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A MIXED METHOD APPROACH TO COLLEGIATE AVIATION SELF-ASSESSMENT OF G-LOAD ON LANDING: PILOT PERCEPTION VERSUS REALITY

by

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This thesis, submitted by Karin Louise Hensellek in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

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DATE

PERMISSION

Title	A Mixed Method Approach to Collegiate Aviation Self-Assessment of G-Load on Landing: Pilot Perception Versus Reality
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ABSTRACT

Because there is no universal definition of a hard landing, pilots themselves must determine if a landing was hard enough to require an unscheduled maintenance inspection. Large, transport category aircraft are equipped with flight data monitoring (FDM) as a secondary data source that can help pilots determine if a hard landing occurred, but FDM is not commonplace in general aviation. It is important for a pilot to be able to differentiate between a firm landing that does not cause damage to the aircraft and hard landing that potentially could cause damage to the aircraft by means of vestibular, visual, and proprioceptive cues. Self-assessment of these cues helps pilots determine if the landing should be considered a hard landing. Self-assessments are subjective and depending upon metacognitive level, a pilot may fall prey to self-serving bias.

To determine if self-serving bias is present in the aviation domain, participants completed a survey on landing perceptions. Additionally, flight data monitoring equipment provided actual landing data. Results suggest that self-serving bias is not common in the aviation domain unlike existing literature suggests. Many participants were unable to accurately perceive landing G-load, indicating that FDM equipment provides reliable data.

CHAPTER I

INTRODUCTION

Statement of the Problem

Hard landings damage approximately 500 aircraft per year (Ibold, 2002). The frequency of aircraft damaged as the result of a hard landing exceeds aircraft damage due to runway overrun, departing the sides of the runway, landing gear failure on takeoff and landing, and controlled flight into terrain. Hard landings are the cause of the highest number of aircraft accidents worldwide (Flight Safety Foundation Editorial Staff, 2004). Many aircraft undergo repair and fly again following a hard landing, but it is the pilot who witnesses how an aircraft lands. This situation means it is predominantly the pilot's responsibility to report the potential hard landing.

Unfortunately, there is no universal definition for a hard landing making it difficult for pilots to identify and report. The Flight Safety Foundation Editorial Staff (2004) state, the International Civil Aviation Organization (ICAO) has a reporting code for hard landings, but no formal definition. The National Transportation Safety Board (NTSB) (1998) defines a hard landing in The NTSB Coding Manual as "stalling onto or flying into a runway or other intended landing area with abnormally high vertical speed" (p.8). The Federal Aviation Administration publication, the *Airplane Flying Handbook* (2004), considers any sink rate in excess of 800-1000 feet per minute abnormally high. An abnormally high vertical speed on landing can lead to a hard landing, but also be classified as a less threatening firm landing. Determining the difference between a firm landing and hard landing is subtle, but necessary to differentiate for preserving aircraft structural integrity.

It is important to realize the subtle differences between a firm landing and a hard landing because not all damage is visible on a post flight inspection of the aircraft. On a post flight inspection the pilot visually looks for damage to the aircraft. Items looked at include the landing gear assembly, tires, general airframe, and powerplant. In one instance, the crew of a Boeing 747 experienced an abnormally high sink rate in the last few seconds of an approach that lead to a potential hard landing. The post flight inspection revealed no damage, but the crew referred the aircraft to maintenance for inspection. Maintenance found extensive damage to the aircraft resulting in a long maintenance down time. Multiple similar events have occurred in large, transport category aircraft (Flight Safety Foundation Editorial Staff, 2004).

It is not only the pilot's perception maintenance takes into account when determining if a hard landing inspection is required, but also utilizes a second form of data to assist identifying potential damage. The Boeing 747, like many other transport category aircraft, has flight data recording capabilities onboard the aircraft used in monitoring and assuring safe aircraft operations. A flight data monitoring (FDM) program "provides insight into the flight operations environment through selective automated recording and analysis of data generated during line operations" (Mitchell, Sholy, & Stolzer, 2007, p.9). The aircraft data monitors have set thresholds for aircraft profile, engine parameters, and system operations. When a parameter exceeds the prescribed threshold, it is termed an exceedence. The FDM system flags the exceedence for review. The operation uses the flagged data to locate trends. The trends could indicate a problematic area of operation that needs more attention. The airlines have utilized FDM as “an important safety tool” (Holtom, 2000, p. 7); however, is not yet commonly found in general aviation.

FDM in the airlines behaves similarly to FDM in general aviation. A commonality between airline and general aviation FDM is assisted maintenance inspections. Specific, unscheduled inspections are required when a pilot informs maintenance of a potential hard landing (Garber & Van Kirk, 2001). Comparison of pilot perception and judgment to monitored data determines the severity of the impact report. If the pilot perception and monitored data reveal the same information, the severity of impact report is higher than if the pilot’s perception and monitored data are dissimilar. Monitored data acts as a secondary source of information because recorded data is generally more accurate than pilot perception and visual post flight inspection (Holtom, 2000). FDM is a second data source because like pilot perception, the equipment has inherent inaccuracies with vertical acceleration recordings. Inaccuracies arise from position error, aircraft weight, aircraft center of gravity, aircraft motion, external forces on the aircraft, and structural dynamics (Holtom, 2000). A visual post flight inspection can identify physical damage. Impact damage to the landing gear and structural components can occur internally; therefore, go unseen and unreported.

The landing gear assembly and aircraft structural design withstands the static and dynamic loads of normal flight conditions including taxi, takeoff, landing, and ground handling. Most abnormal, overloading conditions, which cause aircraft strain and fatigue are hard to predict (Tao, Smith, & Duff, 2009). Not only are abnormal, overloading conditions difficult to predict, each event has subjective perceptions. For example, a Boeing 737 experienced a hard landing and both pilots and the flight attendant had differing perceptions of the landing's magnitude. The aircraft did not receive maintenance referral, but later found to have incurred structural damage because of the landing (Air Safety Foundation Editorial Staff, 2004). With subjective perceptions of landing loads, aircraft may continue flying structurally unsound.

A reason for the subjectivity of perceptions of landing load is pilot experience. A certified flight instructor teaches the proper landing technique early in a pilot's training. Other factors assisting in proper landing technique are ground instruction, pilot manuals, publications, and practice. A study by Benbassat and Abramson (2002) found that most general aviation collegiate pilots prefer practice followed by flight instruction to gain the knowledge in proper landing technique. Regardless of experience level, a pilot continually tries to perfect the landing maneuver and avoid hard landings.

Purpose of the Study

The Federal Aviation Administration's publication, *Airplane Flying Handbook* (2004) divides a landing into multiple phases with associated proper techniques. A landing is broken down into final approach, roundout, and touchdown. Pilots are challenged to keep an aircraft's longitudinal alignment as it flies the final approach. Adjustments to flaps, pitch, and power, made by the pilot, keep the aircraft on the proper approach path. Perceptual skills determine the estimation of height and speed as the aircraft gets closer to the ground. As the aircraft nears touch down, the pilot's central vision shifts to peripheral vision (Federal Aviation Administration, 2004). At about 10-20 feet above ground level (AGL), the pilot commands control inputs for a smooth, continuous transition to the landing attitude. During the roundout phase, the airspeed decreases, while control surface inputs control lift, so the aircraft will settle gently on the ground (Federal Aviation Administration, 2004). As the aircraft makes contact with the runway, the vertical speed instantly reduces to zero. Without proper precautions to slow the vertical rate of descent and allow a smooth touchdown, high contact force can occur (Federal Aviation Administration, 2004).

Previous research has examined the ingredients of a hard landing: aircraft mass, vertical speed and true vertical acceleration. Each axis' load factor calculates the true vertical acceleration (Aigion, 2012). Although FDM records and identifies outliers, the pilot still may not recognize or discern between a firm landing and a hard landing. One parameter FDM cannot capture for review is pilot perception of a landing. The airlines and general aviation rely on pilot perception to report a potential hard landing to maintenance. Through literature review, airlines receive the greatest amount of attention in studying pilot perception of landings in comparison to general aviation. General aviation's collegiate flying is regular, making it feasible to study pilot perception of hard landings. In addition, the aircraft accrue many landing cycles. Through high landing cycles there is potential for hard landings to occur which may go unreported. A better understanding of pilot perception of landing in general aviation could benefit pilots, maintenance, and the operational facility in respect to aircraft structural integrity. The purpose of this study is to investigate the self and average perceptions by assessing the actual g-loads on landing to the self-reported, focusing on flight experience and evidence of self-serving bias on detection accuracy.

Significance of the Study

The European Aviation Safety Agency (2010) found that abnormal runway contact, which includes hard landings, has the highest number of fatal and non-fatal accidents between both transport category aircraft and general aviation aircraft. Aircraft damage resulting from hard landings surpasses other aircraft accident and incident categories, making landings a focal point. An important aspect of hard landings, often overlooked, is the pilot's perception. Pilot perception is based on metacognitive skills (Kruger & Dunning, 1999). Metacognitive skill is the "ability to know how well one is performing, when one is likely to be accurate in judgment, and when one is likely to be in error (Kruger & Dunning, 1999, p.1121). Perception is based on the individual making it difficult to determine if the aircraft should be referred to maintenance for an unscheduled inspection. If there is a correlation between perception of landing and the metacognitive skill level in assessing the landing, it could provide an explanation as to why some hard landing aircraft go unreported to maintenance following a hard landing. Pilots with lower metacognitive skills often have a higher self-serving bias (Metcalfe, 1998). If data shows a correlation between metacognitive skills and self-serving bias, this could provide an explanation to unreported hard landings. This study aims to study accuracy of g-load detection through FDM recordings, pilot flight experience, and to detect the presence of self-serving bias.

Research Questions

1) Does pilot experience determine the accuracy of g-load detection?
2) How do pilots determine if the aircraft requires an unscheduled hard landing inspection?
3) Does pilot experience correlate with self-serving bias associated to perception?

Assumptions

- All participants attend or are employed at a 14 CFR Part 141 flight training school.
- Participants received similar flight training, with regard to aircraft landing, following an Federal Aviation Administration approved standardization manual.
- All participants answered survey questions accurately and honestly.
- Each participant completed the survey independently.
- Data received from the FDM equipment is linear in nature.

Limitations

- The study and survey addresses pilot perceptions in one type of aircraft, Cessna 172S.
- The study only looked at data from one collegiate flight school.
- Participants could have received dissimilar flight training.
- Some participants may become aware of the study and alter their reporting or landing performance.
- Some participants may independently study self-assessment and self-enhancement processes.

Definitions

- 14 CFR Part 141 – Code of Federal Regulations that the Federal Aviation Administration uses for flight schools. The flight schools are structured and based on an approved syllabus.
- Average – For the purpose of this study, the average individual is someone who is better than one-half and worse than one-half of the individuals in the similar flight course.
- Expert pilot – For the purpose of this study is a pilot with more than 250 total flight hours.
- Flight data monitoring (FDM) – "Systematic analysis of aircraft parameters that were recorded during flight" (Holtom, 2000, p. 7).
- Intermediate pilot – For the purpose of this study is a pilot with 40.1 – 250.0 total flight hours.
- Novice pilot – For the purpose of this study is a pilot with 0 – 40.0 total flight hours.

Review of Literature

The review provides background information of the physiological factors of human perception and the psychological aspects of self-assessment. The first area investigated is the human physiology of perception. It is important to understand the formation of a perception before exposing the psychology of a perception because the formation of a perception is a complex, multi-sense process. The second area looked at is the psychology of human perception. The psychological points focus on self-serving bias and metacognition.

Physiology

The human ability to sense, perceive, and orientate in three dimensions depends on the learned ability to interpret signals from multiple sensory receptors (Gutterman *et al.*, 2012). The three sensory organs investigated in this section are the inner ear, eyes, and proprioceptive. These three sensory organs transmit their respective information to the central nervous system, building the perception of self-motion in space (Reymond, Droulez, & Kemeny, 2000). This first sensory organ looked at is the inner ear.

