LANDING FLARE ACCIDENTS AND THE ROLE OF DEPTH PERCEPTION

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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; 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 maneuver that most pilots struggle with (Matson, 1973). According to the National Traffic Safety Board (NTSB), the landing maneuver is 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 descent attitude to the landing attitude and is also known as the flareout, roundout, or leveloff (Jeppesen, 1985). Many pilots intuitively acknowledge and struggle with the challenge of performing proper flares. For example, Barnhart (as cited in Matson, 1973) notes that, "without reservation, the roundout requires keener judgment and more practice than any other single part of basic flying" (p. 4:337).

Nature of the Problem

A review of aircraft accidents draws attention to the flare phase of landing operations. For instance, on February 10, 1996, a Mooney M20M flared too high. The aircraft dropped 3.0m to 3.7m (10 to 12 ft), landed hard, departed the runway, and struck a drainage ditch. Subsequently, the landing gear collapsed and the left wing spar was damaged (National Transportation Safety Board Identification: FTW96LA114). On May 13, 1996, a student pilot on a solo cross-country stalled his Cessna 172 while attempting to land. The student pilot later stated that he ". . . flared [too] early causing the plane to balloon up, and then the aircraft stalled. The aircraft slammed to the ground before I could apply throttle." The airplane was "approximately 5-10 feet above the runway. . . " when it stalled. (National Transportation Safety Board Identification: IAD96LA084). On July 16, 1987, a student pilot was attempting his first solo flight in a Cessna 152. The student failed to achieve a proper flare attitude on his second landing. The aircraft touched down flat and fast, porpoised, and bounced three times. Subsequently, the aircraft's nose gear collapsed, bringing the aircraft to a rest (National Transportation Safety Board Identification: CHI87LA168). Unfortunately, the former vignette is typical of numerous landing accidents. Monthly aircraft landing accident synopses released by the National Transportation Safety Board implicate a probable cause or contributing factor: "Flare. . . Improper / Misjudged . . .Pilot in command".

According to the Airplane Flying Handbook (Federal Aviation Administration, Revised 1999)

> the roundout is a slow, smooth transition from a normal approach attitude to a landing attitude. When the airplane, in a normal descent, approaches within what appears to be about 10 to 20 feet above the ground, the roundout or flare should be started, and once started should be a continuous process until the airplane touches down on the ground (p. 7-6).

Furthermore,

> as the airplane reaches a height above the ground where a timely change can be made into the proper landing attitude, back elevator pressure should be gradually applied to slowly increase the pitch attitude and angle of attack. This will cause the airplane's nose to gradually rise toward the desired landing attitude. The angle of attack should be increased at a rate that will allow the airplane to continue settling slowly as forward speed decreases (Federal Aviation Administration, Revised 1999, p. 7-6).

Evidently, the flare is a crucial phase of the landing operation in which the aircraft transitions from a controlled descent to actual contact with the landing surface (Grosz, et al., 1995). Less apparent are the factors fundamental to the execution of a successful landing flare.

As indicated, the flare is initiated "within what appears to be about 3.0 to 6.1m (10 to 20 ft.) above the ground." How should the pilot-in-command interpret "what appears to be" a certain distance from the ground? Furthermore, what are the ways to assess vertical distance above the ground? Langewiesche (1972) explains, "your first problem is to know when (in the glide) the time has come for you to 'flare out', that is, stop the descent and make the airplane float level" (pp. 297 - 298).

Bramson (1982) exposed the ambiguity of flare instructions by providing flight manual examples of when to flare. One such example suggests, "at a reasonable height, move the stick gently back and make the aircraft fly just above the ground" (p. 44). Bramson remarks, "one man's 'reasonable' is another man's 'outrageous' " (p. 44). Instructors may also provide ambiguous instructions. Bramson (1982) notes that "many instructors like to say 'Round-out at the height of a double decker' (which is all very well if you have ever been on the top deck of a London bus - not everyone has) or 'Ease back on the elevators at 20 ft above the ground', whereas experiments seem to indicate that experienced pilots begin the transition from approach to hold-off rather higher than that" (p. 45).

Others recommend initiating the flare at "hangar height" (Kershner, 1998, p. 13-5). Instructing students to flare at hangar height may be of little use since not all hangars have standard heights and not all runways have hangars adjacent to them. Yet another common recommendation is to use one-half of the aircraft wingspan as a measure unit to initiate the flare (Christy, 1991). Once again, attempting to judge vertical distance with the aid of a measurement scale that is parallel to the ground may prove especially difficult.

Some flight instructors never really try to explain vertical distance appreciation on approach to landing. When executing a misjudged approach, Bramson (1982) remembers comments such as " 'You're too bloody high!' or, in Texas, 'Yo'all tryin' to kill me, lootenant?' But there was no real attempt to explain why I was too high or, more important, how I was supposed to know" (p. 51). Penglis (1994) adds,

> your instructor compounds the humiliation by stating the obvious about your landing ten feet high or ground plowing. They might come back with something useless to cure it, like telling you that you were 'behind the airplane,' which means you didn't think far enough ahead. That doesn't deal with the problem of you not knowing where the ground begins (p. 91).

Furthermore,

> after a frustrating lesson, you can sit with your instructor and try and remember what you did during the lesson. You can't because you won't remember, you won't think that is the problem. If your instructor only deals with the standard teaching methods, he won't know why you don't know where the ground is either. How can the instructor solve a problem that neither of you understand? None of the standard stuff will work because it does not identify and deal with the real problem. . . Because the reason no student knows where the ground begins is because the method we use to teach landing to students is wrong and does not work (Penglis, 1994, p. 91).

Finally, it seems that the flare maneuver poses a significant problem to pilots since,

> 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. You only know where the ground was when you started the transition from the approach to the landing. Anything beyond that is at best a guess, as you try to round out the airplane based only on where you think the ground might be. You cannot be ready for contact with the ground when you have no idea when that will occur . . . you think you have learned something but are frustrated when you cannot repeat the performance. That is why it takes so long to learn how to land an airplane (Penglis, 1994, p. 90).

Statement of The Problem

Many pilots and authors intuitively recognize the flare as a difficult maneuver. This study will explore whether improper flares are indeed a significant issue, determine causes for improper flares, and evaluate flare training methods. This task was undertaken using both qualitative and quantitative methods.

Objectives of the Study

The primary objective was to determine whether improper flares are a significant factor in general aviation. This goal was achieved through the analysis of archival NTSB aircraft accident reports, as well as assessment of pilot perceptions of the flare as a function of experience.

The secondary objective was to determine probable causes for improper flares. The extensive literature review of current flare training methods, and depth perception cues, along with information yielded from the pilot perception questionnaire, were instrumental in achieving this goal.

Finally, the tertiary objective was to assess the effectiveness and identify weaknesses in current flare training methods.

Significance of the Study

Improper flares influence both financial and psychological well being. Failure to correctly judge height during the flare contributes to increased payloads on the main landing gear tires and struts at impact, which may contribute to landing gear and structural damage. In addition, improper or misjudged flares also increase brake, nosewheel tire, and nosewheel shimmy dampener (on Cessnas) wear (Chrisy, 1991; Jorgensen, & Schley, 1990).

As mentioned earlier, perfect landings are the ambition of every pilot and landings are frequently used to evaluate pilot performance (Collins, 1981; King, 1998). As a consequence, it is plausible that improper or misjudged flares may affect pilot self-esteem and self-efficacy. Since student pilots are especially prone to misjudge a landing flare, 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

Expert group was defined as Certified Flight Instructors (CFIs) that are actively involved in student training. CFI total pilot time exceeded 300 hrs at the time of the study.

Flare was defined as the ability to judge height above the ground during the leveloff for the purpose of this study.

Intermediate group was defined as instrument student pilots. Instrument pilot total time exceeded 150 hrs but did not exceed 200 hrs at the time of the study.

Novice group was defined as student pilots that are training for the private pilot certificate. Student pilot total time exceeded 10 hrs but did not exceed 60 hrs at the time of the study.

Normal Conditions were defined as optimal Visual Flight Rules (VFR) conditions (i.e., no wind, 10 miles visibility, etc.).

NTSB Accident Reports were defined as all accident reports produced by the NTSB for the years 1995, 1996, and 1997. These years were chosen because they represented the most current accident report data at the time of the study.

Part 141 schools were defined as flight schools that follow a standardized Flight Aviation Regulation (FAR) method of training.

Scope and Limitations

Perceptions were gathered from pilots undergoing intensive training or instruction in Part 141 flight schools. The fact that all pilots were "current" or have had recent flight experience may limit the ability to generalize findings to general aviation pilots that are not frequent flyers. For example, Part 61 pilots are allowed to complete flight training at their own pace, are not required to attend ground school or flight labs, and typically interact with other pilots less frequently.

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", the 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 purpose of this literature review is to describe (a) the flare maneuver, (b) current flare instruction methods, (c) vision and depth perception, and (d) vertical distance appreciation studies.

Definition and Significance

As shown in Figure 1, the leading cause of non-fatal aircraft accidents is the landing phase of operations (National Transportation Safety Board [NTSB], September 1998; NTSB, May 1999; NTSB, September 2000). According to Balfour (1988), "only about 25% of accidents happen in mid-flight, and over 50% on the approach or landing" (p. 697). Nagel (1988) concurs that more than half of all airline accidents occur during the approach and landing phase of operations. Nagel adds, "As interesting is the fact that the approach and landing accidents are more reliably caused by human error than those of any other phase of flight (nearly 75%)" (p. 278). Pilots are confronted by various tasks during all phases of operations (see Wickens and Andre, 1999) but it is the landing phase that seems to be the most crucial since "in other maneuvers, the pilot can continuously correct his mistakes as they become apparent to him . . . in the landing, the error becomes apparent often only upon contact with the ground, at the instant when it is too late for corrections" (Langewiesche, 1972, p. 287).

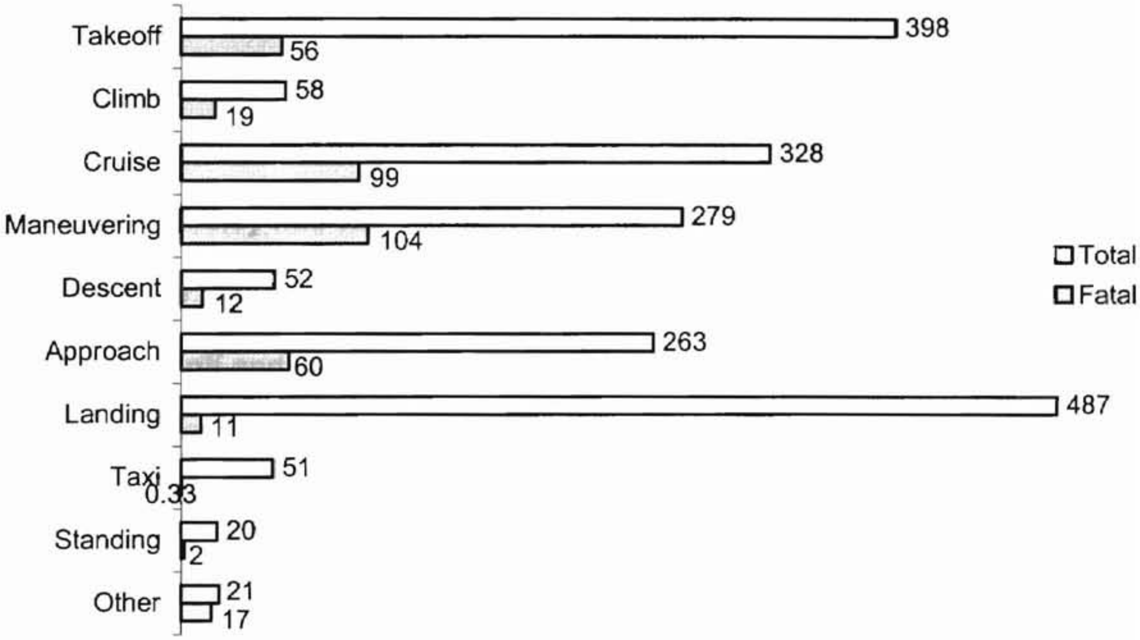

Figure 1. A breakdown of mean total and fatal accident-involved aircraft by first phase of operation, 1995, 1996, and 1997 (adapted from National Transportation Safety Board [NTSB], September 1998; NTSB, May 1999; NTSB, September 2000).

