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PILOT WEATHER DECISION MAKING AND THE INFLUENCE OF PASSENGER PRESSURE

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PILOT WEATHER DECISION MAKING AND THE INFLUENCE OF PASSENGER PRESSURE

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Industrial Engineering

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by
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Accepted by:
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ABSTRACT

The purpose of this study is to determine the effect of social pressure on general aviation (GA) pilots' weather decision making. Data have shown that GA accidents associated with visual flight rules (VFR) flight into instrument meteorological conditions (IMC) are more likely to result in fatalities than other types of GA accidents. This problem is compounded by the addition of passengers, who have been found to be present onboard during VFR into IMC accidents more frequently than in other types of GA accidents. The question is whether passengers influence a pilot's decision to continue flight into adverse weather. The extent other individual factors play a role in a pilots' decision to continue through adverse weather, including prior experience (i.e., flight hours), basic weather knowledge, decision-making, risk perception and tolerance, and the ability of the pilot to assert themselves in the cockpit were explored. To examine these questions, social pressure by passengers during flight was manipulated to encourage pilots to continue or divert from adverse weather.

Results conclude that the distance the pilot continued into the weather for positively motivated pilots (persuaded to continue) increased, and decreased for the pilots who were negatively motivated (persuaded to divert). The significant findings of persuasion on distance into the weather were compounded by the lack of awareness of the pilots on the impact of the passenger on their decision making behavior. Additional findings suggest that private pilots with instrument ratings are continuing further than either the low time VFR pilots or the high time commercial and/or ATP pilots.

DEDICATION

I would like to dedicate this dissertation to my family, who has supported every endeavor I have pursued throughout my life with enthusiasm, regardless of what it was, or what assistance was needed to accomplish it. Your unwavering support, encouragement, and confidence in me have allowed me to succeed. I would like to thank my parents, Sandy and Keith Baron, who have supported me every step of the way. To my grandparents, Edith and Stanford Baron, who have always encouraged me throughout this process. To my grandfather, Irving Sirota, who is a constant source of support in my life, and my late grandmother, Edith Sirota, who is one of the best people I have ever known.

ACKNOWLEDGEMENTS

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CHAPTER 1: INTRODUCTION

Ever since the first flight by the Wright Brothers on December 17, 1903, Americans have been captivated by the thrill of flight. That momentous day sparked a culture that relishes in the joy of flight, and some direct this passion into a profession, others a hobby. Of the three main categories of flight, those pilots who choose to make a career of flight typically fall into either the commercial or military sectors. However, some of these pilots also make a living while flying under general aviation (GA), which refers to non-military and non-commercial applications. GA also includes a subsection of pilots who chose to fly for recreational purposes, as the purposes for pilots flying under GA ranges from crop dusting to air transport. Therefore, recreational GA pilots make up a subset of general aviation (GA), which encompasses a wide range of flight activities.

In the early years of flight, pilot fatalities were not uncommon due to the high level of risk associated with their new pastime. However, improvements in both aircraft and training methods have afforded a safer flying experience today. The accident rate dropped to an all time low in the 1980's, and has remained leveled out ever since (Figure 1; NTSB, 2005). With continued advances in technology, mechanical problems have become less and less frequent (Shappell & Wiegmann, 1996). Figure 1 shows the large decrease in aviation accidents (per 100,000 flight hours) with a leveling-off of the accident rate in the 1980's for both military and general aviation. This is in comparison to the more recent accident rates for commercial accidents, which occur much less frequently. Figure 2 (Annual Safety Report, 2005) provides a brief historical overview of commercial aviation accidents showing passenger fatalities per 100 million hours. Both of these figures show significant improvements in aviation safety since the 1950's, leaving one main area in need of improvement.