Vestibular

The human body has the unique ability to detect acceleration force. The inner ear mechanisms sense acceleration. The inner ear is divided into two parts, anatomically and functionally, the organ for hearing, the cochlea, and the organ of equilibrium, the vestibular apparatus (Ernsting & King, 1988). The organ for hearing is the cochlea. The intensity of a sound relates directly to the sound wave amplitude entering the ear. Sound waves vibrate the tympanic membrane, or eardrum, located in the middle ear, in turn, moving the ossicles. The ossicles' move a membrane, oval window, located in the cochlea. The pressure waves from the initial sound moves fluid in the cochlea, which moves a membrane, the basilar membrane. As the fluid in the basilar membrane moves, so do sensory hair cells. The moving sensory hair cells stimulate action potentials that are transmitted to the brain and the sound interpreted (Fox, 2004). Although hearing influences perceptions, the vestibular apparatus plays a larger role in the perception of self-motion. The vestibular apparatus senses the body's motion and gravity through the semicircular canals and otolith organs (Gutterman *et al.*, 2012). The semicircular canals detect angular acceleration, while the otolith organs sense linear acceleration and gravity. In motion, the otolith organs sense the body's motion and translate the sensations into an orientation in space. When stationary and experiencing no acceleration force, the otolith organs continue to sense the continuous force of gravity (Day & Fitzpatrick, 2005). Since this study looked at the vertical linear acceleration of light aircraft landings, the otolith organs are the primary organs of consideration.

Located below the semicircular canals lies the otolith organs: the utricle and the saccule, as seen in figure 1 from Johns Hopkins Medicine (n.d). The otolith organs can sense any type of linear acceleration and gravity because the utricle lies in the horizontal plane and the saccule in the vertical plane.

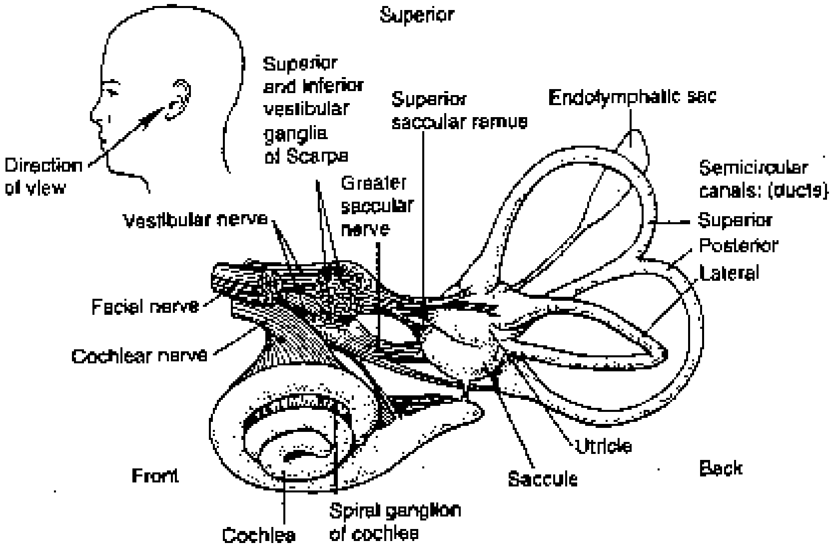


Figure 1. Anatomy of the Inner Ear.

The utricle and saccule contain hair like sensory cells called maculae. A gelatinous layer covers the grouped maculae cells, the outermost layer with small calcium carbonate crystals called otoconia. Figure 2 from Purves, Augustine, and Fitzpatrick (2001) illustrates the construction of the otolith organ.

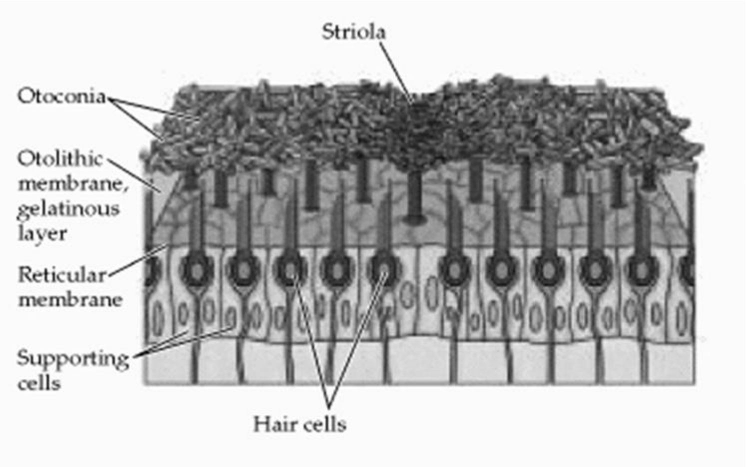


Figure 2. Otolith Organs.

The fluid, which fills the utricle and saccule, is dense. When exposed to changing gravitoinertial forces, the otolithic membrane changes position along with the sensory hairs bending with the force of gravity (Purves, Augustine, Fitzpatrick, 2001). The changing position of the otolithic membrane and sensory hairs transmit a signal to the central nervous system, giving the body a perception of linear acceleration. The otolith organs allow perception of linear acceleration and gravity except when the stimulus is outside of the vestibular perception range.

The ability to sense linear acceleration and gravity depends on if the stimulus falls within the vestibular detection range. The vestibular system is extremely sensitive and able to detect vertical and longitudinal linear acceleration as minimal as 0.001 – 0.03G's and 0.006G's respectively (Davis, Johnson, Stepanek, & Fogarty, 2008). In terms of weight detection, 0.001G added to 200 pounds is a weight detection of 0.2 pounds. Detection of motion does not rest singularly on the vestibular system. The portion of the brain stem that interprets vestibular motion also receives visual motion perception (Brandt, Dichgans, & Koenig, 1973).

Vision

Vision comprises of two parts, central vision and peripheral vision. The retina forms central and peripheral vision through cones and rods. The cones centralize in the macula at a point called the fovea to construct central vision. Cones have a high light threshold, provide sharp visual discrimination, and provide color vision. The rods, located away from the macula, contain less visual acuity and specialize in night vision and motion sensing. Visual motion assessment of the peripheral retina responds to direction of movement, velocity of movement, size of the stimulus, orientation in space, and level of illumination (Gillingham & Previc, 1996).

The retinal periphery plays a larger role in visual motion detection than focal does. The focal vision encompasses only 30 degrees of the central vision, allowing a larger viewing area for the peripheral vision. The larger viewing area provides motion cues and position cues (Gillingham & Previc, 1996). During the roundout and touchdown, a pilot relies heavily on peripheral cues. The focal vision must transition to peripheral during landing or the pilot may experience a hard landing (Federal Aviation Administration, 2004). An industry example of focal vision not transitioning to peripheral vision during landing, therefore resulting in a hard landing is in the use of a head-up display (HUD). A HUD projects instruments and symbology into the pilot's forward field of view enabling the pilot to monitor the instrumentation without shifting the focus from outside the cockpit to inside the cockpit. As Carmona (2012) cites on a National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) report, a B737-400 experienced a hard landing in response to the pilot relying on focal vision through the HUD rather than transition to peripheral vision. As a result, the crew of the B737-400 felt the gear struts depress and re-extend accompanied with two discrepancies inside the aircraft. Maintenance performed a hard landing inspection on the incident aircraft. Through practice, the pilot uses learned peripheral cues to determine height above the runway and speed over the ground.

As the pilot flies the aircraft onto the runway, outside objects move through the periphery. The movement of objects over the large peripheral area creates vection. Vection is a phenomenon, defined by Warren and Kurtz (1992), as a subjective experience of self-motion. Sitting in a train exemplifies vection. As a train on an adjacent track moves past, in the opposite direction, the feeling of motion occurs. As the background surface area increases, the stronger the feeling of vection becomes (Gutterman *et al.*, 2012). Vection comes in two forms, circular and linear. The above train example and a landing aircraft exhibit linear motion sensation termed linearvection (Tarita-Nistor *et al.*, 2006).

Linearvection occurs during all segments of flight, but is especially important during the landing phase. It is important for the pilot to judge movement, speed, approach angle, and height over the ground during landing (Federal Aviation Administration, 2004). Whether because of inexperience or external factors, hard landings occur due to misperception or illusions of the visual sense (Gillingham & Previc, 1996). Some common peripheral misjudgments and illusions include inappropriate roundout, terrain misidentification, and absent ambient cues such as when a pilot cannot differentiate between ground and sky.

Improper roundout, generally seen in novice pilots, includes a high roundout or a late roundout. A high roundout occurs when the aircraft appears to stop descending. The novice pilot, inappropriately, determines height above the terrain, so continues into the flare for touchdown. The aircraft's sink rate quickly increases causing a hard landing. The late roundout is similar to the high roundout in respect to misinterpretation of height above the terrain. The late roundout occurs because the pilot does not detect the incoming terrain until a hard landing occurs (Federal Aviation Administration, 2004). High roundout and late roundout are different from terrain misidentification and absent ambient cues because distinction still exists between individual objects, ground, and sky.

Terrain misidentification transpires when terrain textures are lost. Glassy water or a snow-covered ground makes it difficult to judge height accurately (Gillingham & Previc, 1996). In addition to ground terrain, runway width can make it difficult for a pilot to judge height over terrain. The Federal Aviation Administration (2012) highlights in the Aeronautical Information Manual (AIM) that

> "a narrower-than-usual runway can create the illusion that the aircraft is at a higher altitude than it actually is. The pilot who does not recognize this illusion will fly a lower approach, with the risk of striking objects along the approach path or landing short. A wider-than-usual runway can have the opposite effect, with the risk of leveling out high and landing hard or overshooting the runway" (p.941).

When lost ground textures mix with an obscured horizon the absence of ambient cues, exist. Two common examples of absent ambient cues are a black hole approach and white out. A black hole approach occurs at night over unlit terrain. The peripheral vision is unable to detect contrast, making motion, speed, and height detection extremely difficult. Likewise, with atmospheric whiteout conditions, a snow covered ground and overcast sky make peripheral cues difficult to identify (Gillingham & Previc, 1996). Vision, alone, or combined with the vestibular system, form many human perceptions, but other sensory systems contribute, as well.

Proprioceptive

Without the vestibular or visual systems, the human body is still capable of perceiving motion through pressure sense. Pressure sensory receptors act as transducers converting energy into sensory neurons (Barrett, Boitano, Barman, & Brooks, 2012). The central nervous system produces perceptions of the touch sensations. Two types of touch senses form a perception, proprioceptors and cutaneous exteroreceptors. Proprioceptors provide awareness of static and dynamic body posture, while cutaneous exteroreceptors provide orientation sense (Davis, Johnson, Stepanek, & Fogarty, 2008). Proprioceptors defined by Gillingham & Previc (1996) include muscles, tendons, and joint receptors.

Muscles come in multiple forms. Skeletal muscles are of importance because they provide position sense (Lackner & Dizio, 2000). The ability to provide position sense derives from the sensory input of complex sensory end organs called spindle fibers. The many, small spindle fibers have afferent neurons sending information to the spinal cord (Gillingham & Previc, 1996). As the muscles expand and stretch the frequency of afferent neuron transmission increases. Inversely, as the muscles contract, the spindle fibers reduce transmission frequency (Gillingham & Previc, 1996). The different frequencies translate into perception by the central nervous system. Tendons act similarly to muscle proprioceptors, whereas joint sensation is different. Joints do not have the muscle position sense; therefore, rely on three types of receptors, lamellated pacinian-lined end organs, spray type structures, and free nerve endings (Gillingham & Previc, 1996). The three joint receptor types provide information to the central nervous system about joint position and movement. Although proprioceptors provide copious amounts of information about pressure sense, they are unable to provide information about perception of orientation.