Of special concern is the landing flare phase. For instance, Bramson (1982, p. 12) noted that there were 3,264 aircraft accidents during the flare and touchdown phase of operations between 1975-1979. Interest in the flare maneuver has waned since the 1970s. However, preliminary investigation of aircraft accident reports suggests that a renewed interest in the maneuver is appropriate.

Various authors have discussed the landing flare. According to Barnhart (as cited in Matson, 1973), "early in their training many students can do everything but land the plane" (p. 39:36) and " without reservation, the roundout requires keener judgment and more practice than any other single part of basic flying" (p. 4:337). Love (1995) concurs, "one of the most difficult skills student pilots need to master is determining the height of the aircraft during the flare" (p. 61). Finally, Bramson (1982) states that, "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, wheels just above the ground, power off and airspeed decreased" (p. 44).

According to the Airplane Flying Handbook (Federal Aviation Administration, Revised 1999),

> the roundout is a slow, smooth transition from a normal approach attitude to a landing attitude. When the airplane, in a normal descent, approaches within what appears to be about 10 to 20 feet above the ground, the roundout or flare should be started, and once started should be a continuous process until the airplane touches down on the ground (p. 7-6).

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Current Flare Instruction

As indicated, the flare is initiated “within what appears to be about 3.0 to 6.1m (10 to 20 ft.) above the ground.” How should the pilot-in-command interpret “what appears to be” a certain distance from the ground? Furthermore, what are the ways to assess vertical distance above the ground? Langewiesche (1972) explains, "your first problem is to know when (in the glide) the time has come for you to 'flare out', that is, stop the descent and make the airplane float level" (pp. 297 - 298).

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Common Errors

According to King (1999), the length of time between the start of the flare and the touchdown point is fundamental for a proper landing. Some of the most common errors in this fundamental length of time are (a) flaring too high, (b) flaring too late, (c) bouncing, and (d) ballooning, (Kershner, 1998; King, 1999).

According to Gleim (1998), "a student tends to **round out high** during a landing because (s)he is focusing on references that are too close or looking directly down" (p. 305). Focusing too close leads to blurred perception and faulty depth perception (also see Christy, 1991; Jeppesen, 1985; Kershner, 1998; King, 1999; Quinlan, 1999). The continuation of a high flare may result in a stall that would lead to a hard landing (Federal Aviation Administration, Revised 1999).

Another common error is executing the flare too late. Pilots tend to flare too late when they focus too far ahead (Christy, 1991; Jeppesen, 1985; Kershner, 1981; Love, 1995). Kershner (1998) explains, "if you look too far ahead, the error in your depth perception may cause you to fly the plane into the ground" (p. 13-6). Attempting to correct for a late flare by applying rapid back elevator pressure may impose heavy load factors on the wings and cause an imminent stall. Such a correction and stall may "cause the airplane to land extremely hard on the main landing gear, and then bounce back into the air" (Federal Aviation Administration, Revised 1999, p. 8-2). Kershner (1998) agrees that flying the airplane into the ground may result in a bounce. In his words "the plane hit the ground with quite a bit of flying speed left because the pilot hadn't gotten the nose up to slow the plane down. The wheels hit and the rebound forced the nose up suddenly, giving the wings added lift. The result was that most of the height of the bounce was caused by this lift -- not by the bouncing rubber tires . . . " (p.13-14). Finally, Love (1995) and Butcher (1996) note that flaring too late may result in the nosewheel impacting the ground, or a "wheelbarrow" landing.

Penglis (1994) suggests that standard flaring methods are the cause of common errors during the flare

> since the traditional round out or flare is dependent on precisely timing your arrival at the landing attitude, so that it is just above the ground, when you run out of lift, at the slowest possible speed, you can't possibly do it if you cannot see the ground. That is why you flare too soon and end up hanging in the air or too late and fly into the ground. If you ever time it right, it is sheer luck (p. 90).

Vision and Depth Perception

Judging vertical distance above the ground during the flare is crucial to a smooth and safe landing (Love, 1995). In reference to the process of estimating height and movement, the Airplane Flying Handbook (Federal Aviation Administration, Revised 1999) states, "during the approach, roundout, and touchdown, vision is of prime importance" (p. 7-6). Thom (1992) states, "vision is the most important sense you have for landing" (p.13-13). Furthermore, "accurate estimation of distance is, besides being a matter of practice, dependent upon how clearly objects are seen" (Airplane Flying Handbook, Revised 1999, p. 7-6). The reliance on vision seems to be overwhelming "despite the fact that our visual sense is not completely reliable, pilots often tend to rely on it more than on their instruments; in many approach and landing accidents, primary flight display equipment which would indicate the presence of guidance errors during the final approach has been found to have been functioning normally" (Nagel, 1988, p. 280) (also see Manon, 1996).

In reference to the visual and kinesthetic cues pilots use during the flare and landing, Jeppesen (1985) notes that

> descents and approaches to stalls have been practiced to build sensitivity to control responses and smoothness in preparation for the flare and landing. Generally, kinesthetic sensitivity is not developed fully at the time landing practice begins; therefore, vision is the most important sense (p. 4-17).

Green, Muir, James, Gradwell, & Green (1996) add, "probably the most critical visual tasks that pilots are presented with are the judgments involved in landing. These may be divided into three phases: initial judgment of an appropriate (eg 3°) glide slope, maintenance of the glide slope during the approach, and ground proximity judgments before touchdown" (p. 52).

Various authors have addressed the visual tasks that confront pilots during landings. For example, Butcher (1996), Kershner (1998), and Love (1995) remark that vision should not be fixed on one point during the approach and touchdown. Nevertheless, continuous eye movement may be difficult since "when you get tense, you will almost certainly stare; approaching the ground, most students do get tense; that is largely why the landing is so difficult for most beginners" (Langewiesche, 1972, p. 297). In reference to how far pilots should look during the approach, Christy (1991) recommends looking as far ahead as if you were driving a car at the same speed. However, Kershner (1981) remarks that if this recommendation is taken, pilots will flare too late since drivers tend to look too far ahead and do not judge height (also see Grosz, et al. 1995).

In order to understand how pilots use vision to judge depth perception during an approach for landing, a discussion of depth perception cues will follow.

Binocular Cues

Stereopsis. Binocular disparity (refer to Table 1) depends on both eyes (see Goldstein, 1980). Our two eyes see two different visual fields because of the distance between them. The overlap of the visual fields allows for three-dimensional vision, which is synonymous with depth perception. For every point on the retina of one eye there is a corresponding point on the retina of the other eye. Thus, if we were to place one retina on top of the other, the corresponding retinal points would overlap. However, only images that pass through the observer's point of fixation fall on corresponding points. The imaginary line that passes through the point of fixation is called the horoptor. Images that are not located on the horoptor fall on noncorresponding or disparate points. The distance between the corresponding and disparate retinal points on each retina is called the degree of disparity. The farther an object is from the horoptor, the greater is the degree of disparity. Thus, disparity provides information about depth of objects relative to our point of fixation.

Accommodation and convergence. Accommodation and convergence depend on the muscles of the eyes rather than on information projected onto the retina. Accommodation is the change in the shape of the lenses with change in distance. The lenses of the eyes bulge (protrude) for close objects and flatten for distant objects. The lenses bulge and flatten due to the action of the ligaments that hold the lenses in place. Convergence is the way the eyes move inward to look at a near point and outward to look at a distant point. It has been suggested that accommodation and convergence may only provide depth information for objects closer than about 3.0m (10 ft) from the observer (Goldstein, 1980).

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**. This is the visual appreciation of three dimensions during binocular vision, occurring during fusion of signals from slightly disparate retinal points.

Binocular vision: Innate or learned? Evidence suggests that depth perception information is available even before the visual stimuli reaches the cerebral cortex (Kalat, 1998). Specialized stereoscopic depth perception cells are evident at the level of the retina and it is possible that cells in the magnocellular pathway are sensitive to retinal disparity.

Several reports have suggested that binocular vision is present at a very early age (Fox, Aslin, Shea, & Dumais, 1980; Reinecke & Simons, 1974). In fact, normal binocular vision may be present from 3 to 6 months of age (Reading, 1983). It remains unclear whether humans are born with the ability to detect depth perception. Kalat (1998) stated that "the fine-tuning of binocular vision must depend on experience" (p. 174). Nevertheless, it seems that humans acquire the ability for stereoscopic vision very early in life.

Monocular Cues

Monocular cues (refer to Table 2) may produce depth information even when using one eye. In other words, depth perception information may be acquired in a two dimensional environment (Hawkins, 1993). A brief discussion of monocular cues will ensue (see Bond, Bryan, Gigney, & Warren, March 1962; Goldstein, 1980; Peter, 1999; Reinhart, 1993; Riordan, 1974).

Overlap (interposition). Closer objects overlap or cover more distant objects.

Relative size. Larger objects seem to appear closer relative to smaller objects.

Relative height. Objects that appear higher in the field of vision usually appear to be more distant.

Atmospheric (aerial) perspective. When we look at an object we also look at the air particles that are suspended between the object and us. These particles make far objects look fuzzy and blue. The bluish tint is a result of the short wave lengths that are between the viewer and the far away object. On the other hand, closer objects appear sharper since there are less air particles between the object and the viewer.

TABLE 2

DESCRIPTION OF MONOCULAR CUES

1. **Aerial perspective** - distant objects appear more bluish and hazy than do near objects.
2. **Illumination perspective -** light sources are assumed to be from above.
3. **Interposition** - closer objects obscure distant objects from vision.
4. **Linear perspective** - parallel lines seem to converge with distance.
5. **Motion parallax** - the relative motion of images across the retina. Nearer objects appear to move faster than distant objects.
6. **Relative height** – objects that appear higher in the visual field appear more distant than lower objects.
7. **Relative size** – larger objects seem to appear closer than distant objects.
8. **Shadow** - closer objects usually cast shorter shadows than distant objects.
9. **Texture gradient** - detail is lost with increasing distance.

Texture gradient. Farther objects seem to be closer together or appear to be clustered. The level of detail decreases with distance. Evidence suggests that texture gradient improves landing performance (Mulder, Pleijsant, vand der Vaart, & van Wieringen, 2000), and provides slope information (Goldstein, 1980).

Convergence of parallel lines. Parallel lines seem to converge or meet as distance increases.

Movement parallax. As you move, objects that are closer seem to move relatively faster than objects that are farther away. The farther an object, the more slowly it appears to move. In addition, while nearer objects appear to move against the observer's motion, distant objects appear to move in the same direction. Thus, movement parallax refers to the difference in the speed of movement for far and near objects.