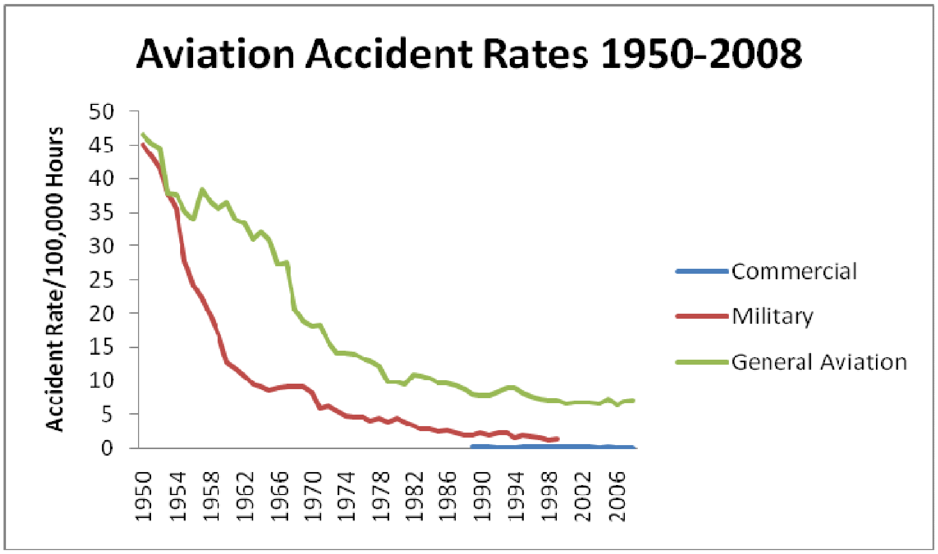


Figure 1: Overall Accident Rate per 100,000 hours: 1950-2008

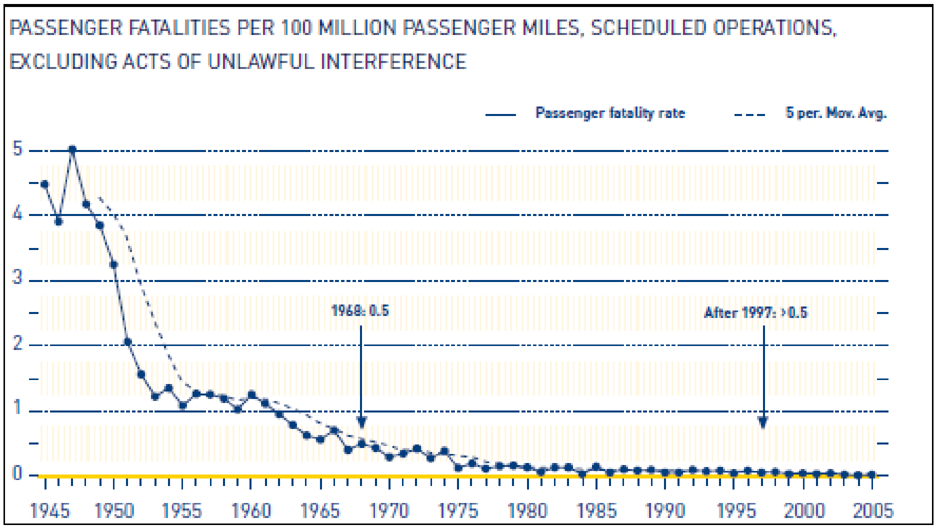


Figure 2: Passenger Fatalities: Commercial Aviation Accidents per 100 million miles

Pilot performance in the form of human error contributes to approximately 50% to 90% of aviation crashes (Billings & Reynard, 1984; Diehl, 1989; Hawkins, 1993; Nagel, 1988;

Trollip & Jensen, 1991; Yacavone, 1993), and in comparison to mechanical factors, improvements have occurred at a much slower rate (Shappell & Wiegmann, 1996). Human error related accidents fluctuate based on flight categorization (Li, Baker, Grabowski, & Rebok, 2001), with human error contributing to 85% of GA accidents but only 38% of major commercial accidents. If additional gains are to be made to improve the current accident rate, it is essential to investigate the causes of human error, particularly because of the catastrophic consequences that can result from this type of high-risk activity.