Cutaneous exteroceptors include mechanoreceptors, thermoreceptors, and nociceptors. Of the three, only mechanoreceptors provide orientation perception (Davis, Johnson, Stepanek, & Fogarty, 2008). Mechanoreceptors reside in the skin. Depending upon modality, location, intensity, and duration (Barrett, Boitano, Barman, and Brooks, 2012), determines which of four receptors produces the sensation. Johnson (2001) describes the four-receptor types: Merkel -slowly adapting type 1 afferents (SA1), Meissner-rapidly adapting afferents (RA), Pacinian afferents (PC), and Ruffini-slowly adapting type 2 afferents (SA2).

SA1 afferents are suited to monitor static pressures and PC afferents have a high frequency response to skin displacement. PC afferents are good monitors to vibrations and transient touch stimuli. Neither SA1 afferents nor PC afferents are primarily involved with motion or direction. RA afferents and SA2 afferents process motion and motion direction. RA afferents are relatively large cells housed beneath the dermis. The cells’ large size responds to stimuli over the entire perceptive field, making static sense less sensitive than dynamic sense. As an example, RA afferents are less sensitive to a body sitting stationary in an aircraft with minimal external forces and more sensitive to a body sitting in an aircraft with a vertical force imposed on the aircraft. In addition to the cells’ large size is its particular arrangement. The arrangement aids in protecting the velocity sensitive endings from static pressures (Johnson, 2001). Also, less sensitive to static pressures are SA2 afferents. SA2 afferents are present in the connective tissues of the dermis and serve two important roles. Firstly, SA2 afferents respond to skin stretch and secondly, perceive the direction of an object’s motion. With respect to landing aircraft, the SA2 afferents’ primary role is to perceive direction of motion (Johnson, 2001). Cutaneous mechanoreceptors play an important role in producing perception, as with hearing, vestibular and visual senses.

Psychology

Sensory systems such as the vestibular, visual, and proprioceptive are not the only ingredients forming a perception of a landing. Both physiological and psychological factors influence the accurate detection and/or report of a hard landing. Many psychological frameworks can influence perception. The psychological framework and theoretical framework of this study is the self-enhancement process: self-serving bias.

Self-enhancement Process

The self-enhancement process is one where individuals attribute negative outcomes to external circumstances and a positive outcome to internal factors in order to protect self-views (Krusemark, Campbell, & Clementz, 2008). Self-enhancement comes in multiple forms. The self-enhancement process reviewed in this study is self-serving bias. Self-serving bias appears when individuals express overconfidence in their abilities. The expression of overconfidence occurs in all gender types and ages (Dunning, Meyerowitz, & Holzberg, 1989). Self-serving bias commonly occurs during self-evaluation (Dunning, Meyerowitz, & Holzberg, 1989) and its appearance is dependent on multiple factors, including ambiguity of self-assessments and metacognitive level.

Self-serving Bias

Biased overconfidence shows through on self-evaluating tasks. A study by Moore and Cain (2007) determined subjectively more difficult tasks produce a higher self-serving bias than subjectively easier tasks. Although the task difficulty is subjective, the effects compare an individual to that of the average. The term average ignores the relation the individual has with the average. Individuals may judge themselves as better as or worse than the average and may judge the average individual accurately or inaccurately. With variability in what average is, participants fall into four groups: overestimate own ability and overestimate the average ability, overestimate own ability and underestimate the average ability, underestimate own ability and overestimate the average ability, underestimate own ability and underestimate the average ability (Walton & Bathurst, 1998). Walton and Bathurst's (1998) study states that the overconfidence seen in drivers' speed perception is not due to subjective judgment, but rather to the perceived average driver. The "improper assessment" (Kruger & Dunning, 1999, p. 1122), comparing to the average, has high ambiguity. High ambiguity is present because individuals have a tendency to define ambiguous traits and abilities in a way to emphasize one own strengths (Kruger & Dunning, 1999). Because of this ambiguity, subjects seek satisfaction as a means to quantify perceptions (Song & Chung, 2001).

Individuals are unable to quantify the term average because of the terminology’s high ambiguity and in turn place themselves in a positive light, or produce a higher self-serving bias, to protect one’s self-esteem (Groeger & Grande, 1996). In some cases, protection of self-serving bias and terminology ambiguity is not present because the individual actually possesses skill and ability on a task or in a domain (Moore, 2007). The metacognitive level of individuals, in a specified domain, plays a role to the extent of self-serving bias.

Metacognition

Every domain, like aviation or medicine, has specialized skills required for success and satisfaction. Success and satisfaction is strongly dependent upon knowledge, which varies widely (Kruger & Dunning, 1996). Knowledge level varies through a domain because competence level varies referring to a group. Competence of a group in a domain is unclear, leaving individuals to self-define criteria to evaluate themselves against (Dunning, Meyerowitz, & Holzberg, 1989). Research by Dunning, Meyerowitz, and Holzberg (1989) has provided evidence that individuals use their personal traits, such as skill and ability, as a baseline for the average comparison because it puts them into a positive light. A novice is commonly more incompetent than their expert counterpart. Metacognitive skills provide the knowledge of understanding of how well one is performing, when one is likely to be accurate in judgment and when one is likely to be in error (Kruger & Dunning, 1999). Novices commit errors because of inexperience and/or lack of development of knowledge, skill, and ability. Due to the lack of experience, a novice may not realize an error was committed; therefore, may experience an impression of good performance.

The lack of metacognitive skills explains performance misjudgment and overall imperfection of skill and ability assessment (Kruger & Dunning, 1999). Experience and training teach and increase accuracy of metacognitive skills. Information at hand forms perception and judgment, but subjects may misunderstand or misinterpret (Metcalfe, 1998). Misunderstanding or misinterpretation more commonly arises in the incompetent or a novice individual, due to the lack of metacognitive skills for accurate self-assessment. Kruger and Dunning (1999) found that novices lack metacognitive skills compared to their expert counterparts. The study evaluated physics students, chess players, and tennis players. The novice physics students were unable to gauge problem difficulty, the novice chess players were unable to predict opponent moves, and novice tennis players were unable to determine successful versus unsuccessful plays. More than just the incompetent, novice individuals showed overconfidence and poor assessment skills as compared to experts.

Proven in a study by Kruger and Dunning (1999), all novice and intermediate individuals, within a domain, show self-serving overconfidence, when evaluating against their peers. Experts on the other hand, show under confidence. The consensus of the Kruger and Dunning (1999) study found that under confident experts performed well and thought their counterparts performed well, too. Even the experts in a domain did not focus on their absolute abilities, but against the performance of their peers. The differences in self-serving bias, seen on self-assessments, between novices and experts stem from knowledge and the ability to understand knowledge level. To improve from novice to expert, one must not stop at “the inadvertent acceptance of the nearly right” (Metcalfe, 1998, p. 106) and think the current level is good enough, but rather move through the current state of knowledge and onto the next level of knowledge understanding (Metcalfe, 1998).

Summary

Humans have the unique ability to sense acceleration and gravitational forces through multiple sensory receptors. The sensations received by the central nervous system form a perception. It is important for a pilot to recognize and interpret these perceptions. An individual’s metacognitive skills influence the ability to recognize and interpret a perception correctly. Prior research has evaluated the presence of self-enhancement processes, specifically self-serving bias, in individuals’ assessment of a task. Self-serving bias has been positively identified in various task assessments, but research has not yet identified if there is a self-serving bias associated to pilot perception. Aircraft landings are the highest accident category worldwide. It is predominantly the pilot’s responsibility to report a potential hard landing, even though FDM provides a second data source for maintenance to determine the severity of impact report. Since the pilot’s judgment is the primary data source, if self-serving bias is noted within the pilot group, potential hard landings may go unreported because of inaccurate self-assessments.

CHAPTER II

METHODOLOGY

Introduction

According to the European Aviation Safety Agency, hard landings are a leading cause of aircraft accidents and incidents each year. With the lack of a formal hard landing definition, maintenance relies on pilot perception and judgment to identify and report a hard landing. Pilot perception and interpretation in collegiate general aviation pilots is the target of this study. This study evaluated individual ability of participants to quantify the landing G-force and to quantify individual ability compared to others. Pilot demographic, experience, comparison to the average, and perception of maintenance inspections were variables associated with this study. The study comprised of a sample of collegiate general aviation pilots flying a C172S at the University of North Dakota (UND).

Setting

UND Flight Operation's facility at the Grand Forks International Airport hosted the study. The John D. Odegard School of Aerospace Sciences at UND is a certified 14 CFR Part 141 flight school. The four-year Bachelor of Science in Aeronautics program offers a major in Commercial Aviation, along with other majors related to aviation.

Participants

The study analyzed the data of 37 participants. The participants of this study were students enrolled, and currently on active flight status, and certified flight instructors (CFIs) employed at UND. The study aimed to target the largest number of pilots and relied on the aircraft to have an FDM unit installed. The student sample included flight courses ranging from student pilot to CFI applicants, as seen in table 1. The aircraft flown was a C172S aircraft with an Appareo Systems Vision 1000 equipped.

Table 1. Flight Courses Used in the Study.

Course Number	**Course Title**
101	Survey of Flight
102	Introduction to Aviation
112	Private Pilot Transition to UND Standard Operating Procedures
221	Basic Attitude Instrument Flying
222	IFR Regulations and Procedures
323	Aerodynamics-Airplanes
414	CFI Certification
415	Instrument Flight Instructor

For the purpose of this study, pilot flight time defined experience (novice, intermediate, or expert) as outlined in 14 CFR Part 61. Regulations used as a baseline for flight experience were §61.109 and §61.129, minimum total flight time to obtain a private and commercial certificate, respectively. Table 2 outlines the definitions of novice, intermediate, and expert pilots in this study.

Table 2. Pilot Experience Used in the Study.

Pilot Experience	**Total Flight Time (Hours)**
Novice	0 – 40.0
Intermediate	40.1 – 250.0
Expert	250.1 – and above

Study Design

The methodology used in this study was a mixed method concurrent transformative strategy. The concurrent transformative strategy was selected because the use of the psychological theory, self-serving bias, being the driving force of the study. The study's problem, research questions, and survey questions revolve around a self-serving focus.

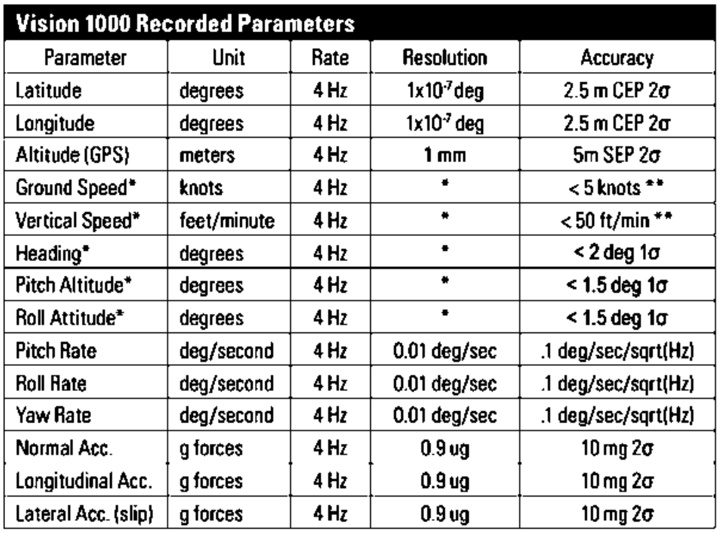
The transformative strategy adopts parts of both the triangulation and embedded strategies. The study utilized an Appareo Systems equipped C172S from UND's fleet of Cessna aircraft. Flight Operations dispatch scheduled the aircraft's use making the sample random. Throughout the duration of the flight, the Appareo Systems FDM unit continually recorded aircraft data. The data obtained from the FDM unit, Vision 1000, provided purely quantitative data. Along with analyzing data from the Vision 1000, the study compared data from a second source, a survey. Upon completion of each flight, the crew filled out a survey containing quantitative and qualitative questions. The survey dominantly consisted of quantitative questions. Embedded qualitative questions, collecting data at a different level, still held similar weight as the quantitative questions. The data analysis phase mixed the two sources and data types using an integrating mixing method.