According to Kershner (1981) "there is a definite correlation between apparent relative motion and judgment of height (or distance) if the size of the reference is known . . . the student will tend to level off too high because . . . the faster-than-normal movement of the runway tends to make him believe that he is lower than he actually is, so he gets the nose up to the landing attitude too soon. (crunch.)" (p. 84). Benson (1999) adds, "in addition to the visual cues that are employed to perceive distance and its derivatives, the movement of objects in the parafoveal and peripheral visual fields gives information about speed and altitude, particularly during the final phase of the approach when the aircraft is close to the ground" (p. 449).

Shadow. Closer objects usually cast shorter shadows than distant objects.

Other Monocular Cues

Horizon. The horizon is where the sky meets the earth. Whether on the ground or in the air, the horizon appears to surround us at eye level. Thus, objects that appear below the horizon are lower than you, those that appear above are higher, and those that appear at eye level are at your altitude. The horizon also provides distance information. Objects farthest from the horizon are perceived to be closer, while those nearer are perceived to be farther away (Bond, Bryan, Rigney, Warren, March 1962; Riordan, 1974; Green, 1988). In reference to the landing maneuver, one constant cue is the angle between the horizon and the touchdown point. During a controlled descent for landing the horizon and visual touchdown point will be placed at familiar locations on the canopy (Benson, 1999).

According to Langewiesche (1972), experienced pilots are not concerned with absolute estimates of height, depth, and distance. Contrarily, pilots are interested in the angles formed between the horizon and objects below them in terra firma. In Langewiesche's words, "it is angle, rather than actual height and distance, that matters" (p. 271).

Familiar objects. Perspective of familiar objects (say, hangars, cars, or other aircraft) also allow the pilot to assess vertical distance above the ground. If familiar objects appear distorted (i.e., slanting upward or downward) you are looking slightly up or down at them respectively. On the other hand, if familiar objects do not seem distorted they are at eye level (Langewiesche,1972).

Associated with the perception of familiar objects is the concept of size constancy. Size constancy refers to the fact that familiar objects that are far away and have smaller visual angle and retinal image are not perceived to have smaller absolute size. In other words, the size of a familiar object is perceived to be constant regardless of its distance (Goldstein, 1980).

Despite the ability to identify and define relevant monocular cues, it is not clear which cues are most important for the landing phase of operations. For example, Riordan (1974) surveyed 360 highly experienced (average total pilot time was estimated to be 10,000 hrs) jet commercial airline pilots. The captains and first officers were asked to "identify, in his own words, the visual cues or 'things' which are observed during a visual approach to landing made without the aid of VASI (Visual Approach Slope Indicator) or during a nonprecision visual approach" (p. 767). The questionnaires revealed that the three most important monocular cues were (a) size and shape of the runway, (b) retinal image of familiar objects, and (c) motion parallax. The relationship of the horizon to the runway and motion perspective (also see Reinhardt-Rutland, 1997) were not rated frequently. Nevertheless, other authors recognize other monocular cues as most important. To mention a few, Tredici (1996) notes motion parallax and size of retinal images, while Langewiesche (1972) recognizes the horizon and familiar objects as cues that are used together to judge height.

In reference to identifying cues in order of importance, Green (1988) advises that "it would require difficult experimentation to discover which of the cues to horizon location any particular pilot uses, and it may fairly be suggested that different pilots use different combinations of them" (p. 399) (also see Bond, Bryan, Rigney, & Warren, March 1962). An analysis of pilot eye movement during landing of a Piper Cub J-3 also failed to discover consistent visual habits and suggested that instructors should not teach students to look at specific things and not others during the landing (Tiffin and Bromer, 1943). Riordan (1973) concurs, "the perception of depth or distance during visual approach to landing is a highly complex and integrative perceptual process involving continually changing monocular visual cues" (p. 770).

Monocular vision: Innate or learned? Unlike binocular cues, which seem to be present early in life, monocular cues require "experience, even a person with perfect vision must learn them--learn them formally or informally" (Langewiesche, 1972, p. 296). Benson (1999) concurs that "the perceptual processes are complex and have to be learned by repeated experience in the flight environment" (pp. 311 - 312). Finally, according to Tredici (1996), "the monocular cues are learned, and some investigators believe that they can be improved by study and training" (p. 539). It seems that the accurate interpretation of monocular cues depends on visual experience or learning (Bramson, 1982; Love, 1995; Marieb,1995).

Binocular or Monocular?

Which cues do pilots use to estimate depth perception during the flare? Since the qualitative difference between binocular and monocular cues is that of nature vs. nurture, the question is fundamental to pilot training methods. Benson (1999) maintains that, "at some stage in all landings, except those which are fully automatic, the pilot has to make use of external visual cues to judge distance from touch-down, altitude and derivatives of these variables. These visual cues are essentially monocular cues" (pp. 448 - 449). Bond et al. (March 1962) question the importance of binocular cues in aviation and state, "it is true that there are many functions in flying an airplane which involve short distances, such as reaching for controls within a cockpit, or observing the relative positions of objects near the airplane on the ground. However, when one observes objects at much greater distance than the wing span of his airplane he is probably more dependent upon monocular cues" (p. 5-8).

Other authors have suggested that stereoscopic vision is only reliable for short distances (Langewiesche, 1972; Reinhardt-Rutland, 1997; Reinhart, 1996) whereas monocular cues "work over almost limitless ranges" (Green, 1988, p. 395). For example, Reinhart, (1982) explains that "depth perception (having both of your eyes working together to determine the distance of objects) is only critical up to about 20 feet. Beyond that, depth perception is based on 'visual cues'. That is, over the years that you have lived, your eyes and your brain have become familiar with the relative sizes of different objects; for example, if you see a distant tree with a car next to it, you know the approximate size of each and are able to judge how far you are from them . . . " (p. 67). Langewiesche (1972) concludes that stereoscopic vision is only used in tasks that involve depth perception for short distances such as formation flying and taxiing the airplane on the ground. In reference to aerospace medical testing, Reinhart (1982) states that testing for stereoscopic vision is "not as critical as one would expect, unless there is marked inability to 'fuse' the eyes for vision less than 20 feet" (p. 68).

Various other authors provide evidence to contradict the "old superstition" (Langewiesche, 1972, p. 296) that binocular vision is fundamental for pilots.

Wiley Post is often mentioned in reference to the ability of one-eyed pilots to judge a landing just as well as pilots with normal vision (Hawkins, 1993; Langewiesche, 1972). Nagel (1988) provides evidence from unmanned aircraft operations. He explains that "a number of demonstrations over the past several decades have shown that an aircraft can be flown safely using a closed-circuit television camera to replace the natural visual cues seen through the windscreen" (p. 281).

Finally, evidence for the functional differences between binocular and monocular vision stem from animal research. Unlike humans, who have stereoscopic vision, some animals have panoramic vision. Panoramic vision is possible in animals with laterally placed eyes. In such animals, the location of the eyes minimizes the overlap of the two visual fields. Since convergence is minimized, animals with panoramic vision have a greater visual field, but lack or have limited stereoscopic vision (Marieb, 1995). However, studies have suggested that birds such as pigeons have pathways that are specialized for stereoscopic (binocular) and panoramic (monocular) vision (Güntürkün, Miceli, & Watanabe, 1993). In such birds, binocular vision is controlled by the frontal pathways, and monocular vision by the lateral pathways. It has been suggested that behaviors such as detection of enemies and foraging, which require depth perception for distant objects, are performed by the lateral visual pathways. On the other hand, behaviors such as pecking, which require depth perception for close objects are performed by the frontal visual pathways. Similarly, eagles and falcons also alternate between the two pathways. They utilize lateral (monocular) vision to fixate on distant objects and switch to binocular vision when approaching their prey. Thus, monocular cues are used to assess depth perception for distant objects and binocular cues for close objects.

Reliance on binocular cues may actually discourage 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. 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 cognitive interpretations might have had an advantage over continuous visual guidance. In their words, "vision did not seem to help in reducing the impacts with the ground . . . dependence on visual information may interfere with the adoption of a more appropriate landing strategy. Subjects in vision trials rely only on this continuous source of information, while blindfolded individuals adopted a specific strategy, and prepared in advance instead" (p. 1404).

Since depth perception at landing and touchdown depend on monocular cues, pilots must learn to interpret those cues. The learning process of interpreting perceptual cues is influenced by experience (Hawkins,1993). For example, "stepping onto a moving walkway or an escalator when it is stationary gives a strange sensation. A conflict has arisen between the visual message, which says it is stationary, and past experience which says it should be moving . . ." (p. 114).

Langewiesche (1972) emphasized that all pilots learn to interpret and use monocular clues in order to assess depth perception. Furthermore, "the experienced pilot will say, 'I never use any of that stuff' . . . but the fact is that even the experienced pilot does use these clues and probably no others. He just calls it sense. Any landing field, even the loneliest, most desolate, has an abundance of clues of the kind described" (p. 299).

Support to the notion that depth perception improves with experience comes from a study that assessed the ability of pilots and non-pilots to estimate low-level altitudes from photographs (Rinalducci, Patterson, Forren, & Andes, 1985). Participants were presented with photographs taken at different altitudes and asked to estimate the altitude based on visual cues such as object density, terrain features of known size, terrain features with vertical development, and shading. Results indicated that pilots were more accurate in altitude estimation than non-pilots, suggesting that experience is a necessary ingredient in interpreting low-level flight depth perception cues (on the ability to extract depth perception information from a two dimensional highway-in-the-sky display, see Williams, 2000).

If one accepts the premise that depth perception during the flare depends on monocular cues, and that the interpretation of monocular cues depends on experience, then a paradox emerges. Those that are prone to commit improper flares, such as student pilots, have the least experience. Matters are further complicated since a 5000 hrs total time pilot only has about 8 hrs of flare time (King, 1998). According to Langewiesche (1972), "the more experienced pilot, too, frequently misjudges his height slightly . . ." (p. 291). Kershner (as cited in Matson, 1973) adds, "this disease of sweating landings even strikes old pilots who should know better" (34:82).

Flare and Depth Perception Instructions

Simulating the landing attitude while the airplane is safely parked on the ground is one exercise for improving vertical distance appreciation (Bramson, 1982; Kershner, 1981). Achieving the proper level of attack may be attained by placing a box under the nose wheel of a grounded aircraft (as suggested by Bramson), or by pushing down on the tail (as suggested by Kershner). Bramson recommends spending at least 30 min absorbing the visual cues as they appear from the cockpit at the landing attitude. The exercise may also help pilots to practice shifting their gaze down the left side of the aircraft as the level of attack increases and anterior view is blocked. Kershner recommends that flight instructors walk to the left of the aircraft nose and show the student pilot the appropriate visual field for scanning. This exercise is imaginative but may be more suitable for the roundout phase, as back elevator pressure is gradually increased, compared to the leveloff phase when pilots judge their height above the ground.

Another exercise suggested is flying the aircraft low and slow down the runway at hold off altitude (Bramson, 1982; Kershner, 1981). Bramson maintains that holding the aircraft just above the runway teaches vertical distance appreciation as well as proper scanning techniques. Matson (1973) examined the effectiveness of a prolonged flare 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, sequence of maneuvers). No significant differences were found among the students taught by the prolonged flare and those taught by the normal flare methods.