One subset in aviation that may have the largest impact on the overall accident rate and aviation safety as a whole is that of GA operations. Both historically and currently, GA has the highest accident rate for any of the three main types of aviation, and, as previously mentioned, the highest rate of human error (Figure 1; Li et al, 2001). Commercial aviation has by far the most impressive record of 0.29 accidents per 100,000 flight hours, followed by the military with 1.4 accidents. This is in comparison to GA with 7.05 accidents per 100,000 flight hours (1999 rates). Therefore, during any given flight, a GA pilot is over four times more likely to be involved in a crash than a commercial pilot.

The safety differences seen between GA and other types of aviation may have a lot to do with the pilot population. GA pilots may be flying for instruction, training, business, agricultural purposes, or for a number of other reasons, including recreational purposes (Wiegmann & Shappell, 2003). Commercial and military pilots are typically career pilots, with a minimum of 1500 flight hours required to attain a commercial license. A large number of GA pilots, particularly the recreational pilots, do not receive the training or log even a fraction of a commercial pilot's hours.

One area where this issue of experience and training is especially important is in the area of weather decision making. During a flight a pilot may encounter any number of different weather conditions. However, these conditions can generally be categorized into three main types of conditions that pilots can fly under, visual meteorological conditions (VMC) and instrument meteorological conditions (IMC). VMC represents clear weather conditions where the pilot controls the aircraft by relying on what can be seen out of the window. Controlling attitude, navigating, and maintaining separation from obstacles such as terrain and other aircraft is maintained visually during VMC.

In contrast, IMC represents deteriorated weather conditions where pilots may be unable to see and avoid obstacles. During IMC, pilots must be able to fly using only their instrumentation since visual cues are severely limited, if present. The pilot must control the attitude of the aircraft by monitoring the flight instruments and relies entirely on ATC for separation of aircraft. The ability to control the plane using only instrumentation is required to obtain an instrument rating, which allow pilots to fly during both types of weather and entitles them to additional privileges.

The Federal Aviation Regulations (FARs) contains a list of regulations that correspond to each aspect of flight, from the airworthiness of the aircraft to the weather conditions and airspace restrictions. FARs have two sets of rules corresponding to the two categories of weather conditions, visual flight rules (VFR) and instrument flight rules (IFR). VFR involves a set of weather conditions consistent only with visually clear conditions (VMC). VMC minima, the minimum meteorological requirements for VFR are the minimum requirements necessary during VFR flight. In contrast, pilots who file for IFR flights can fly in both VMC and IMC conditions. Interestingly, the vast majority of IFR flying is done under visually clear conditions. These categorizations, VFR and IFR impose additional regulations such as requirements on airspace type and class. In the United States and Canada, all airspace between 18,000 and 60,000 feet above ground requires aircraft to operate under IFR regardless of actual weather conditions.

Pilots who have attained their instrument ratings are entitled to fly under IFR, and commercial and military pilots typically conduct the majority of these flights. In comparison, much fewer GA pilots are instrument rated. The majority of GA recreational pilots are qualified to fly only during VMC, often due to having limited flight hours and/or training. These limitations are often due in part to the expensive nature of flying, which causes many pilots to have trouble affording the time or money to acquire training for IMC. Without the necessary training and flight hours, VFR only pilots have limited experience recognizing and handling deteriorated weather conditions.

VFR only pilots may enter IMC without the permission, rating, and/or experience to do so for a variety of reasons. This phenomenon is known as VFR into IMC. VFR into IMC is one of the leading causes for concern in GA, as it represents only 3.5% of GA accidents but is associated with nearly 20% of all GA fatalities. Fatal VFR into IMC accidents have an 80% fatality rate, in contrast to the 19% fatality rate associated with other types of GA accidents (Figure 3; Detwiler, Holcomb, Hackworth, & Shappell, 2008). This rate has been consistent across many studies and is relatively stable over time (Batt & O'Hare, 20005; Li & Baker, 1999, 2007; NTSB, 1989, 2005, 2009).