Data Collection

Two sources contributed to incoming data: FDM information from the Appareo Systems Vision 1000 and a survey tool for pilot self-assessment. For flight operations quality assurance, Appareo Systems created Aircraft Logging and Event Recording for

Training and Safety (ALERTS) software. ALERTS has a couple of units to support FDM. The C172S at UND, utilized for this study, contains the Vision 1000. Following calibration, the Vision 1000 captures real-time critical inertial and position data through accelerometers and global positioning system (GPS) (Reyno, 2012). Table 3 displays recorded parameters of the Vision 1000. A removable SD card houses the data recorded along with a crash-hardened internal memory module (Reyno, 2012). The Vision 1000 collected quantitative data from one source, while a survey tool collected pilot self-evaluation data. The second source of data came from a survey tool. Upon arrival from a flight, the author of the study disseminated a survey to the crew of the aircraft providing FDM information.

Table 3. Vision 1000 Recorded Parameters.



Vision 1000 Recorded Parameters

Parameter	Unit	Rate	Resolution	Accuracy
Latitude	degrees	4 Hz	1x10^{-7}deg	2.5 m CEP 2σ
Longitude	degrees	4 Hz	1x10^{-7} deg	2.5 m CEP 2σ
Altitude (GPS)	meters	4 Hz	1 mm	5m SEP 2σ
Ground Speed*	knots	4 Hz	*	< 5 knots **
Vertical Speed*	feet/minute	4 Hz	*	< 50 ft/min **
Heading*	degrees	4 Hz	*	< 2 deg 1σ
Pitch Altitude*	degrees	4 Hz	*	< 1.5 deg 1σ
Roll Attitude*	degrees	4 Hz	*	< 1.5 deg 1σ
Pitch Rate	deg/second	4 Hz	0.01 deg/sec	.1 deg/sec/sqrt(Hz)
Roll Rate	deg/second	4 Hz	0.01 deg/sec	.1 deg/sec/sqrt(Hz)
Yaw Rate	deg/second	4 Hz	0.01 deg/sec	.1 deg/sec/sqrt(Hz)
Normal Acc.	g forces	4 Hz	0.9 ug	10 mg 2σ
Longitudinal Acc.	g forces	4 Hz	0.9 ug	10 mg 2σ
Lateral Acc. (slip)	g forces	4 Hz	0.9 ug	10 mg 2σ

The survey consisted of three sections. The first section was the informed consent form. Each crew member consented to the study by returning the survey to the author of the study. The second section of the survey consisted of demographic information. Aircraft launch time linked the survey to the proper FDM recording. The remainder of the demographics included questions of dual or solo flight and total flight time. The third section of the survey comprised of quantitative and qualitative type questions. The quantitative and qualitative section identified the presence of self-serving bias in pilots. Quantitative material ranged from experience to subjective maneuver difficulty. Qualitative questions ranged from open-ended questions pertaining to determination of a hard landing to when a subject felt an unscheduled hard landing inspection was required. All quantitative scale questions used a continuous scale.

Instrument Reliability and Validity

Literature has well documented the reliability and validity of the instrument used to capture real time FDM information, the Appareo Systems Vision 1000. Some of the world’s leading aviation companies incorporate the Vision 1000 into their daily operations. Eurocopter is a continued customer of Appareo Systems, especially having jointly created the Vision 1000. Other companies, such as The Bristow Group and The United States Forest Service, incorporate Appareo Systems’ hardware and software into their daily operations, as well. Along with reputable companies and government agencies, Appareo Systems has multiple other products available in assisting with FDM and safety of the aviation industry.

Industry experts revised the survey tool disseminated in this study. Experts revised questions for clarity, bias, and ambiguity. Along with expert revisions, several members of the aviation industry piloted the survey.

Proposed Data Analysis

The study used SPSS statistical software for computations and for identifying significance to the .05 alpha-level. The study relied on a two-tailed, non-directional hypothesis. A two-tailed, non-directional hypothesis comes from there being no previous literature on the topic of pilot perception. Relationships among multiple variables allowed for thorough, in depth analysis. Tables 4, 5, and 6 outline the proposed data analysis pertaining to each research question.

Table 4. Research Question 1 Proposed Data Analysis.

Dependent Variable	**Independent Variable**	**Statistical Test**
Detection accuracy	Pilot experience	Regression

Table 5. Research Question 2 Proposed Data Analysis.

Variable 1	**Variable 2**	**Statistical Test**
Pilot experience	Determination of if a landing inspection required	Qualitative
Pilot experience	Determination of a hard landing	Qualitative
Number of aircraft referred to maintenance	Determination of if a landing inspection required	Qualitative

Table 6. Research Question 3 Proposed Data Analysis.

Dependent Variable	**Independent Variable**	**Statistical Test**
Pilot Experience	Perceived G-load & Perceived average G-load	ANOVA
Perceived landing firmness	Pilot experience	Regression
Maneuver difficulty	Pilot experience	Spearman’s Rho
Landing g-load of the average	Pilot experience	Regression
Landings good enough	Pilot experience	Regression

Protection of Human Subjects

Participants who agreed via consent form to complete the survey receive no repercussions based on their responses. In addition, participants received no reprimand from linked FDM information. Individuals, for the purpose of data linking, volunteered demographic information. Following data linking, subjects received a research number, used for the remainder of the study. The author notified and received permission from UND Flight Operations to conduct the study. Finally, the Institutional Review Board at UND reviewed and approved the project, survey, research questions, proposed sample, research method, and consent procedures.

CHAPTER III

RESULTS

The study utilized data from two sources, aircraft FDM recordings and a survey. The FDM recordings are purely quantitative in nature. The survey comprised of both quantitative and qualitative data. Three sections made up the survey; quantitative demographics, quantitative self-assessments, and qualitative self-assessments.

Demographics of the Participants

Thirty-seven (N=37) pilots completed the survey. Survey results indicated all participant flights were dual flights and all but one survey indicated that the student crewmember conducted the landing. The range of the flight experience was 16,990 flight hours. Mean flight experience was 814.92 hours. Figures 3 and 4 show the grouped histograms based on total flight time (experience). The novice category included three (N=3) participants with a mean of 12. The intermediate category included sixteen (N=16) participants with a mean of 132.75. The expert category included 18 (N=18) participants with a mean of 1,555.11. One participant accrued markedly more flight hours than any other participant. Figure 4 is a replicate graph of figure 3 minus the one participant who accrued 17,000 estimated total flight hours, to better show the distribution of lower flight experience

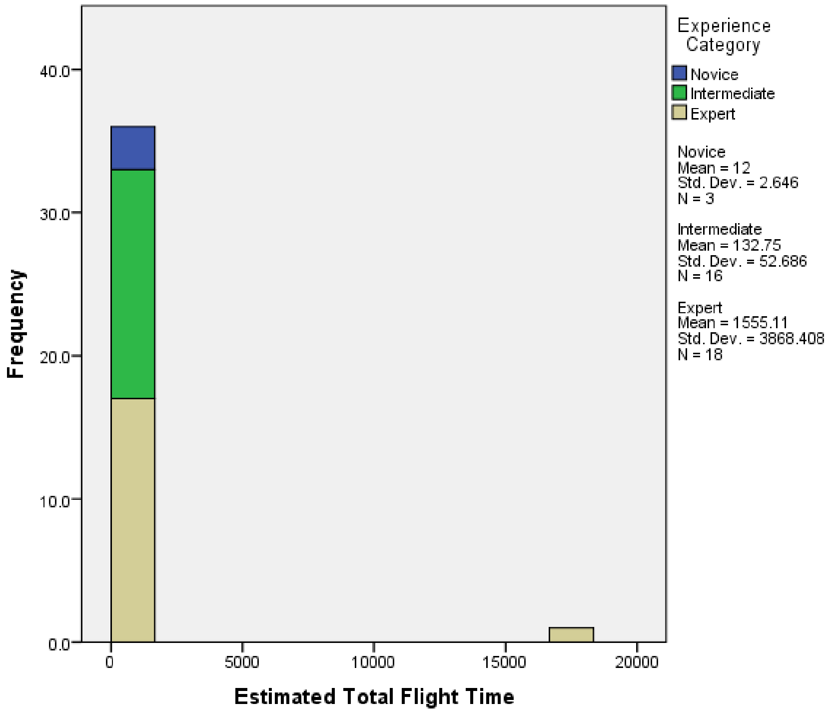


Figure 3. Grouped Histogram of Estimated Total Flight Time.

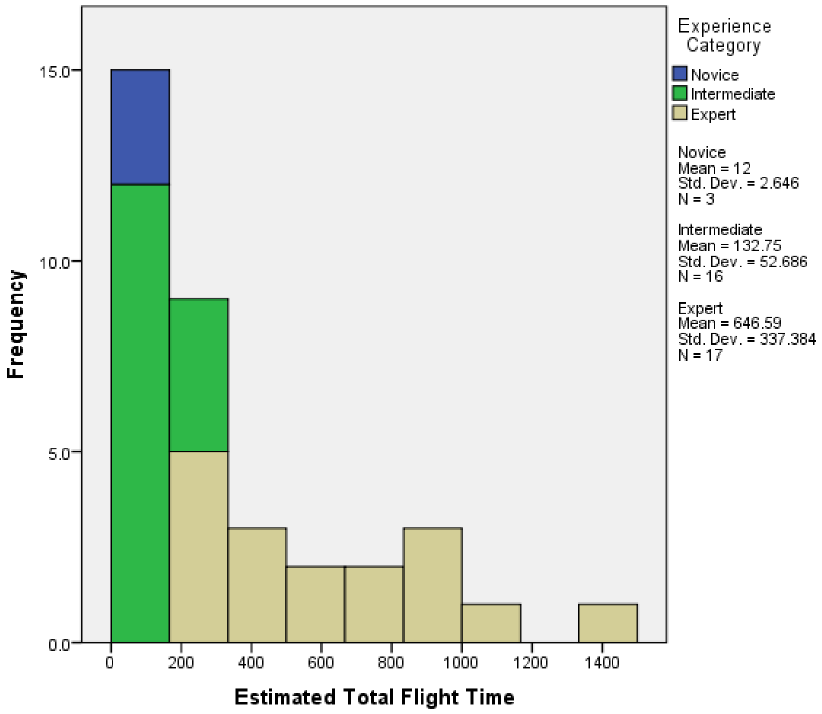


Figure 4. Grouped Histogram of Estimated Total Flight Time Excluding Outliers.

Self-Assessments

The second section of the survey asked participants to self-assess multiple aspects both quantitative and qualitative in nature.

Quantitative

The first self-assessment tool evaluated perceived maneuver difficulty. Maneuvers selected to be on the survey were landing, power-off stall, steep turns, and slip. Landing was the focal maneuver investigated. Power-off stall and slip directly relate to the landing maneuver for rank comparison and so were listed maneuvers. Steep turns were on the survey to counterinfluence selection because of all other maneuvers having a direct relationship to the landing maneuver. The landing maneuver proved to be the most difficult maneuver by all experience categories, followed by steep turns, slip, and power-off stall. Each of the four maneuvers received a rank score between one (1) and four (4), one being the ‘easiest’ maneuver and four being the ‘hardest’ maneuver. Figure 5 displays a grouped histogram of the landing maneuver.