In reference to the role of vision during the flare, Penglis (1994) identified an optical illusion. During a normal approach the aircraft appears to be descending towards the ground. However, as the aircraft transitions for landing, the ground appears to rise toward the aircraft. That is when, according to Penglis, the flare begins. Penglis adds that

> all the coaching in the world won't stop the mistake that every student makes. You fly the airplane down near where you think the ground is, raise the nose to where it totally obscures any forward vision, idle the

> engine, release all control pressures which neutralize your flight controls, stare straight ahead at the blue sky over the nose, wait, pray, and hope for the best. All students give up flying the airplane the minute the ground disappears from view. From then on the landing is just a guess (p. 91).

Penglis recommends placing the nose of the aircraft just under the end of the runway during the transition for landing. When the nose is at a level attitude with the far end of the runway the flare should be initiated. In order to keep the end of the runway just under the nose the pilot must increase back-elevator pressure. That necessity will protect against improper flares. For example, pilots that tend to flare too high will be forced 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.

Interim Discussion

The transition from a descent attitude to leveloff flight marks the beginning of the flare. During this transition, vision is of prime importance. Nevertheless, there is no agreement among training methods how to use vision during the landing flare, and no one method is more effective than another (also see Matson, 1973). Generally, flare instructions and flight training manuals, which have not changed since the 1930s (see Matson, 1973), fail to explain how to judge what "appears to be" 10 - 20 ft from the ground, and regard the ability as natural.

It is reasonable to assume that pilots learn appropriate depth perception cues through experience even though the process may not be conscious. Dependence on experience represents a significant problem, since, on average, the flare only lasts 6 sec (King, 1998) and general aviation pilots in general, and students in particular, lack experience.

In conclusion, a review of the literature suggests that the flare maneuver may represent a problem in general aviation. Assessing the frequency of flare accidents and pilot perception of the flare as a function of experience are the first steps to understanding the magnitude and significance of this problem.

III DESIGN AND METHODOLOGY

Study 1 – National Traffic Safety Board Accident Reports

In order to determine the magnitude and significance of improper flares, accident 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 the final description of accidents and probable cause were used. Since the lag time between preliminary to final reports is approximately three years, this study analyzed accident reports from 1995, 1996, and 1997. 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 explicit clues within the narrative that implicated a flare accident. Overall, 6676 accident reports were analyzed.

Study 2 – Pilot Perception Questionnaire

In order to determine the factors that contribute to improper flares this study employed a questionnaire. The questionnaire was constructed for the purpose of the study and assessed pilot perceptions of the flare as a function of experience.

Participants

In order to assess pilot perceptions of the flare as a function of experience, three groups of pilots (novice, intermediate, expert) were surveyed using purposive sampling.

An a priori power analysis was conducted with the statistical software Gpower. Results suggested a total sample size of at least 159 pilots (minimum of 53 novice, 53 intermediate, and 53 expert; alpha = .05, power = .80, effect size "f" = 0.25). However, due to insufficient response rates, only 134 pilots (novice = 55, intermediate = 45, expert = 34) participated in the survey design. Appendix A provides descriptive information by school and experience.

The novice group included student pilots (n = 55; mean age = 20.45, SD = 3.31; mean total flight time = 27.68 hrs, SD = 16.26). Only student pilots that were training for the private pilot certificate were considered as participants. Student pilot total time exceeded 10 hrs, but did not exceed 60 hrs at the time of the study. The intermediate experience group included instrument student pilots (n = 45; mean age = 22.27, SD =4.46; mean total flight time = 183.02 hrs, SD = 39.49). Only pilots that were training for the instrument-rating certificate were considered as participants. Instrument pilot total time exceeded 150 hrs but was not more than 200 hrs at the time of the study. Finally, the expert group consisted of Certified Flight Instructors (CFIs) that were actively involved in student training (n = 34; mean age = 25.85, SD = 5.21; mean total flight time = 785.53 hrs, SD = 750.59). Certified flight instructors total pilot time exceeded 300 hrs at the time of the study.

Pilots were drawn from three Part 141 approved flight schools. The schools were (a) the department of aviation and space program at Oklahoma State University located in Stillwater, OK, (b) Spartan School of Aeronautics located in Tulsa, OK, and (c) the department of aviation at the University of Oklahoma located in Norman, OK.

Oklahoma State University (OSU) is a large (approximately 19,553 students, Oklahoma State University, 2000) comprehensive research university. Students participating in the bachelor degree in aviation sciences with specialization in the professional pilot program were recruited. The department of aviation and space program operates from Stillwater Municipal Airport (SWO) located in Stillwater. Spartan is a private aeronautical college. The college offers diploma, as well as associate degree programs in aviation maintenance, aviation flight, aviation electronics, instruments, communications, quality control and nondestructive testing. Students participating in the professional pilot diploma program, as well as the professional pilot degree program were recruited. Spartan School of Aeronautics operates from Richard Lloyd Jones Airport (RVS) in Tulsa. Finally, the University of Oklahoma (OU) is a large (approximately 23,153 students, University of Oklahoma, 2000) comprehensive research university. Students specializing in the professional pilot or aviation management program that leads to an undergraduate degree in aviation were recruited. The department of aviation operates from Max Westheimer Airpark (OUN) in Norman, OK.

Participation in the study was voluntary. Participants were notified that their participation was voluntary, and that they were permitted to refuse to participate or withdraw from participating at any time. Demographic information included (a) gender, (b) age, (c) total flight time, (d) approximate flight hours within 90 days, and (e) type of aircraft most frequently flown. Participants were debriefed upon completion of the study.

Research Instrument

As evident from Appendix B, pilot perceptions were assessed using a 23-item questionnaire. The first part consisted of 10 standard flight maneuvers. Pilots were asked to assess how difficult they believe each maneuver is to execute properly based on their experience. In reality, the landing flare was the only item of interest. The other nine items were presented to increase the sensitivity of the measuring scale.

The remaining items were specific to the landing flare. Items 11 - 13 were designed to assess perceptions of landing flare accident frequencies. Answers were compared to accident statistics derived from this study. That comparison provided an index to the perceived significance of the flare maneuver. Pilots were asked to assess the frequency of landing flare accidents, how confident they were in their assessment of landing flare accident frequencies, and the probability of being involved in a flare accident during the landing phase of operations. Convergent validity was assessed through items 11 and 13.

Items 14 - 20 assessed the factors that contribute to successful landing flares, perceived difficulty of the flare, and perceived need for improved training methods. Pilots were asked if they were confident that they were at flare altitude before initiating the flare, what factors assisted them to estimate height in the past, whether they perceived the task of judging height difficult, how they knew it was time to flare, was there a need for improved flare training methods, to what they attributed their current successful landing flares, and if they perceived the ability to judge height during the flare as innate or learned. Partial convergent validity was provided through items 15 and 19.

Whereas items 1 - 20 were forced choice questions (Likert scale or multiple choice), the remaining three (21 - 23) were open-ended. Items 21 - 22 were designed to allow pilots to elaborate on answers made previously. Pilots were reminded of items 17 and 19 and asked to explain how they knew it was time to initiate the flare, and to what they attributed their current successful flares. Finally, item 23 attempted to identify the visual cues necessary for depth perception during the flare.

Questionnaire design and development. The questionnaire was developed with the assistance of novice, intermediate, and expert pilots.

Content validity. Experts in the field of aviation and psychology were asked to evaluate whether each item assessed what it purported to assess. Experts rated each item on a 10 point scale (1 = low content validity, 10 = high content validity). Only items with mean rating of 8 or higher were included in the questionnaire.

Research Design and Procedure

Flight schools were visited pending (a) prior arrangement with flight school officials, (b) approval of Internal Review Board, and (c) approval of individual flight center review board (if any).

Pilots were contacted while in ground school or flight center settings. The investigator explained (a) his affiliation, (b) the purpose of the study, and (c) participant rights. Participants were then allowed to complete the questionnaire at their own pace. Upon completion, pilots were debriefed.

Questionnaire data was scrutinized using a between-subjects one-way ANOVA (novice, intermediate, expert). A total sample size of 134 pilots (novice=55, intermediate=45, expert=34) responded to the questionnaire. All assumptions underlying the use of a one-factor linear ANOVA model (independence, normality, homogeneity of variance) were verified.

Analysis of data. The first step was to test for possible effects of flight schools on pilot perceptions. Homogeneous experience groups were compared across school environments to test for main effect of school. Next, depending on the results, each item was analyzed for effects of experience on pilot perceptions. One-factor ANOVA was used to test the effects of experience on perceptions for items that did not show a significant main effect of school environment. Conversely, treatment by block design was used to test effects of experience on perceptions for items that did show a significant main effect of school environment. Tukey Honestly Significant Different (HSD) tests were used to explore significant main effects. All comparisons were conducted at the .05 level of significance.

Dependent variable. Pilot perceptions of the flare, operationally defined by individual item scores.

Independent variable. Pilot experience (novice, intermediate, expert).

Hypotheses

H_0. There will be no significant difference in mean perceptions among the novice, intermediate, and expert groups.

H_1. There will be a significant difference in mean perceptions among the novice, intermediate, and expert groups.

Exploratory F test. Three separate sets of exploratory tests were conducted for each item to determine main effect of learning environment (OU, OSU, Spartan). One set examined the effects of school environment on novice pilot perceptions, another the effects of school environment on intermediate pilot perceptions, and the last, the effects of school environment on expert pilot perceptions. Significant differences in mean pilot perceptions may have suggested the existence of confounding variables such as quality of instruction or type of aircraft used.

It was hypothesized that there would be no significant differences in mean perception among the three training locations for each homogeneous experience group, $\mu_{osu} = \mu_{ou} = \mu_{s}$.

Rationale. Review of the literature suggested that pilot perceptions of the flare depend on experience or learning. Level of experience was a factor in the design, and thus was measured. Furthermore, all training locations followed standardized Part 141 Federal Aviation Rules, thus controlling for quality of training. It was determined that items with a significant main effect of school environment will be blocked with a treatment by block design.

CHAPTER IV

RESULTS

General

This thesis employed quantitative and qualitative measures. The results for each are presented next.

National Traffic Safety Board Accident Reports

Overall, 6676 accident reports produced by the National Traffic Safety Board (NTSB) were analyzed for frequency of flare accidents. Since the frequency of flare accidents is subsumed within the approach and landing category, results presented in this section are unique to this study. Appendix C provides frequency of flare accidents by year and aircraft type. It was discovered that the National Traffic Safety Board (NTSB) investigated an average of 7.44 (SD = 3.91) 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). Given outliers, it would be prudent to consider that the mode and median of flare accidents across the three years was eight. There was no significant difference in mean flare accidents among the three years, F = (2, 33) = 1.654 > .05.

As shown in Figure 2, the frequencies of flare accidents increased during the warmer months. That trend can be found across phases of operation. The reason may be simple, since more aircraft are flown during the warmer months the probability of accidents increases.

