Act Flare Alt (ft)						
Mean	2795.73	2804.38	2813.21	2823.35	2833.53	2843.2
Median	2795.70	2804.34	2813.50	2823.31	2833.15	2843.1
STEV	1.968	3.083	2.174	3.232	2.828	2.775
Vtd (kts)						
Mean	49.17	51.97	53.03	50.80	52.80	51.233
Median	49.00	52	53	51.00	53.00	52.00
STEV	3.074	.808	1.033	1.989	1.030	1.633
Remarks	Bounce[1, 2]	Bounce[3]				

<u>Note</u>:
N = 30
VStd = Vertical speed at touch down
Dist = Distance from aiming point
Alt = Altitude
Vtd = Velocity at touch down

---

[1] Initial touchdown point <u>M</u> = 0.0836 km before aiming point (landings 1, 4, 5, 10, 19, 28, 29)

[2] Crash (landings 22, 25)

[3] Initial touchdown point <u>M</u> = 0.0317 km before aiming point (landings 18, 23, 24, 29)

APPENDIX E

PILOT PERCEPTION QUESTIONNAIRE

OSU OKLAHOMA STATE UNIVERSITY

In order to ensure anonymity, please do not write your name on this form. However, for the purpose of demographic information please answer the following items,

A. Gender: ______ male ______ female

B. Age: ______ years old.

❶ The following are standard maneuvers during the landing phase of operation. To the right of each maneuver you will find a scale that indicates level of difficulty (1=extremely easy - 7=extremely difficult). Based on your experience, please indicate how easy or difficult you believe each maneuver is to execute properly.

Please **Circle** your choices to the following maneuvers.

	Extremely Easy						Extremely Difficult
✈ Holding Airspeed	1	2	3	4	5	6	7
✈ Lowering Flaps	1	2	3	4	5	6	7
✈ Aligning with Centerline	1	2	3	4	5	6	7
✈ Flaring the Aircraft	1	2	3	4	5	6	7
✈ Aiming for Touchdown Point	1	2	3	4	5	6	7
✈ Holding Glide Altitude	1	2	3	4	5	6	7

The following questions will be specific to the **landing flare** phase of operations. Answer each question based on your perceptions.

❷ Pilots are required to initiate the flare 10 – 20 feet from the ground. How would you rate the task of judging your aircraft height above the ground when initiating the flare (1=very easy, 7=very difficult)?

1	2	3	4	5	6	7
Very Easy						Very Difficult

❸ **Imagine that you are about to flare the aircraft. How confident are you that your aircraft is 10-20 ft from the ground (1=low confidence, 7=high confidence)?**

1	2	3	4	5	6	7
Low Confidence						High Confidence

❹ Do you think there is a need for improved flare training methods (1=definitely yes, 7=definitely no)?

1	2	3	4	5	6	7
Definitely Yes						Definitely No

❺ How would you rate your landings (1=very good, 7=very poor)?

1	2	3	4	5	6	7
Very Good						Very Poor

❻ If you were interested, how would you rate your potential of becoming a pilot (1=very good, 7=very poor)?

1	2	3	4	5	6	7
Very Good						Very Poor

APPENDIX F

ACCIDENT REPORT ANALYSIS

Aircraft type	Year				
	1995	1996	1997	1998	**Total**
Single engine					
Aero Commander 100	0	0	0	1	**1**
Aeronca 11-AC	0	1	0	0	**1**
Aviat A-1	1	0	0	0	**1**
Ayres S2R	1	0	1	0	**2**
Barrigar RV-6 (hb)	0	0	1	0	**1**
Beech 23	0	2	1	0	**3**
Beech 33	0	0	2	0	**2**
Beech 35	1	1	0	0	**2**
Bellanca 7KCAB	0	1	0	0	**1**
Boeing B75	0	1	0	0	**1**
Brown Air Shark III (hb)	0	0	1	0	**1**
Cessna 140	0	3	0	0	**3**
Cessna 150	5	6	4	12	**27**
Cessna 152	8	21	8	5	**42**
Cessna 170	1	0	1	0	**2**
Cessna 172	13	29	16	15	**73**
Cessna 175	0	0	1	0	**1**
Cessna 177	2	2	2	0	**6**

Aircraft type	Year				
	1995	1996	1997	1998	**Total**
Cessna 180	0	0	1	1	**2**
Cessna 182	3	4	7	4	**18**
Cessna 185	2	0	1	0	**3**
Cessna 195	0	0	0	1	**1**
Cessna 206	2	0	2	0	**4**
Cessna 210	1	2	1	1	**5**
Champion 7ECA /GCBC	2	0	0	0	**2**
Curtis-Wright P-40	0	0	1	0	**1**
Glasair 3SH-3R (exp)	0	1	0	0	**1**
Globe SWIFT	0	0	0	1	**1**
Grumman	1	0	1	1	**3**
Kitfox XL	0	0	0	1	**1**
Knapp Packard (exp)	1	0	0	0	**1**
Kolb Mark III (exp)	0	1	0	0	**1**
LAKE LA-4-200	1	1	0	1	**3**
Lancair 320	1	0	0	1	**2**
Maule	0	1	0	1	**2**
Mooney M20	2	2	2	0	**6**
Mustang II	0	0	0	1	**1**