The landing maneuver ranking was the focal point of the study. Of those maneuvers to choose from, landing maneuver received no novice pilots believing this maneuver was the ‘easiest’ or ‘second easiest’ maneuver. A majority of novice pilots (n=2) ranked the landing maneuver as the ‘hardest’ maneuver. The intermediate pilot experience group had more scattered data than the novice group. A majority of intermediate pilots (n=6) ranked the landing maneuvers as the ‘hardest’ maneuver, followed by four (4) intermediate pilots indicating the landing maneuver was ‘easiest’. In similar fashion as intermediate pilots, a majority of expert pilots (n=8) ranked the landing maneuver as the 'hardest' maneuvers, but the 'second easiest' ranking held the next largest group of expert pilots (n=4).

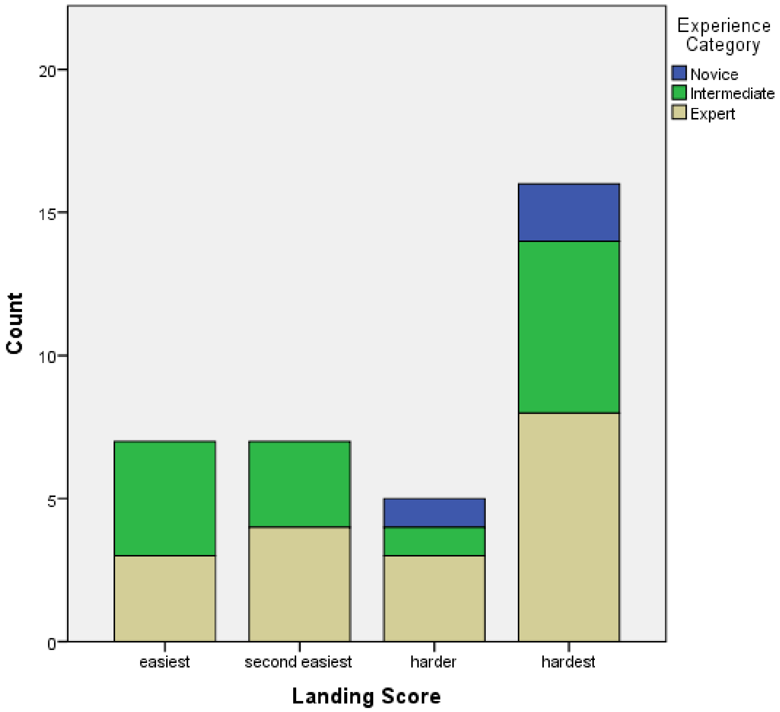


Figure 5. Grouped Histogram of the Landing Maneuver.

The next three self-assessment questions asked each participant to indicate their landing ability, graphed as perceived skill, the landing ability of the average pilot in the same flight course, and if participants considered their landings good enough. All three questions relied on the use of a continuous scale and that the participants mark an 'X' in the appropriate spot on the line provided. Each of the continuous scales measured 85 millimeters in length.

The first of the three continuous scales, perceived landing firmness, in terms of G-load, had the words 'softer' and 'harder' at either end of a line segment. Based purely on perception, the participant's mark indicated the firmness of the last landing of that flight lesson. The minimum perceived firmness recorded was one (1) millimeter and the maximum 71 millimeters. The mean perceived landing G-load was 30.54 millimeters, which fell below the line segment's midpoint of 42.5 millimeters. The upper and lower actual vertical G-loads, 1.08 and 1.68, respectively, were applied at either end of the line segment translating the mean perceived firmness of 30.54 millimeters to 1.30 G's. Figure 6 graphically represents the perceived landing ability of novice, intermediate, and expert pilots compared to the actual G-load of the landing.

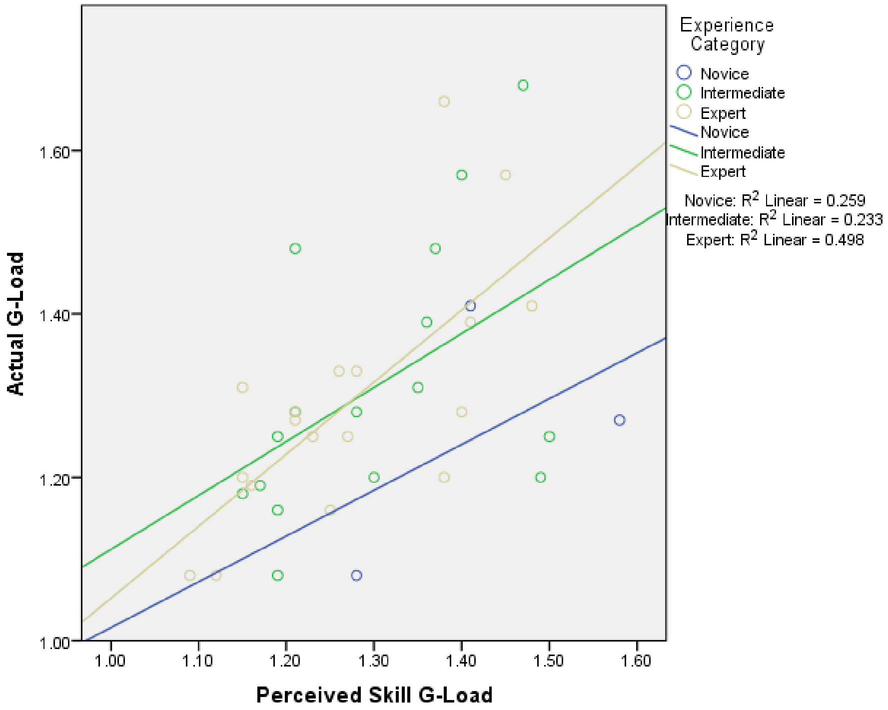


Figure 6. Perceived Versus Actual G-load.

Participants were next asked to indicate with an 'X' on a continuous scale, as before, how hard or soft the landings of the average pilot in the same flight course were. The line segment provided had 'soft' written at one end and 'hard' at the other. Measured in millimeters, the minimum value of this data set was 4 millimeters and had a maximum value 70 millimeters. The average measured length was 36.46 millimeters falling below the line segments midpoint of 42.5 millimeters. As with landing ability, the line segment applied the minimum and maximum actual vertical G-load at either end transforming 36.46 millimeters to an average G-load of 1.35 G's. Figure 7 presents what participants perceived as the average G-load on landing.

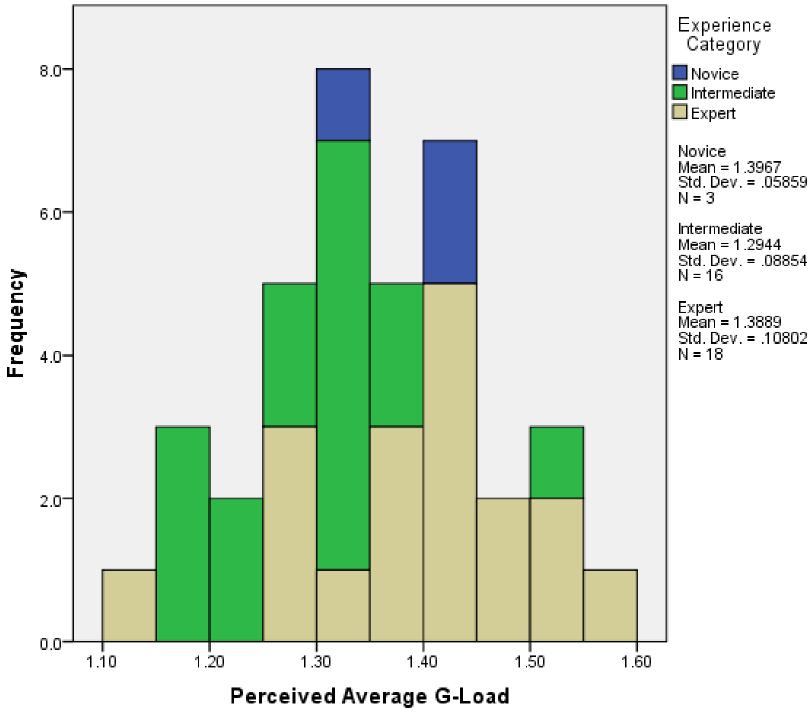


Figure 7. Perceived G-load of the Average.

Novice pilot participants estimated the average pilot in their flight course to have a vertical G-load to be around the mean. Intermediate participants estimated the average pilot across a wider range of vertical G-loads, but weighing a little heavier below the mean. Expert pilots, also estimating the average pilot across a wider range of vertical G-loads, estimated the average pilot sat above the data's mean.

The final continuous scale developed for self-assessment asked participants to indicate if their landings were currently good enough. As before, an 'X' marked the participant's answer on a line segment. The line segment read 'needs great improvement' on one end and 'my landings are perfect' on the other. 'Good enough' read at the midpoint of 42.5 millimeters. The minimum value recorded for this data set was 10 millimeters. One participant recorded their landings as currently being perfect with a millimeter marking at the maximum distance of 85 millimeters. The mean recording was 51.86 millimeters, which is higher than the line segment's midpoint reading of 'good enough' indicating a majority of participants felt their landings were more the good enough. Figure 8 is a simple error bar chart of participants' responses comparing if their landing is good enough to actual vertical G-load.

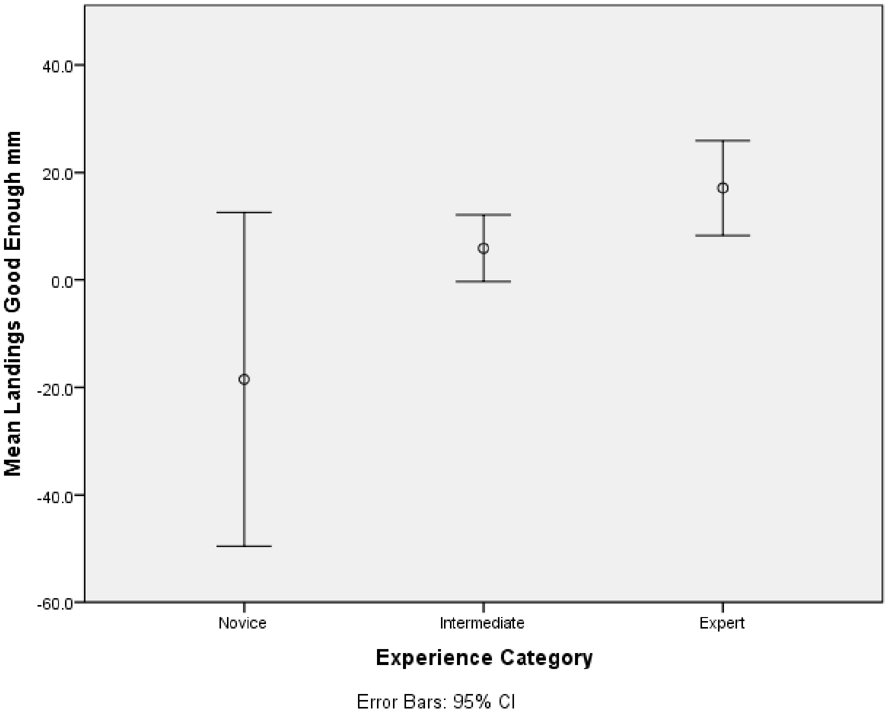


Figure 8. Simple Error Bar Chart of Good Enough Landings.

Although only three (3) participants represented novice pilots, all responses indicated their landings were less than good enough. The 95% confidence interval is greatest with novice pilots because of the small sample of novice pilots (n=3). The 95% confidence intervals for intermediate and expert pilot participants are comparatively similar. The intermediate pilot participants predominantly (n=11) felt their landings were more than ‘good enough’. Expert pilot participants also predominantly (n=16) felt their landings were more than ‘good enough’ with one participant determining their landings as ‘perfect’.