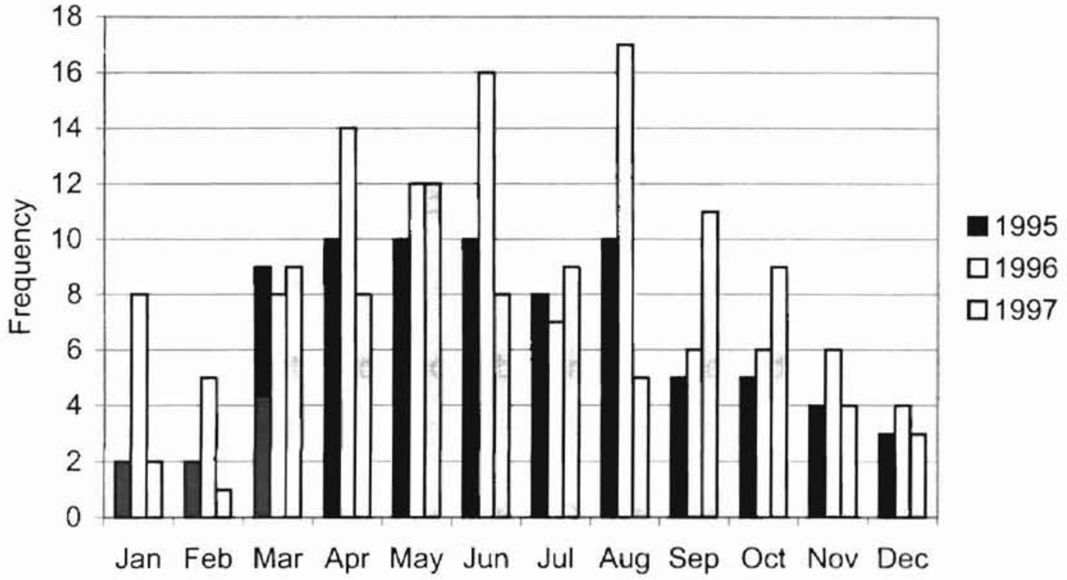

Figure 2. Flare Accident Frequencies by Month

Flare accident frequencies by aircraft type and year are presented in Figure 3. Overall, across the years 1995, 1996, and 1997, 83.96% of all aircraft involved in flare accidents were single engine aircraft. Helicopter flare accident frequencies constituted 7.09% of all flare accidents, multi-engine 5.97%, Jet engine 1.49%, glider 1.12%, and gyroplane 0.37%. Similar frequencies are reflected in accident by aircraft type data for total aircraft accidents published by the National Transportation Safety Board.

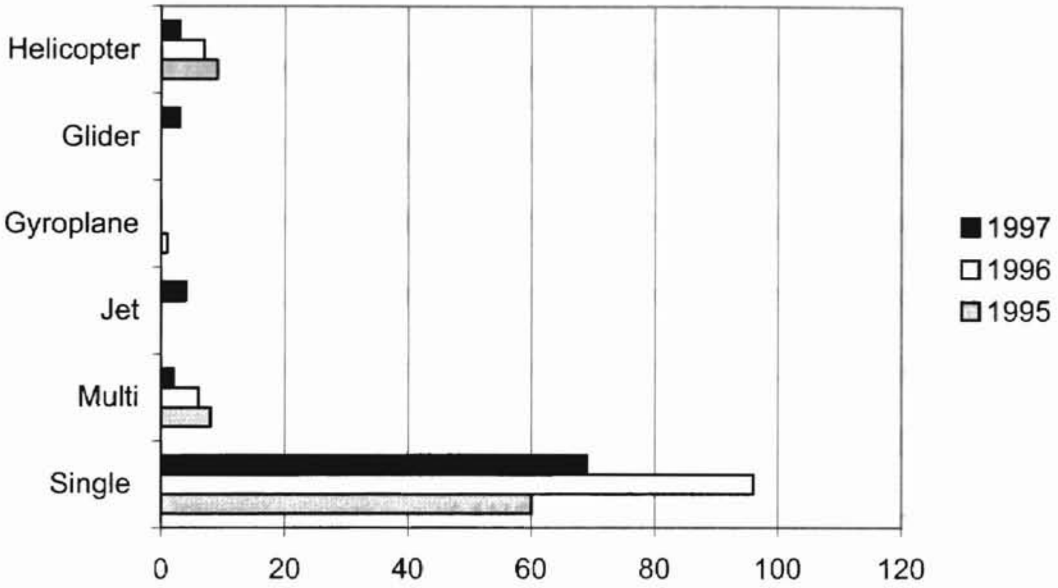

Figure 3. Flare Accident Frequencies by Aircraft Type and Year

Pilot Perception Questionnaire

Content Validity

A 23-item questionnaire was constructed for the purpose of this study. Experts in the fields of psychology and aviation were asked to rate the items for content validity. Only items with a mean content validity of 8 and above were included in the questionnaire. Mean expert rating for items 1 - 10, 12, 13, and 15 - 23 was 10. Item 11 received a mean rating of 9.5. A mean rating of 8.5 was awarded to item 14.

Assumption of ANOVA

The questionnaire design used unequal sample sizes. It is important to stress that the unequal sample sizes were unrelated to the dependent variable. In other words, failure to achieve equal sample sizes was not due to a systematic manipulation. Therefore, it was decided to use an unweighted mean design.

The likelihood of violating the assumptions of normality and homogeneity increase in unequal sample size designs (Keppel, 1991). Even mild deviations from the assumptions of normality and homogeneity require careful interpretation of the results. The assumptions of ANOVA, deviations from the assumptions, and corrections to violations of the assumptions are presented next.

Independence. In order to ensure independence of scores, pilots were advised not to converse while completing the questionnaire and encouraged to work individually. Furthermore, pilots were notified that there are no right or wrong answers since the questionnaire measures individual opinions or beliefs.

Normality. ANOVA is robust to violations of normality when cells include less than twelve cases. Assumptions of normality were met when effects of experience on pilot perceptions were measured.

However, when the effect of school environment on pilot perceptions was measured, assumptions of normality were not met for the expert group. Two expert cells contained less than 12 subjects (OSU = 11, Spartan=11). As suggested by Keppel (1991), the significance level for the expert group was shifted from .05 to .025 in order to correct for the asymmetric distribution. Thus, effects of school environment on expert pilot perceptions was conducted at the .025 alpha level.

Homogeneity of Variance. Results suggested that group variances were significantly different for two items. Group variances were significantly different for contribution of instrument reading on the ability to estimate aircraft height in the past, Fmax (2, 131) = 1.72, $p < .05$, and contribution of CFI instruction to the success of current landing flares, Fmax (2, 131) = 2.97 $p < .05$.

Since the Fmax ratio did not exceed three (Kepple, 1991), a more stringent alpha level (.01) was adopted for the items mentioned above in order to correct for type I error.

Exploratory F Test

As mentioned, the effects of school environment on pilot perception were measured before testing for effects of experience on pilot perceptions. Three sets of exploratory tests were conducted for each item. One set measured the effects of school on novice pilot perceptions, another the effects of school on intermediate pilot perceptions, and the last, the effects of school on expert pilot perceptions. Whereas a one-way ANOVA design was used to analyze effects of experience on pilot perceptions for items that did not show a main effect of school environment, a treatment by block design was used to analyze items that did show a main effect of school. Thus, school was co-varied for items that showed a main effect of school. Items that were robust to the effects of school environment are listed next.

An exploratory main effect analysis of variance revealed a significant effect of school environment (OU, OSU, Spartan) on pilot perceptions for estimated number of flare accidents per year, contribution of innate abilities to depth perception during the flare, and improved training methods.

Significant effects of school on novice pilot perceptions regarding flare accident frequencies were found, F (2, 52) = 8.100, p = .001. Post hoc analysis revealed that Spartan novice pilots (M = 303.54, SD = 137.43) estimated higher accident frequencies than Oklahoma State University (M = 208.00, SD = 128.02) or University of Oklahoma (M = 130.15, SD = 100.08) novice pilots.

In addition, significant effects of school on intermediate pilot perceptions regarding the contribution of innate abilities to judgment of height during the flare were found, F (2, 45) = 3.351, p = .045. However, these differences in perceptions among Oklahoma State University (M = 3.83, SD = 1.42), University of Oklahoma (M = 3.78, SD = 1.25), and Spartan (M = 2.77, SD = .832) intermediate pilots were subsumed within a non-significant Tukey's Honestly Significant Difference post hoc analysis. Nevertheless, school was blocked when the effects of experience on pilot perceptions for the above-mentioned item were analyzed.

Finally, significant effects of school on intermediate pilot perceptions regarding the need for improved flare training methods were found, F (2, 42) = 3.355, p = .044. Post hoc analysis suggested that Oklahoma State University intermediate pilots (M = 4.39, SD = 1.50) were more likely to believe that there is a need for improved flare training methods than Spartan intermediate pilots (M = 3.23, SD = 1.24).

Findings

Effects of experience on pilot perceptions for each item, as well as omnibus findings are presented next.

Perceived difficulty. As shown in Figure 4, significant effects of standard flight maneuvers on pilot perceptions of difficulty were found, F (9, 1330) = 32.469, p = .001 (effect size "eta^2" = .180, power = 1.00). Post hoc analysis revealed that pilots believed the flare maneuver (M = 3.07, SD = 1.42) to be more difficult than steep turns (M = 2.61, SD = 1.18), takeoff roll (M = 1.42, SD = .778), holding altitude (M = 2.18, SD = 1.13), climbing (M = 1.57, SD = .862), descending (M = 1.62, SD = .940), taxiing (M = 1.42, SD = .843), coordinated turns (M = 2.04, SD = 1.07), forward slip (M = 2.31, SD = 1.26), and landing roll (M = 2.06, SD = 1.35).

Furthermore, significant effects of experience on perceived difficulty of the flare maneuver were found, F (2, 131) = 6.875, p = .001 (effect size "eta^2" = .095, power = .917). Post hoc analysis indicated that novice pilots (M = 3.58, SD = 1.41) believed the flare maneuver to be more difficult than intermediate (M = 2.84, SD = 1.15) or expert (M = 2.56, SD = 1.54) pilots. Intermediate and expert pilot perceptions did not differ.

When isolated from other maneuvers, there was no effect of experience on the perceived difficulty of judging the aircraft height during the flare, F (2, 131) = .911, p > .05. Marginal means for perceived difficulty were (M = 3.32, SD = 1.41). Moreover, confidence in estimating the aircraft altitude during the flare was not effected by experience, F (2, 131) = 1.960, p > .05. Overall, pilots were confident in their ability to estimate the aircraft altitude during the flare (M = 5.57, SD = 1.13).

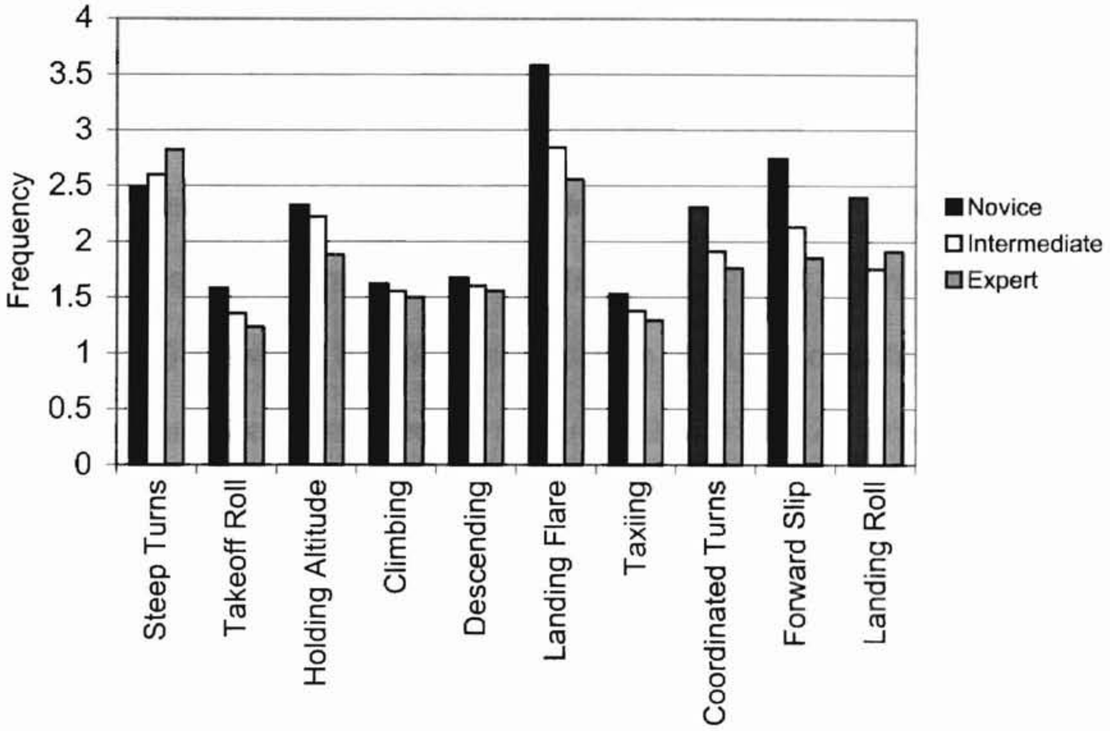

Figure 4. Task Difficulty by Maneuver and Pilot Experience

Perceived significance of the flare maneuver. Experience did not influence pilot estimation of flare accident frequencies, F (2, 125) = 2.773, p > .05. Overall, regardless of experience, pilots estimated that there were 199.39 (SD = 135.81) flare accidents per year. Pilot assessments were compared with flare accident frequencies for 1995, 1996, and 1997. The mean number of flare accidents across the three years was 89.33 (SD = 17.09). Thus, pilots estimated flare accident frequencies to be twice as frequent as they really are.