Aircraft type	Year				
	1995	1996	1997	1998	**Total**
Piper J3C	0	2	1	0	**3**
Piper PA-18	1	0	0	0	**1**
Piper PA-22	0	0	0	2	**2**
Piper PA-24	0	1	0	0	**1**
Piper PA-25	0	0	1	1	**2**
Piper PA-28	4	7	5	7	**23**
Piper PA-32	0	1	2	2	**5**
Piper PA-34	2	0	2	3	**7**
Piper PA-38	0	2	3	0	**5**
Pitts	2	0	1	1	**4**
Rans s-12 xl (exp)	0	0	1	0	**1**
Rominger EYAS (exp)	0	1	0	0	**1**
Russell KR-2 (exp)	1	0	0	0	**1**
Skybolt TD8 (exp)	0	0	0	1	**1**
Siai-Marchetti F206C	0	1	0	0	**1**
Steinke Early Bird	1	0	0	0	**1**
Stoddard Hamilton II	0	0	0	1	**1**
Travel Air	1	0	0	0	**1**
Waco	0	2	0	0	**2**

Aircraft type	Year				
	1995	1996	1997	1998	**Total**
Single total	60	96	69	64	**289**
Multi engine					
Beech 18	1	0	0	0	**1**
Beech 19	1	1	1	1	**4**
Beech 55	1	1	0	0	**2**
Beech 95	0	1	0	0	**1**
Beech 99	0	0	0	1	**1**
Beech 100	0	0	1	0	**1**
Beech 1900	0	1	0	0	**1**
Cessna 310	1	0	0	2	**3**
Cessna 336	0	0	0	1	**1**
Cessna 337	2	0	0	1	**3**
Cessna 402	0	0	0	1	**1**
Fairchild Merlin IIIA	1	0	0	0	**1**
Lockheed L-382	1	0	0	0	**1**
Piper PA-30	0	1	0	0	**1**
Piper PA-44	0	1	0	1	**2**
Multi total	8	6	2	8	**24**

Aircraft type	Year				
	1995	1996	1997	1998	**Total**
Jet engine					
Aero L-39 (exp)	0	0	0	1	**1**
Boeing 747	0	0	1	0	**1**
Boeing 767	0	0	1	0	**1**
Cessna 551 Citation II	0	0	0	1	**1**
Cessna 650 Citation III	0	0	1	0	**1**
Mikoyan Gurevich MIG 15UTI	0	0	1	0	**1**
Jet total	0	0	4	2	**6**
Gyroplane					
Butler-Tool RAF 2000	0	0	0	1	**1**
Clark Barnett J4B2	0	0	0	1	**1**
Knoll-Bensen B-80	1	0	0	0	**1**
Gyroplane total	1	0	0	2	**3**
Glider					
Aeromot AMT-200 (p)	0	0	1	0	**1**
Grob 103	0	0	1	0	**1**
Schempp-Hirth Ventus	0	0	0	1	**1**
Vickers-Slingsby T65A	0	0	1	0	**1**
Glider total	0	0	3	1	**4**

Aircraft type	Year				
	1995	1996	1997	1998	**Total**
Helicopter					
Bell 47	2	2	0	1	**5**
Bell 206	1	1	0	1	**3**
Brantly B-2	0	1	0	0	**1**
Enstrom F-28	0	0	0	2	**2**
Fairchild Hiller FH-1100	0	0	1	0	**1**
Hiller UH-12A	1	0	0	0	**1**
Hughes 269	0	2	1	0	**3**
Hughes 369	1	1	0	1	**3**
McDonnell Douglas 600N	0	0	0	1	**1**
Robinson R-22	4	0	1	2	**7**
Rotorway 162-F	0	0	0	1	**1**
Helicopter total	9	7	3	9	**28**
Total	**78**	**109**	**81**	**86**	**354**

APPENDIX G

INSTITUTIONAL REVIEW BOARD APPROVAL FORM

Oklahoma State University
Institutional Review Board

Protocol Expires: 4/26/02

Date : Friday, April 27, 2001

IRB Application No AS0159

Proposal Title: SIMULATED LANDING FLARE INSTRUCTIONS IN A GENERAL AVIATION AIRCRFT

Principal Investigator(s) :

Charles Abramson
401 N Murray
Stillwater, OK 74078

Danny Benbassat
215 N. Murray
Stillwater, OK 74078

Reviewed and Processed as: Expedited

Approval Status Recommended by Reviewer(s) : Approved

Signature : Carol Olson

Carol Olson, Director of University Research Compliance

Friday, April 27, 2001
Date

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modifications to the research project approved by the IRB must be submitted for approval with the advisor's signature. The IRB office MUST be notified in writing when a project is complete. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

VITA 2

Danny Benbassat

Candidate for the Degree of

Doctor of Philosophy

Thesis: USE OF A DISCRIMINATIVE AUDITORY CUE TO IMPROVE LANDING FLARE PERFORMANCE

Major Field: Psychology

Biographical:

Education: Received a Bachelor of Art in Psychology with a minor in Music from Slippery Rock University of Pennsylvania, Slippery Rock, Pennsylvania in May, 1997; received a Master of Arts degree in Counseling Psychology from Slippery Rock University of Pennsylvania, Slippery Rock, Pennsylvania in May, 1999; receive a Master of Science degree in Psychology for Oklahoma State University, Stillwater, Oklahoma in may 2000; completed requirements for the Doctor of Philosophy degree in Experimental Psychology at Oklahoma State University in August, 2002.

Professional Experience: Graduate assistant in the Department of Counseling and Educational Psychology, Slippery Rock University of Pennsylvania, Slippery Rock, Pennsylvania, 1997 - 1999; Teaching Assistant in the Department of Psychology, Oklahoma State University, Stillwater, Oklahoma, 1999 to 2002; Member of the American Psychological Association; Member of the American Psychological Society.