Qualitative

The third section of the survey consisted of two open-ended type questions. Categories or themes emerged from each of the qualitative questions. Some participants fell into multiple categories based on their response.

The first qualitative question examined how the participant personally determined if a hard landing occurred. Upon reviewing each response the following categories or themes were established, physical discrepancy, landing results in a go-around, abnormal runway contact, feel/sound, and unsure. The category physical discrepancy includes responses using terminology such as tire wear, strut damage, and bent metal. Abnormal runway contact encompasses terms such as airspeed, no flare, and high impact. Feel/sound covers responses written as ‘feel of the aircraft’ or ‘sound of the aircraft’. Finally, a participant fell into the unsure category if they indicated that they were unable to decipher a hard landing from any other landing. Figure 9 presents the emerged categories and their rate of occurrence by experience category.

All participants responded to the open-ended question evaluating how each pilot, personally, determined if a hard landing occurred. Except for the unsure category, at least one (1) novice pilot participant’s response fell into each category of determination. Most novice participants (n=2) determined a hard landing through abnormal runway contact, such as aircraft airspeed, the landing flare, bouncing the aircraft, or impact force.

Intermediate pilot participant's answers matched into every determination category. A majority of intermediate participants (n=11) determined a hard landing by feel/sound of the aircraft at touch down followed by abnormal runway contact (n=6). One intermediate experienced pilot was the only participant of the study to indicated that they were unable to decipher a between a hard landing and any other landing. Expert pilot participants established themselves into three categories for determining a hard landing. The majority of expert participants (n=14) determined a hard landing by feel/sound. The categories of abnormal runway contact and physical discrepancy followed with n=6 and n=3, respectively.

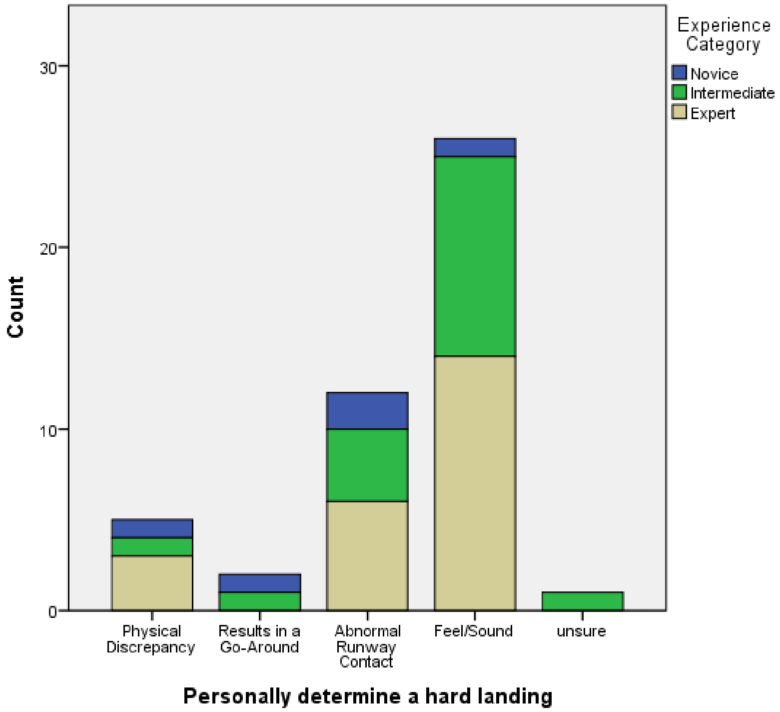


Figure 9. Grouped Histogram of Hard Landing Determination.

The second qualitative question asked participants what it would take, personally, to refer an aircraft to maintenance for an unscheduled hard landing inspection. Following this open-ended question, a yes/ no type question asked whether the participant pilot felt an unscheduled hard landing inspection should be completed, considering all landings completed during the flight.

In similar form, this second qualitative question produced categories or themes. The categories produced included physical discrepancy, proprioceptive sense, hard landing, feeling, control difficulty, and unsure. Physical damage included phrases such as visual damage, tail strike, popped or bald tires, nose strut damage, and bent firewall. Proprioceptive sense encompassed any body movement caused by the landing, including the pilot’s head hitting the top of the cabin. The feeling category included responses written as ‘a feeling’. The unsure category indicated the participant was unsure in determining what it would take to refer the aircraft to maintenance. Figure 10 shows a grouped histogram of how pilot participants determined if the aircraft should be referred to maintenance for an unscheduled hard landing inspection.

Six (6) participants either did not answer the question regarding what it would take to personally refer an aircraft to maintenance or failed to write a legible or appropriate answer, so were not included in the results graphed in figure 10. Reporting novice participants fell into two categories, feeling and unsure. Intermediate and expert participant distributed across more categories. A majority of both intermediate (n=5) and expert (n=13) participants indicated that it would take physical damage to refer the aircraft to maintenance for an unscheduled maintenance inspection.

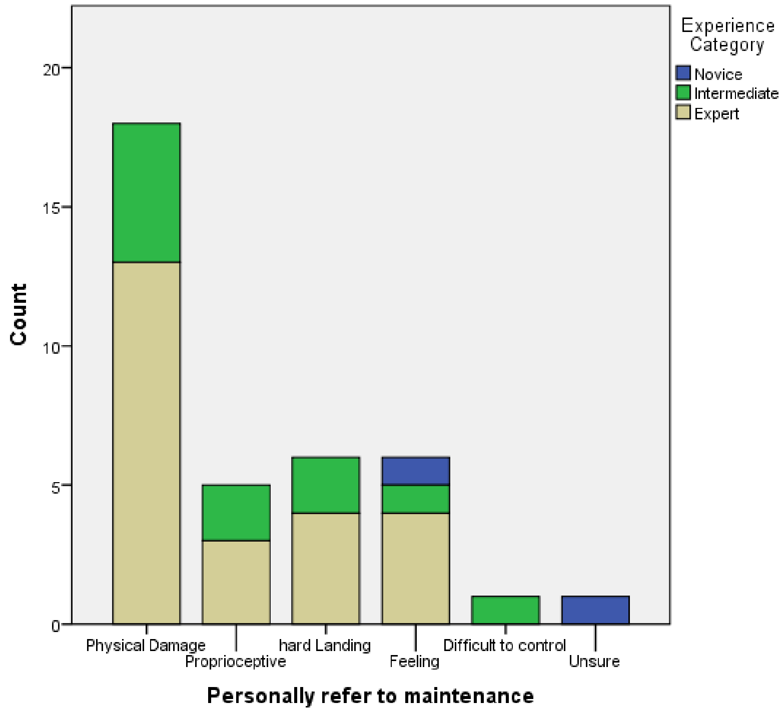


Figure 10. Grouped Histogram of Maintenance Referral Determination.

After responding to the question about what it would take to personally refer an aircraft to maintenance for an unscheduled maintenance inspection, participants were asked whether, based on all of the landings conducted during that lessen, they felt the aircraft should be referred to maintenance. The results of this question are graphed in figure 11. All intermediate and expert participants reported they would not refer the aircraft to maintenance, considering all landings conducted during that flight. One novice pilot identified the need for a maintenance referral following the flight. Determined by matching launch times, the participant's flight instructor felt an unscheduled hard landing inspection was not required following the flight.

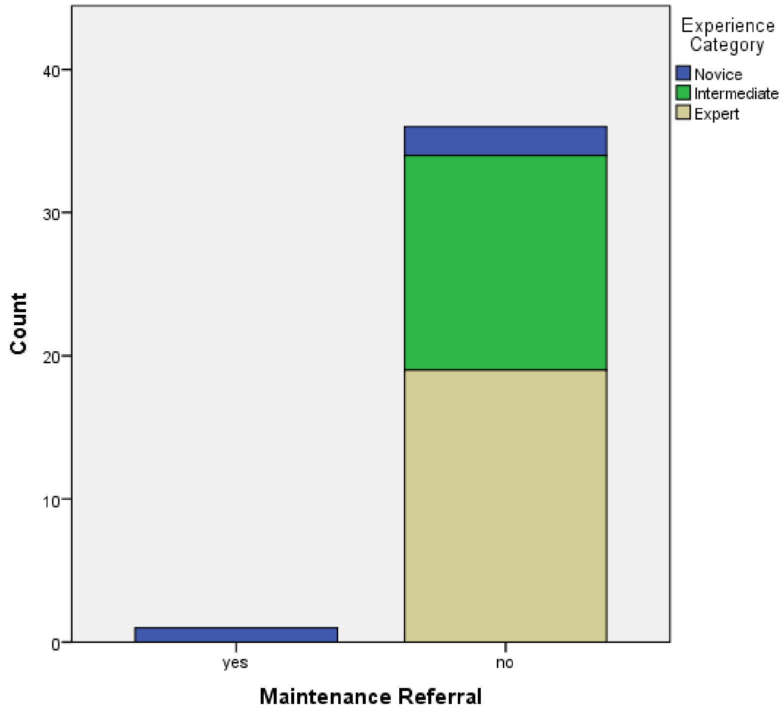
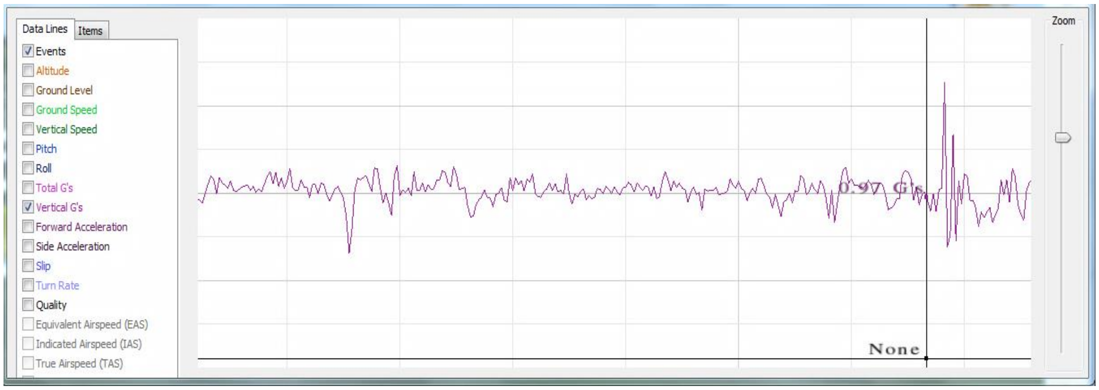


Figure 11. Aircraft Maintenance Referral.

FDM Results

In addition to self-assessment in determining pilot perceptions, a secondary data source provided comparative FDM information. The Appareo Systems Vision 1000 supplied the actual vertical G-load imposed on the aircraft during landing. The information from the Vision 1000 presented data pictorially in Appareo Systems' AS Flight Analysis software. The AS Flight Analysis data presented in figure 12 presents an example of the G-load spike indicating when the aircraft touched down.



☑ Events
☐ Altitude
☐ Ground Level
☐ Ground Speed
☐ Vertical Speed
☐ Pitch
☐ Roll
☐ Total G's
☑ Vertical G's
☐ Forward Acceleration
☐ Side Acceleration
☐ Slip
☐ Turn Rate
☐ Quality
☐ Equivalent Airspeed (EAS)
☐ Indicated Airspeed (IAS)
☐ True Airspeed (TAS)

Figure 12. AS Flight Analysis Actual G-load Presentation.

Statistics

After interpreting the results of each survey question, research questions one and three required statistical tests to answer the research questions posed in Chapter 2.

Research question 1: Does pilot experience determine accuracy of landing G-load detection?