Pilots were not equally likely to be confident in their answers, F (2, 131) = 6.487, p =.002 (effect size "eta^2" = .090, power = .901). Post hoc analysis revealed that expert pilots (M = 3.94, SD = 1.23) were more confident than intermediate (M = 3.18, SD = 1.21) or novice pilots (M = 2.96, SD = 1.23). Overall, regardless of experience, there was no significant relationship among the number of flare accidents reported, and level of confidence, r (134) = .091, p > .05.

When asked for the likelihood of being involved in a flare accident during the landing phase of operations, most pilots (novice=27.3%, intermediate=26.7%, expert=38.2%) answered 0 - 5%. The proportion of flare accidents within total landing accidents was computed for 1995 (19.90%), 1996 (27.59%), and 1997 (19.90%). It was found that flare accidents accounted for 22.44% of the total landing accidents. Thus, while pilots overestimated flare accident frequencies, they underestimated the significance of flare accidents in proportion to overall landing accidents. Nevertheless, it is possible that pilots misunderstood the question and estimated the likelihood of personally being involved in a flare accident.

Components of successful flares. As shown in Figure 5, factors that may have assisted pilots in estimating their height during their first solo flare attempts had a significant effect on pilot perceptions, F (4, 665) = 159.818, p = .001 (effect size "eta^2" = .490, power = 1.000). Post hoc analysis revealed that practice (M = 6.43, SD = .984) assisted pilots more than CFI instructions

(M = 5.33, SD = 1.54), instrument readings (M = 3.20, SD = 1.75), pilot manual (M = 2.43, SD = 1.47), and ground school (M = 3.34, SD = 1.75). Pilots believed that, with the exception of practice, CFI instructions help them more than instrument reading, pilot manual, and ground school in their first solo attempts.

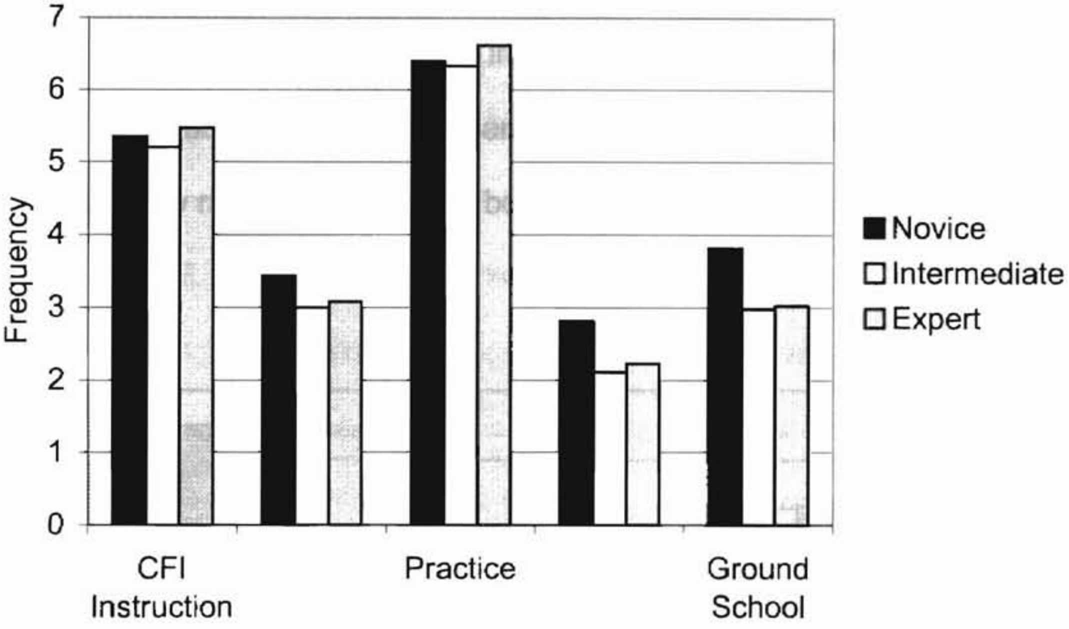

Figure 5. Contributing Factors to Successful Flares During Initial Solo Attempts

Pilots attributed the success of past landing flares to practice, CFI instruction, contribution of ground school, instrument reading, or pilot manual regardless of experience, F (2, 131) = .858, p > .05. Overall, marginal means suggested that pilots did not believe that ground school training (M = 3.34, SD = 1.75), instrument reading (M = 3.20, SD = 1.75), and pilot manual (M = 2.43, SD = 1.47) assisted them in estimating the aircraft height before initiating the flare during their first solo attempts.

As depicted in Figure 6, similar findings were noted among factors that contributed to current successful landing flares, F (4, 665) = 301.606, p = .001 (effect size "eta^2" = .645, power = 1.000). Post hoc analysis revealed that pilots attributed their current successful flares to pattern practice (M = 6.32, SD = 1.10) rather than their instructor (M = 5.70, SD = 1.33), natural ability (M = 4.63, SD = 1.43), aviation books (M = 2.75, SD = 1.35), or sheer luck (M = 1.78, SD = 1.18). Pilots believed that their instructor helped them more than natural ability, aviation books or sheer luck, and attributed their successful landing flares to natural ability rather than aviation books or sheer luck.

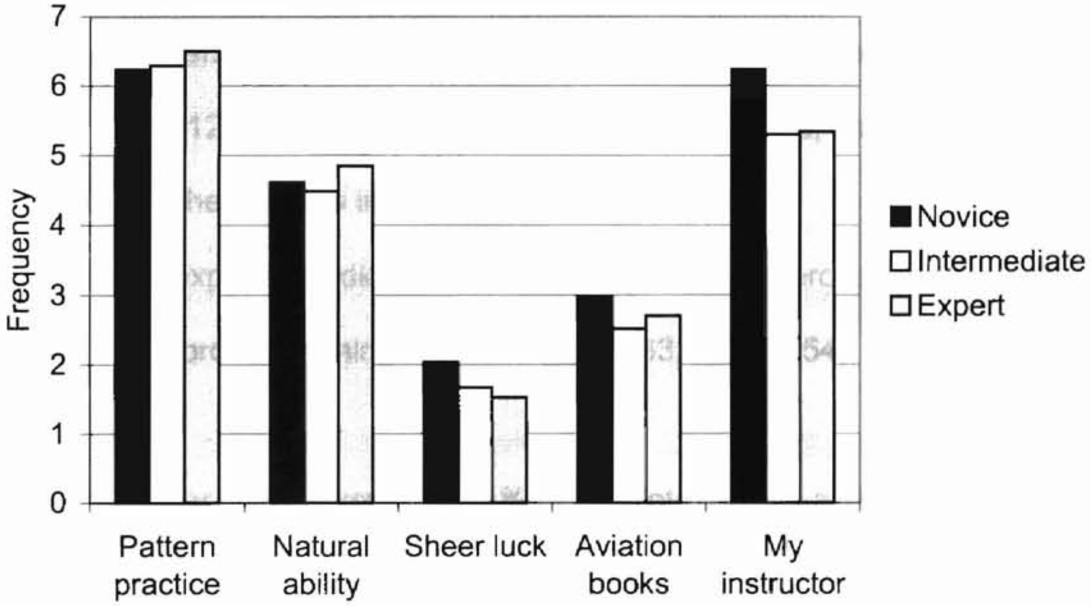

Figure 6. Contributing Factors to Current Successful Landing Flares

Pilot experience did not have an effect on pilot perceptions regarding the significance of pattern practice, F (2, 131) = .628, p > .05. Overall mean significance of pattern practice was (M = 6.32, SD = 1.10). Nevertheless, experience did have an effect on pilot perceptions regarding the contribution of CFI instruction to current successful landing flares, F (2, 131) = 8.442, p = .001 (effect size "eta^2" = .114, power = .962). As suggested by post hoc analysis, novice pilots (M = 6.24, SD = 1.30) contributed their successful landing flares to their CFI more than intermediate (M = 5.31, SD = 1.38) or expert (M = 5.35, SD = 1.38) pilots. On the other hand, intermediate and expert pilots did not differ.

Attributing successful current flares to natural ability was not affected by pilot experience, F (2, 131) = .627, p > .05. Overall descriptive statistics revealed that 66.14% of current successful flares were attributed to natural ability (M = 4.63, SD = 1.43). Similarly, experience did not have an effect on pilot perceptions when they were asked "is the ability to estimate height innate or learned?" F (2, 125) = 1.672, p > .05. However, in this case, only 46.00% answered that the ability is innate (M = 3.22, SD = 1.48).

Finally, experience did not have an effect on pilot perceptions regarding the need for improved training methods (M = 3.63, SD = 1.54), F (2, 125) = .510, p > .05.

Monocular cues. Overall 85.11% of all pilots (novice = 76.4%, intermediate = 84.4%, expert = 100%) stressed the importance of vision during the leveloff. As shown in Figure 8, when asked what type of visual information would assist in estimating the aircraft height before initiating the flare, 26.04% of the pilots (novice = 10.65%, intermediate = 7.69%, expert = 7.69%) indicated the horizon and end of runway, 18.93% (novice = 9.47%, intermediate = 5.92%, expert = 3.55%) indicated shape of runway and runway markings, 9.47% (novice = 4.14%, intermediate = 2.37%, expert = 2.96%) indicated familiar objects, 4.14% (novice = 2.96%, intermediate = 1.18%) indicated angle with runway, 1.18% (novice = 0.59%, intermediate = 0.59%) indicated motion parallax, .059% of the expert pilots indicated relative size, and 0.59% of experts indicated texture gradient. As depicted in Figure 8, 28.99 % (novice = 13.02%, intermediate = 10.06%, expert = 5.92%) were not able to identify what it is in the visual environment that assists in vertical distance estimation during the flare.