A bivariate correlation and simple regression sough to answer research question one. The bivariate correlation compared perceived G-load detection and actual vertical G-load. The data used Pearson's correlation coefficient because the data sets are interval. In addition, the correlation used a two-tailed test of significance. As seen in table 7, the perceived G-load is positively correlated to the actual G-load on landing with a Pearson's correlation coefficient of $r = .534$, p (two-tailed) $< .05$. This means that as perceived G-load increases, actual G-load increases. The coefficient of determination, $R^2 = .2948$ explains the variability in perceived G-load shared by actual G-load. Although perceived G-loads are highly correlated to actual G-loads, it only accounts for 29.5% of the variability.

Table 7. G-load Correlations.

		Perceived Skill G-Load	Actual G-Load
Perceived Skill G-Load	Pearson Correlation	1	.534**
	Sig. (2-tailed)		.001
	N	37	37
Actual G-Load	Pearson Correlation	.534**	1
	Sig. (2-tailed)	.001	
	N	37	37

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

In addition to the bivariate correlation, a simple regression seen in table 8 looked at the estimated total flight time to detection accuracy. Less than a difference of 9 millimeters or 0.063 G's determined an accurate vertical G-load detection. A value of 0.063 G's is double the human body's vertical acceleration detection threshold. Figure 13 shows the number of participants who accurately detected their vertical G-load. A simple regression evaluated the relationship between estimated total flight time and detection accuracy. To determine detection accuracy for the regression, the calculated difference between perceived G-load and actual G-load was converted to G-load differential. A positive difference indicated the perceived G-load was a lower, or better, G-load than actual. Inversely, a negative difference indicated the perceived G-load was a higher, or worse, G-load than actual. The simple regression did not produce significant findings between detection accuracy and flight experience.

Table 8. Detection Accuracy Regression Coefficients.

Model		Unstandardized Coefficients	
		B	Std. Error
1	(Constant)	-.003	.024
	Estimated Total Flight Time	3.480E-006	.000

Note. Dependent Variable: Accurate Detection

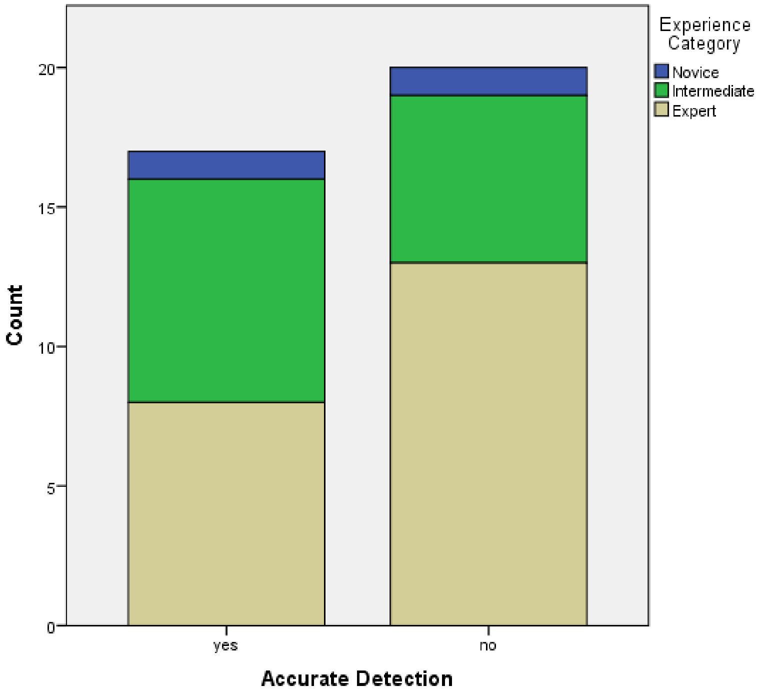


Figure 13. Grouped Histogram of Accurate Detection.

Research question 3: Does pilot experience correlate with self-serving bias associated to perception?

Three statistical tests answered research question three, analysis of variance (ANOVA), Spearman's Rho correlation, and simple regression. The first step in answering research question three was determining if there was an interaction between the mean perceived G-load, mean actual G-load, and experience category. The ANOVA produced answers seen in table 9. The ANOVA Output table shows an F-ratio of 2.027 and 0.194 for the perceived G-load and actual G-load, respectively with neither F-ratio producing significance, p<.05. Figures 14 and 15 show the ANOVA's mean plots. Comparing figures 15 and 16, the mean novice pilots' perceived G-load is at a much higher G-load than actual. The mean intermediate pilots' perceived G-load is almost equal, but slightly higher than actual G-load. Finally, the mean expert pilots' perceived G-load fell at a lower G-load than actual.

Table 9. ANOVA Output.

		Sum of Squares	Df	Mean Square	F	Sig.
Perceived Skill G-Load	Between Groups	.060	2	.030	2.027	.147
	Within Groups	.506	34	.015		
	Total	.566	36			
Actual G-Load	Between Groups	.010	2	.005	.194	.825
	Within Groups	.842	34	.025		
	Total	.851	36			

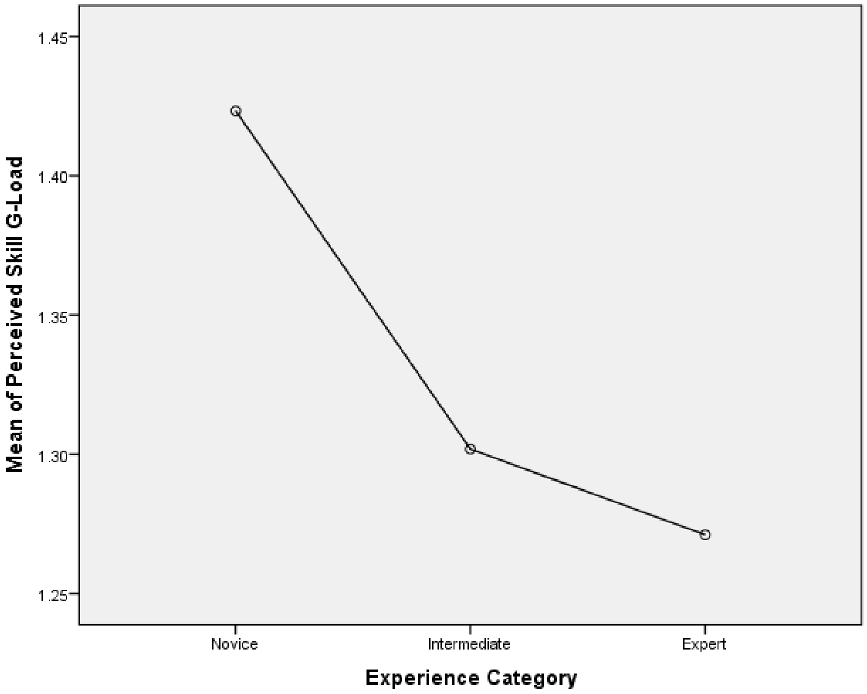


Figure 14. ANOVA Mean Plot Perceived.

Figure 15. ANOVA Mean Plot Actual.

The second part of research question three investigated the ranking of maneuver difficulty. A bivariate correlation used the Spearman's Rho test to look for significance. Table 10 is the SPSS output correlating the landing maneuvers to estimated total flight time. Although maneuvers correlated significantly with each other, the study focused on flight experience and the landing maneuver, which produced non-significant results, r = .916, p<.05.

Table 10. Spearman's Rho Correlation.

			Estimated Total Flight Time	Landing Score
Spearman's rho	Estimated Total Flight Time	Correlation Coefficient	1.000	.018
		Sig. (2-tailed)	.	.916
		N	37	35
	Landing Score	Correlation Coefficient	.018	1.000
		Sig. (2-tailed)	.916	.
		N	35	35

The final three comparisons investigated to answer research question three relied on simple regression. A regression is a sensitive test. For a more robust simple regression, the outlier participant with 17,000 estimated total flight hours accrued was not part of this data set. The first of the three comparisons look at perceived G-load and estimated total flight time. SPSS results, as seen in table 11, indicates experience category is not a significant factor in predicting perceived G-loads, p<.05.

Table 11. Perceived G-load Regression Coefficients.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.313	.031		42.621	.000
	Estimated Total Flight Time	-4.207E-005	.000	-.118	-.693	.493

Note. Dependent Variable: Perceived Skill G-Load

The second relationship looked at the perceived average landing G-load, in the same flight course to those volunteering participants and estimated total flight time. The relationship between these two variables proved non-significant, p<.05. SPSS output, table 12, shows the coefficients results from the simple regression.

Table 12. Perceived Average G-load Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.330	.026		51.352	.000
	Estimated Total Flight Time	4.778E-005	.000	.158	.935	.356

Note. Dependent Variable: Perceived Average G-Load

The final statistical test evaluated the relationship between participant estimated total flight times and if the participant believed their landings were good enough. The SPSS simple regression output, table 13, determined flight time experience has a significant impact on whether participants answered if they believed their landings were good enough, p<.05. As flight experience increased, so did the belief that landings were more than ‘good enough’. The coefficient of determination, $R^2 = .230$ explains the variability in estimated total flight time and whether participants believed their landings to be good enough. Although flight experience is highly correlated to belief of good enough landings, it only accounts for 23% of the variability.

Table 13. Landings Good Enough Regression Coefficients.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.689	3.846		.179	.859
	Estimated Total Flight Time	.024	.008	.480	3.189	.003

Note. Dependent Variable: Landings Good Enough mm

CHAPTER IV

DISCUSSION

Discussion of Results

This study explores pilot perceptions of vertical G-load imposed on landing and examines whether a self-serving bias is present in those perceptions. This chapter presents a discussion of the research questions' results and concludes with recommendations for future research.

Research Question 1

Research question 1: Does pilot experience determine accuracy of landing G-load detection?

A significant relationship existed between perceived and actual G-load on landing. As one would expect, actual G-load on landing has a direct relationship with perceived G-load. It is import to know when G-load on landing has increased, but more importantly, regardless of G-load imposed, a pilots need to be able to determine if their landing G-load is of accurate detection. An accurate detection is more important because, if necessary, the aircraft can be referred to maintenance for an unscheduled inspection. Accurate G-load detections are possible because the linear acceleration detection range is .001-.003G's. The human body has the unique ability to detect these vertical accelerations (Davis, Johnson, Stepanek, & Fogarty, 2008). Expert pilots should have greater skill in detecting these slight acceleration changes because of having more flight time and landing experience. In this study, flight time experience varied widely with a range of 16,990 hours. The lack of metacognitive skills, which contributes to misjudgments and misunderstandings, would expect novice pilots to inflate their self-assessment of landing G-load. This study indicated the opposite effect. A majority of novice participants (n=2) perceived their landings to be at a higher G-load than actual. Both a majority of intermediate and expert pilot participants (n=10) and (n=10), respectively, perceived landing G-loads to be lower than actual. This situation means these two groups believed they landed at a lower G-load than they did in reality.

The reasoning for the opposite effect than expected may have resulted from confounding variables, which were not looked at in this study. In addition, a survey question did not address how many flight hours the participant accrued in the research aircraft type. Many expert pilots in this study instruct in multiple aircraft types. Expert pilots may have had inaccurate detection from flying another aircraft more regularly.

Regardless of reason, the inability for a large number of participants to accurately detect G-load on landing may result in aircraft not receiving a necessary maintenance referral. FDM can assist pilots, both novice pilots who have not honed the skills of small acceleration change detection and expert pilots who also demonstrated inability to detect landing G-load by providing the actual landing G-load for perception comparison. FDM is a necessary tool to maintain aircraft structural integrity.

Research Question 2

Research Question 2: How do pilots determine if the aircraft requires an unscheduled hard landing inspection?

There is no universal definition for a hard landing leaving pilots to rely on individual perceptions to determine if a hard landing occurred. Aircraft require an unscheduled maintenance inspection if the aircraft is suspected to have incurred a hard landing (Garber & van Kirk, 2001). The Federal Aviation Administration's (2004) publication *Airplane Flying Handbook* and Aigion (2012) outline the ingredients that commonly result in a hard landing, but one parameter not previously investigated is pilot perception. This study sought to determine what participants felt must exist in order to determine a hard landing. Five categories or themes emerged from the compiled data. A majority (n=26) of responses determined a hard landing by feel or sound. The generated themes and responses establish that a hard landing is subjective. In addition to hard landing determination being subjective, some emerged themes were dependent upon metacognitive level.

The present study also sought to determine when a pilot would refer an aircraft to maintenance for an unscheduled hand landing inspection. Six themes surfaced from the maintenance referral determination data obtained from participants. An apparent majority (n=18) reported that it would take physical damage to report an aircraft to maintenance. As the Air Safety Foundation Editorial Staff (2004) reported with a B-737 crew, even though physical damage is unseen on the aircraft following a suspected hard landing, the aircraft may still have incurred non-visible damage.

In addition to physical damage, the current study reported that a hard landing or feeling would translate into referring the aircraft to maintenance. As previously determined, a majority of intermediate and expert pilots were inaccurate in determining the G-load of their landing, implying the inability to determine a hard landing and, therefore a maintenance referral. Novice and intermediate pilots based the maintenance referral determination on a feeling. This category warrants more research because the term feeling is ambiguous.

Regardless of hard landing determination and determination of a maintenance referral, the participants answered if they felt the aircraft should be referred to maintenance following the flight. All intermediate and expert participants responded that a maintenance referral was not required. One novice participant felt that, including all landings conducted, a maintenance referral was necessary. This finding is consistent with the fact that all novice participants in this study perceived their landings as harder than actual.

Because pilot perceptions are subjective and are dependent on metacognitive level, the data presented in this study agrees with Holtom (2007) that FDM is an "important safety tool" (p. 7) to use as a secondary data source in determining if a hard landing occurred because human perceptions vary. To aid pilots in the determination of if a maintenance referral is necessary, the FDM equipment senses a hard landing even if the pilot did not feel the aircraft needed a maintenance referral. In addition, FDM helps maintenance create a severity of impact report by comparing pilot perception to actual G-load.

Research Question 3

Research Question 3: Does pilot experience correlate with self-serving bias associated to perception?

This study produced the result of perceived G-load mean, including all groups, and actual G-load mean to be 1.30 G's. Initially this finding is not consistent with previous literate. Previous literature by Dunning, Meyerowitz, and Holzberg, (1989) states, competence in a domain is unclear leaving individuals to self-define criteria to evaluate themselves against. The identical means of these two variables could indicate that individuals understand actual G-loads for comparisons. Inaccuracies may have arisen in the data because of the study's small, unequal experience categories. Rather than evaluating the sample as a whole, previous literature identified metacognitive level to influence self-assessments (Kruger & Dunning, 1996). To evaluate each metacognitive level's perceptions, perceived G-load, maneuver difficulty, comparison to the average G-load, and input as to if an individual felt their landings are good enough were evaluated against estimated total flight time.

Perceptions are subjective, but self-serving bias appears when individuals express overconfidence in their abilities (Dunning, Meyerowitz, & Holzberg, 1989). Kruger and Dunning (1999) suggest novices will be most likely to express overconfidence and their study's findings indicated this to be a correct assessment in the domains of physics, tennis, and chess. The present study sought to replicate this outcome in the aviation domain. Unlike other domains, this aviation study did not identify metacognitive level to impact perceived G-loads. A possible reasoning to this finding is that only three participants contributed to the novice category.

Perception plays a large role in landing G-load determination. A study by Moore and Cain (2007) determined overconfidence and self-serving bias to be present on subjectively more difficult tasks. The four maneuvers evaluated ranked closely, but the landing maneuver resulted in being the most difficult maneuver. A majority (n=20) of participants identified the landing maneuver as the most difficult, but only eight of those 20 had a self-serving bias associated with this ranking. In addition to maneuver difficulty being inconsistent with previous literature, this study determined expert pilots predominantly overestimated (land at a lower G-load) landing performance. This finding may be a result of study confounding issues, such as participants coming from various cultures or individual ego. Although task difficulty is subjective, the effects compare the individual to that of the average.

The term average ignores the relation the individual has with the average. Ambiguity in the term average leaves the individual to judge themselves better or worse than the average, which may be judged accurately or inaccurately (Walton & Bathurst, 1998). To understand more clearly, if a self-serving bias is present in aviation, this study evaluated more than just individual perception of performance. The study investigated assessment of the average. The study expected to follow past literature and find that by using the term average, individuals would produce a self-serving bias when comparing themselves to that average. In addition, the study sought to determine if aviation metacognitive level played a role in comparison to the average.

Of the 37 total participants, 15 individuals believed themselves to produce a better (lower G-load) landing than the average individual. Self-serving bias appeared in a majority (n=2) of novice participants, as well as, in a majority (n=13) of expert participants. A majority (n=9) of intermediate participants felt their landing performance was worse than that of the average pilot at the same experience level. This study's findings divide when it comes to following past literature. The novice participants predominantly expressed a self-serving bias when comparing their performance to the average individual at the same flight level. Intermediate participants though, rather than also expressing a self-serving bias, showed an under confidence in their performance compared to the average. Expert participants in previous literature were found to show an under confidence, but in the current study expressed an overconfidence just like their novice counterpart. These findings suggest that perhaps the intermediate pilots who showed an under confidence may possess the skills and ability to accurately determine the performance of the average pilot with similar experience. Expert pilots did not follow previous literature in showing the expert metacognitive level faults in the perception of the average, rather the expert pilot participants failed in the perception of the self like their novice counterpart.

The final analysis in determining if self-serving bias is apparent in aviation was to see if pilots halted the metacognitive level at " the inadvertent acceptance of the nearly right" (Metcalfe, 1998, p. 106). For a pilot to move from the novice level to the expert level they cannot stop and think their skills are good enough. The regression between the continuous scale asking if landings are good enough and flight experience yielded the answer that as flight time increases so does the belief that landings are more than good enough. All novice participants were able to assess accurately that their landings were not yet to the point of being good enough, whereas their expert counterpart, to a significant degree, felt their landings were more than good enough. Contrary to previous literature, aviation does not show a self-serving bias with metacognitive level and stopping at the nearly right. This situation means that perhaps not all pilots continually try to perfect the landing maneuver.

Conclusions

Many variables contribute to the formation of a perception on landing. Perceptions form from physiological information gathered from the vestibular, visual, and proprioceptive senses. These formed perceptions allow pilots to identify and differentiate between landing firmness. Although a pilot senses a g-load, it is commonly unknown if the g-load corresponds to a hard landing. This situation is unknown because there is no universal definition of a hard landing. The first step in identifying a hard landing is the ability to match a perception to a definition. This study established the need for a universal definition for a hard landing. The results of research question two of this study provides evidence for this need because participants of the study created individual definitions for a hard landing and for when an aircraft should be referred to maintenance for an unscheduled inspection.

Even if the term hard landing received a definition, previous literature identified a connection between formed perceptions and metacognitive level. This study sought to determine if metacognitive level influenced perceptions in aviation. Specifically, this study looked for evidence of whether the psychological self-enhancement process of self-serving bias existed in aviation. The findings showed an overall significant correlation between perceived and actual G-load on landing, but failed to show existence of self-serving bias. Confounding issues such as environmental conditions, participant demographics, participant ego, or sample sizes may contribute to this study's findings.

This study's results were opposite than expected. Although previous literature and publications state otherwise, novice individuals predominantly understood their lack of metacognitive skills and provided accurate assessments or showed under confidence. Perhaps novice participants expressed no self-serving bias because novice individuals perceive the aviation domain as one of high stakes involved with the landing phase of flight. Similar results may be found in other high-stakes domains, such as medicine. Experts, on the other hand, were the participants who showed the self-serving bias. This finding indicates the inability of experts to accurately self-assess performance. This study did not examine why the reverse effects of self-serving bias and metacognitive level emerged.

Opportunities for future research resulted from this study. Replicating the study and placing emphasis on the confounding issues of the current study may yield different results. Also, the present study could be replicated in another high stakes domain such as medicine to compare results with respect to evidence of self-serving bias among results.

APPENDICES

APPENDIX A
Survey Form

GRADUATE THESIS SURVEY:
A MIXED METHOD APPROACH TO COLLEGIATE AVIATION SELF-ASSESSMENT OF G-LOAD ON LANDING: PILOT PERCEPTION VERSUS REALITY

This research is a survey of pilot perception of G-loads on landing. You will be asked questions about launch time, experience, maneuver difficulty, and unscheduled maintenance inspections. All of your information will be kept confidential and your name not recorded. Only the investigator and thesis adviser will have access to the data provided. This survey takes approximately 15 minutes to complete.

You may contact the investigator, Karin Hensellek, at khensellek@aero.und.edu or the adviser, James Higgins, at (701) 777-6793 about any concerns you have about this project. You may also contact the University of North Dakota Institutional Review Board at 701-777-4279 with any questions about research involving human subjects at the University of North Dakota.

Participation in this project is voluntary and you have the right to stop at any time. Whether or not you decide to participate will not reflect your current or future relationship, studies, or flight training at the University of North Dakota. By completing and returning this survey, you agree to participate in this study.

The risks of participating in this study are minimal, and may help improve aviation safety.

1. Launch time ___________________
2. Was your flight dual or solo? Please circle one: DUAL SOLO
3. Approximately how many flight hours do you have? ______________

4. How would you rank the following maneuvers in order of performance difficulty, 1 being the easiest and 4 being the most difficult maneuver? Please use numbers 1-4 only once.

    ____Landing

    ____Power-off stall

    ____Steep turns

    ____Slip

5. How soft or hard was your last landing of this lesson? Please mark the line below with an ‘X’ at the appropriate spot.

Softer ____ Harder

6. How hard or soft are the landings of an average pilot in your flight course? Please mark the line below with an ‘X’ at the appropriate spot.

Soft ____ Hard

7. Are your landings, currently, good enough? Please mark the line below with an ‘X’ at the appropriate spot.

Needs great improvement ____________________ Good Enough ____________________ My landings are perfect

8. Who performed the last landing of this lesson?

Please circle one: STUDENT INSTRUCTOR

9. How do you personally determine if a hard landing occurred?

10. What would it take for you, personally, to refer an aircraft to maintenance?

11. Based on all the landings completed today, do you feel the aircraft should be referred to maintenance for an unscheduled hard landing inspection? YES NO

APPENDIX B
Millimeter to G-load Conversion Table

Table 14. Millimeter to G-load Conversion Table.

mm	Corresponding G-Load	Mm	Corresponding G-Load	mm	Corresponding G-Load
0	1.08	29	1.28	58	1.49
1	1.09	30	1.29	59	1.49
2	1.09	31	1.3	60	1.5
3	1.1	32	1.3	61	1.51
4	1.11	33	1.31	62	1.51
5	1.12	34	1.32	63	1.52
6	1.12	35	1.33	64	1.53
7	1.13	36	1.33	65	1.54
8	1.14	37	1.34	66	1.54
9	1.14	38	1.34	67	1.55
10	1.15	39	1.35	68	1.56
11	1.16	40	1.36	69	1.56
12	1.16	41	1.37	70	1.57
13	1.17	42	1.37	71	1.58
14	1.18	43	1.38	72	1.58
15	1.19	44	1.39	73	1.59
16	1.19	45	1.4	74	1.6
17	1.2	46	1.4	75	1.61
18	1.21	47	1.41	76	1.61
19	1.21	48	1.42	77	1.62
20	1.22	49	1.42	78	1.63
21	1.23	50	1.43	79	1.63
22	1.23	51	1.44	80	1.64
23	1.24	52	1.44	81	1.65
24	1.25	53	1.45	82	1.65
25	1.26	54	1.46	83	1.66
26	1.26	55	1.47	84	1.67
27	1.27	56	1.47	85	1.68
28	1.28	57	1.48		

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