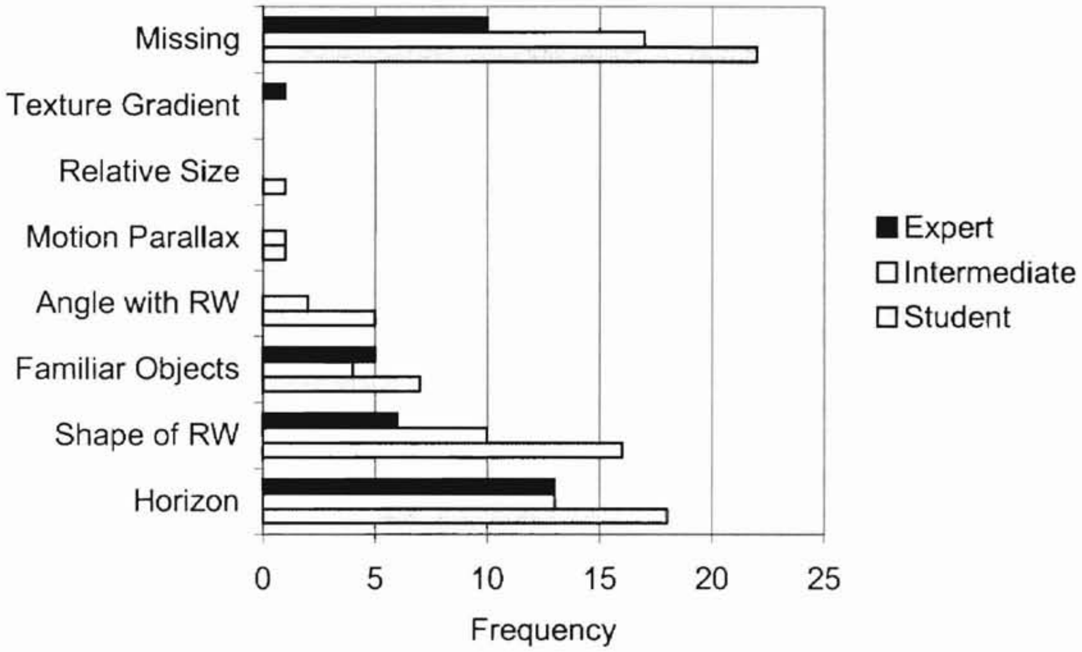

Figure 7. Monocular Cues Employed During the Landing Flare

It is interesting to note that 10.06% (novice = 5.92%, intermediate = 1.18%, expert = 2.96%) indicated the use of kinesthetic information such as ground effect or “sinking rate” as a contributing factor to successful landing flares.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study first separated flare accident frequencies from the approach and landing accident frequencies. The task of sorting out flare accidents from NTSB accident reports was unique to this study and revealed disturbing results. As indicated, there were approximately eight flare accidents per month across the years 1995, 1996, and 1997.

It is important to note that flare related incidents are most likely under reported to the NTSB and the Federal Aviation administration (FAA). Private aircraft owners may underestimate flare incidents or simply avoid the embarrassment of reporting a flare incident. Moreover, it was found that many accident narratives included the symptoms of improper flares, but were not diagnosed as a flare accident. It is possible that the ability to diagnose flare related incidents varies from one investigator to another.

Conclusions yielded from NTSB accident report analyses were supported by pilot perceptions. Overall, pilots believed the flare maneuver to be more difficult than steep turns, takeoff roll, holding altitude, climbing, descending, taxiing, coordinated turns, forward slips, or landing roll, regardless of their experience. Moreover, this study supported the relationship among proper flares and experience. Results suggested that novice pilots found the flare maneuver to be more difficult than intermediate or expert pilots.

It is possible that pilots intuitively recognize the flare as a hurdle to perfect landings but fail to acknowledge the significance of the maneuver. When asked to estimate flare accident rates, pilots grossly overestimated the number of flare accidents per year. Pilot overestimation of flare accident rates may be an implicit admission to the difficulty of the flare maneuver. However, explicit questions revealed a different trend. Overall, pilots underestimated the proportion of flare accidents within total approach and landing accidents, were confident in their ability to estimate height during the flare, and only provided lukewarm support for improved flare-training methods.

In order to understand pilot perceptions, one must explore how pilots perceive depth during the flare. Overall, all pilots recognized vision as the most important tool for depth perception during the leveloff. However, most pilots failed to explain how vision is used during the flare. Thus, it is possible that awareness is not critical to the learning of appropriate visual cues. In fact, whereas the acquisition of flare depth perception cues is a product of experience or learning, approximately one half of the sampled pilots attributed their successful flares to natural or innate abilities.

One of the most significant findings was the importance of experience and proper training. All pilots, regardless of experience, attested to the importance of experience and instruction. Analysis of qualitative data suggested that pilots particularly stressed the importance of repeated practice coupled with proper instruction.

Despite findings of implicit support to the difficulty of the flare maneuver, this study failed to find omnibus effects of experience on pilot perceptions. Similarities among novice, intermediate, and expert perceptions were perplexing. The explanation may be embedded within the design. For the purpose of this study, novices were defined as student pilots, intermediate as instrument pilots, and experts as flight instructors (CFIs). Naturally, CFI and student interaction is frequent and intensive. It is possible that flight instructors may have answered the various items from the perspective of their students, not their own. Alternatively, student pilots may have emphasized CFIs concerns rather than their own.

It is plausible that the intense interaction between pilots typical to Part 141 flight schools may have contributed to regression of pilot perceptions toward the mean. On the other hand, Part 61 flight schools, usually allow pilots to advance at their own pace, are less intensive, and do not mandate ground school, It is possible that Part 61 pilots would be less influenced by perceptions other than their own.

Finally, it is important to address a few limitations that are inherent to all qualitative studies. Low response rates and unavailability of certain groups reduce statistical power and jeopardize statistical assumptions. In this study, failure to obtain the desired number of expert pilots stemmed from the proportionally low number of experts relative to students, low response rates, and lack of accessibility of expert pilots. In addition to low response rates and participant unavailability, survey studies are plagued with validity concerns. For example, participants may interpret identical questions in different ways, and be influenced by demand characteristics or role demands (McBurney, 1994).

In this study, findings suggested that while pilots overestimated flare accident frequencies, they underestimated the proportion of flare accidents within total landing accident frequencies. It is plausible that participants interpreted the later to mean, the likelihood of personally being involved in a flare accident during the landing phase of operations. As a consequence, pilots answered the two questions differently. Furthermore, participants may have responded according to what they believed was expected from them. For example, the role of pilots as "top guns" may have influenced pilot responses. It is possible that pilots are not eager to admit difficulties or lack of confidence. As indicated earlier, difficulty with the flare maneuver was implicitly acknowledged, but explicitly concealed in pilot responses.

Conclusions

The objectives of this study were threefold. The primary goal was to determine whether the flare is a significant maneuver within the approach and landing phase of operations. The secondary objective was to determine probable causes for improper flares. Finally, the tertiary goal was to assess the effectiveness and identify weaknesses in current flare training methods.

The National Traffic Safety Board (NTSB) and leading insurance companies, such as the Aircraft Owners and Pilots Association Insurance Agency (AOPIA) (B. Jennings, personal communication, October 4, 2000), do not distinguish between flare accidents and approach and landing accidents. As a consequence, the significance of flare accidents has been overlooked in the literature. This study revealed relatively high flare accident rates. In fact, 18.33% ~~22.44~~% of all landing accidents in 1995, 1996, and 1997 were flare related accidents.

The financial implications of improper flares are clear. Increased payloads at touchdown may lead to failure of the landing gear tires and struts and to long-term structural damage. However, the psychological implications are subtler. Perfect landings are frequently used to evaluate pilot performance and contribute to positive self-esteem and self-efficacy. Yet, it is specifically the landing phase of operations that most pilots struggle with. This study recognized the landing flare as a significant hurdle in the quest for perfect landings within the approach and landing phase of operation. Possible implications are reduced self-esteem and self-efficacy, increase time-to-solo, and increased drop-off rates at initial General Aviation (GA) training phases, as well as later recreational phases.

As mentioned, vision is the most important tool pilots have during the flare. Appropriate scanning allows the pilot to initiate the flare at an appropriate altitude. However, as evident from pilot answers, the ability may be acquired without conscious awareness through repeated experience in the airport environment. It was found that the horizon and end of runway, shape of runway or runway markings, and familiar objects were the most frequent visual cues that pilots used to estimate their height during the flare. Nevertheless, most pilots were not able to indicate any type of visual cues.

It is possible that the factors that contribute to proper flares are also probable causes for improper flares. The proper flare–experience paradox that was mentioned earlier is obvious. Proper flares depend on monocular cues, and monocular depend on experience. Despite commitment, ambition, and enthusiasm, the one thing that student and many GA pilots lack is experience. Without experience, how are student pilots expected to perform proper flares? Perhaps appropriate monocular cues should be taught in ground schools? However, it is not clear which depth perception cues are most important during the flare. In fact, pilots use different cues or combinations of monocular cues. Furthermore, it may prove especially difficult to teach appropriate monocular cues. It appears that awareness is not critical to the learning of monocular cues, and most pilots cannot explain what cues they use during the flare. If that is the case, how are flight instructors expected to teach what they themselves do not know?

Finally, current flare training methods do not address the problem of experience and proper instruction. In fact, there is no agreement on an effective way to use vision during the flare, and CFI instruction is inconsistent. For example, overall, University of Oklahoma pilots used the horizon or end of runway, whereas Oklahoma State University pilots used the shape of runway or runway markings.

It is possible that "the reason no student knows where the ground begins is because the method we use to teach landing to students is wrong and does not work" (Penglis, 1994, p. 91).

Recommendations

Past studies have attempted to identify and analyze the various monocular cues that enhance depth perception during the flare (for example, Mulder, Pleijsant, vand der Vaart, & van Wieringen, 2000). However, it has already been established that (a) monocular cues enhance depth perception during the landing, approach, and flare, and (b) any attempt to determine how pilots use these cues is futile; pilots use different monocular cues or a combination of cues. Suffice to say that with experience, visual cues are learned and proper flares executed.

Future studies need to address the issues of experience and proper instruction instead of providing further evidence to the usefulness of monocular cues. For example, since proper flares depend on monocular cues, and monocular cues depend on experience, methods that facilitate the association between monocular cues and the proper flare altitude would be prudent.

Concluding Remarks

In conclusion, this study stressed flare accident frequencies, emphasized the inadequacy of current flare training methods to provide proper experience and instruction, and addressed the need for a paradigm shift in future studies.

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APPENDIXES

APPENDIX A

PARTICIPANT STATISTICS BY SCHOOL AND EXPERIENCE

		Gender		Age	Total Flight	Aircraft		
		Male	Female		Time	C152	C172	PA-28
OU	**N**	12	1	22.69	26.85	0%	0%	100%
	I	12	2	22.57	180.71	0%	0%	100%
	E	10	2	25.92	1025.00	0%	0%	100%
Total		34	5	23.73	410.85			
OSU	**N**	18	2	19.85	21.88	100%	0%	0%
	I	18	0	21.50	185.33	16.7%	83.3%	0%
	E	9	2	25.91	593.73	81.8%	18.2%	0%
Total		45	4	22.42	266.98			
SP	**N**	20	2	19.68	33.45	86.40%	13.60%	0%
	I	9	4	23.00	182.31	53.80%	46.20%	0%
	E	11	0	25.73	716.09	54.50%	45.50%	0%
Total		40	6	22.08	310.62			

Legend

OU = University of Oklahoma

OSU = Oklahoma State University

SP = Spartan Aeronautical

N = Novice

I = Intermediate

E = Expert

APPENDIX B

PILOT PERCEPTION QUESTIONNAIRE

OSU OKLAHOMA STATE UNIVERSITY

NOTICE: ORIGINAL FONT SIZE WAS REDUCED TO CONFORM TO THESIS MARGIN REQUIREMENTS

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.

C. Total flight time: _______ hours.

D. Approximate flight hours within 90 days: _______.

E. Type of aircraft most frequently flown: _________________________.

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OSU OKLAHOMA STATE UNIVERSITY

[Student, Instrument, CFI] Pilot,

The following are standard flight maneuvers. 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 as [a(n) Student, Instrument, CFI] pilot, please indicate how easy or difficult you believe each maneuver is to execute properly under optimal conditions (i.e., VFR weather, no wind, 10 miles visibility etc.).

Please **Circle** your choices to the following phases of operations.

	Extremely Easy						**Extremely** Difficult
❶ Steep Turns	1	2	3	4	5	6	7
❷ Takeoff Roll	1	2	3	4	5	6	7
❸ Holding Altitude	1	2	3	4	5	6	7
❹ Climbing	1	2	3	4	5	6	7
❺ Descending	1	2	3	4	5	6	7
❻ Landing Flare	1	2	3	4	5	6	7
❼ Taxiing	1	2	3	4	5	6	7
❽ Coordinated Turns	1	2	3	4	5	6	7
❾ Forward Slip	1	2	3	4	5	6	7
❿ Landing Roll	1	2	3	4	5	6	7

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OSU OKLAHOMA STATE UNIVERSITY

The following questions will be specific to the **landing flare** phase of operations. Answer each question based on your perceptions as [a(n) Student, Instrument, CFI] pilot.

❶❶ Assume that there are a total of 487 landing accidents in the U.S across all aircraft classes (i.e., single, multi, jet, glider, gyroplane, helicopter) in a given year. Please estimate the total number of flare accidents per year.

Answer (insert number): ___________ flare accidents per year.

❶❷ How confident are you in your estimate to the above question (question 11)? Please Circle your answer (1= low confidence, 7=high confidence).

1 2 3 4 5 6 7

Low Confidence High Confidence

❶❸ Please indicate the likelihood of being involved in a flare accident during the landing phase of operations? Please circle your answer?

0-5% 6-10% 11-15% 16-20% 21-25% 26-30% 31-35% 36-40% 41-45%

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OSU OKLAHOMA STATE UNIVERSITY

As you know, the flare is initiated by leveling the aircraft 10 to 20 ft from the ground. Once initiated, back elevator pressure is gradually increased until touchdown.

The following questions refer to the **leveloff phase**, or the transition from descent attitude to leveloff attitude **10 to 20 ft from the ground**.

❶❹ Imagine that you are transitioning from descent to level attitude. How confident are you that your plane is 10-20 ft from the ground (1=low confidence, 7=high confidence)?

1	2	3	4	5	6	7
Low Confidence					High Confidence	

❶❺ Bring to mind your first <u>solo</u> attempts to estimate the aircraft height before initiating the flare? Did the following options assist you in your task (1=not at all, 7=to great extent)?

	Not at All						To Great Extent
(a) CFI instructions	1	2	3	4	5	6	7
(b) Instrument readings	1	2	3	4	5	6	7
(c) Practice	1	2	3	4	5	6	7
(d) Pilot Manual	1	2	3	4	5	6	7
(e) Ground school training	1	2	3	4	5	6	7
(f) Other:_______________	1	2	3	4	5	6	7

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OSU OKLAHOMA STATE UNIVERSITY

❶❻ Pilots are required to flare the aircraft 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)? Please circle your answer.

1	2	3	4	5	6	7
Very Easy						Very Difficult

❶❼ Imagine that you are on approach for landing. How do you know when to start the flare, that is, how do you know when you are about 10 - 20 ft above the ground? Please circle one answer.

(a) Instrument readings

(b) Gut reaction

(c) I don't

(d) Sense of sight

(e) Sense of balance

(f) Other: ________________________________.

❶❽ Do you think there is a need for improved flare training methods? Please circle your choice (1=definitely yes, 7=definitely no)?

1	2	3	4	5	6	7
Definitely Yes						Definitely No

Turn page ☞

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❶❾ To what do you attribute your successful landing flares today? Please rate the following options (1=not at all, 7=to great extent)?

	Not at All					To Great Extent	
(a) Pattern practice	1	2	3	4	5	6	7
(b) Natural ability	1	2	3	4	5	6	7
(c) Sheer luck	1	2	3	4	5	6	7
(d) Aviation books	1	2	3	4	5	6	7
(e) My instructor	1	2	3	4	5	6	7
(f) Other: ________________	1	2	3	4	5	6	7

❷⓿ Is there a need to learn how to judge height above the ground, or are we born with the ability to estimate height during the flare, i.e., the ability is innate or natural. Please circle your choice (1=ability is learned, 7=ability is innate)?

1	2	3	4	5	6	7
Ability is Learned						Ability is Innate

Turn page

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The following three questions require you to write a concise answer. Please think carefully before you answer. Your answer may contribute to general aviation safety.

❷❶ Please elaborate on how you know when to start the flare (i.e., instrument readings; gut reaction; I don't; sense of sight; sense of balance; or other).

For example, if your answer was "I don't", you may write "when it feels right to flare I increase back elevator pressure, close my eyes and hope for the best". Try to be as specific as possible.

(Please print) ______________________________

______________________________ **(use other side if needed)**

Turn page ☞

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❷❷ Please elaborate to what you attribute your successful landing flares today (i.e., pattern practice; natural ability; shear luck; aviation books; my instructor; or other). For example, if your answer was "aviation books", you may write, "since I am a book worm, I learned all that I need from books. The books that I used were the private pilot course manuals by King and Gleim." Try to be as specific as possible.

(Please print) ____________________

____________________ **(use other side if needed)**

Turn page ☞

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❷❸ Some authors claim that vision is an important sense for determining height above the ground. Please indicate what type of visual information would assist you in determining that you are 10 – 20 ft above the ground (i.e., where would you look, what would you look for).

(Please print) ______________________________

______________________________ **(use other side if needed)**

You have completed the questionnaire. Please accept our sincere gratitude and wishes for safe flying.

APPENDIX C

INCLUSIVE AIRCRAFT FLARE ACCIDENT

BY YEAR AND TYPE

Aircraft type	Year			
	1995	1996	1997	**Total**
Single engine				
Aeronca 11-AC	0	**1**	0	**1**
Aviat A-1	1	0	0	**1**
Ayres S2R	1	0	1	**2**
Barrigar RV-6 (hb)	0	0	1	**1**
Beech 23	0	2	1	**3**
Beech 33	0	0	2	**2**
Beech 35	1	1	0	**2**
Bellanca 7KCAB	0	1	0	**1**
Boeing B75	0	1	0	**1**
Brown Air Shark III (hb)	0	0	**1**	**1**
Cessna 140	0	3	0	**3**
Cessna 150	5	6	4	**15**
Cessna 152	8	21	8	**37**
Cessna 170	1	0	1	**2**
Cessna 172	13	29	16	**58**
Cessna 175	0	0	1	**1**
Cessna 177	2	2	2	**6**
Cessna 180	0	0	1	**1**

Aircraft type	Year			
	1995	1996	1997	**Total**
Cessna 182	3	4	7	**14**
Cessna 185	2	0	1	**3**
Cessna 206	2	0	2	**4**
Cessna 210	1	2	1	**4**
Champion 7ECA /GCBC	2	0	0	**2**
Curtis-Wright P-40	0	0	1	**1**
Glasair 3SH-3R (exp)	0	1	0	**1**
Grumman G-164	1	0	1	**2**
Knapp Packard (exp)	1	0	0	**1**
Kolb Mark III (exp)	0	1	0	**1**
LAKE LA-4-200	1	1	0	**2**
Lancair 320	1	0	0	**1**
Maule MT-7-235	0	1	0	**1**
Mooney M20	2	2	2	**6**
Piper J3C	0	2	1	**3**
Piper PA-18	1	0	0	**1**
Piper PA-24	0	1	0	**1**
Piper PA-25	0	0	1	**1**
Piper PA-28	4	7	5	**16**

Aircraft type	Year			
	1995	1996	1997	**Total**
Piper PA-32	0	1	2	**3**
Piper PA-34	2	0	2	**4**
Piper PA-38	0	2	3	**5**
Pitts S-1S	2	0	1	**3**
Rans s-12 xl (exp)	0	0	1	**1**
Rominger EYAS (exp)	0	1	0	**1**
Russell KR-2 (exp)	1	0	0	**1**
Siai-Marchetti F206C	0	1	0	**1**
Steinke Early Bird	1	0	0	**1**
Travel Air	1	0	0	**1**
Waco	0	2	0	**2**
Single total	60	96	69	**225**
Multi engine				
Beech 18	1	0	0	**1**
Beech 19	1	1	1	**3**
Beech 55	1	1	0	**2**
Beech 95	0	1	0	**1**
Beech 100	0	0	1	**1**
Beech 1900	0	1	0	**1**

Aircraft type	Year			
	1995	1996	1997	**Total**
Cessna 310	1	0	0	**1**
Cessna 337	2	0	0	**2**
Fairchild Merlin IIIA	1	0	0	**1**
Lockheed L-382	1	0	0	**1**
Piper PA-30	0	1	0	**1**
Piper PA-44	0	1	0	**1**
Multi total	8	6	2	**16**
Jet engine				
Boeing 747	0	0	1	**1**
Boeing 767	0	0	1	**1**
Cessna 650 Citation III	0	0	1	**1**
Mikoyan Gurevich MIG 15UTI	0	0	1	**1**
Jet total	0	0	4	**4**
Gyroplane				
Knoll-Bensen B-80	1	0	0	**1**
Gyroplane total	1	0	0	**1**
Glider				
Aeromot AMT-200 (p)	0	0	1	**1**
Grob 103	0	0	1	**1**

Aircraft type	Year			
	1995	1996	1997	**Total**
Vickers-Slingsby T65A	0	0	1	**1**
Glider total	0	0	3	**3**
Helicopter				
Bell 47	2	2	0	**4**
Bell 206	1	1	0	**2**
Brantly B-2	0	1	0	**1**
Fairchild Hiller FH-1100	0	0	1	**1**
Hiller UH-12A	1	0	0	**1**
Hughes 269	0	2	1	**3**
Hughes 369	1	1	0	**2**
Robinson R-22	4	0	1	**5**
Helicopter total	9	7	3	**19**
Total	**78**	**109**	**81**	**268**

APPENDIX D

INSTITUTIONAL REVIEW BOARD APPROVAL FORM

Oklahoma State University
Institutional Review Board

Protocol Expires: **10/10/01**

Date : Thursday, October 12, 2000 IRB Application No AS0114

Proposal Title: LANDING FLARE ACCIDENTS AND THE ROLE OF DEPTH PERCEPTION

Principal
Investigator(s) :

Danny Benbassat
215 N. Murray
Stillwater, OK 74078

Charles Abramson
401 N Murray
Stillwater, OK 74078

Reviewed and
Processed as: Exempt

Approval Status Recommended by Reviewer(s) : Approved

Signature : Carol Ol

Carol Olson, Director of University Research Compliance

Thursday, October 12, 2000
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

Danny Benbassat

Candidate for the Degree of

Master of Science

Thesis: LANDING FLARE ACCIDENTS AND THE ROLE OF DEPTH PERCEPTION

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; completed requirements for the Master of Science degree in Experimental Psychology at Oklahoma State University in May, 2000.

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 present; Member of the American Psychological Association; Member of Oklahoma State University Flying Aggies.