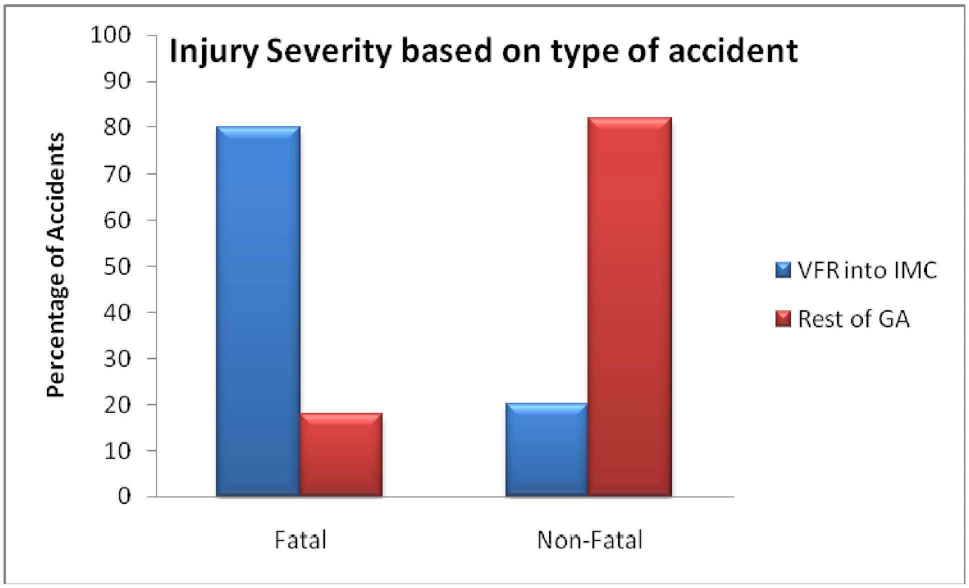


Figure 3: Injury severity for VFR-IMC and non-VFR into IMC

Multiple studies that have explored the VFR into IMC problem have found that a large percentage of GA pilots have entered IMC without the proper training or authorization (Hunter, 2001; O'Hare & Chalamers, 1999). A survey of approximately 1,300 New Zealand pilots found that 27.2% the non-instrument rated pilots had entered IMC on at least one occasion. Similar results were found for pilots in the United States, where approximately 25% of pilots had entered IMC on at least one occasion (Hunter, 2001). What makes these results even more remarkable is that 17.7% of these surveyed GA pilots had been involved in at least one accident (not necessarily related to VFR into IMC incidents).

We must therefore ask, do all pilots who fly into adverse weather do so for the same reasons? Evidence for both a lack of expertise (Batt & O'Hare, 2005; Li & Baker, 1999, 2007; NTSB, 1989, 2005, 2009) and misplaced motivation (Burian, Orasanu, & Hitt, 2000; Craig, 2001; Detwiler et al, 2008; Hunter, 1995; O'Hare & Smitheram, 1995; O'Hare & Rasmussen, 1989) have been supported during the research into the cause of VFR into IMC accidents.

In order to investigate the true cause(s) of VFR into IMC accidents, Goh & Wiegmann (2001b) performed a simulator study to determine if expertise or motivation were leading to this behavior. Their findings suggest that there are two categories of pilots involved in VFR into IMC accidents, those who enter weather inadvertently as a result of misdiagnosing the situation, and those who enter deliberately as a result of misplaced motivation. The first group of pilots who misdiagnose the situation do not accurately recognize the deteriorating weather conditions or the associated risk. This is generally thought to be due to a lack of experience, more specifically, experience relating to the identification of weather cues. The second group of pilots are those who intentionally continue into adverse weather conditions due to motivational factors. These pilots can be influenced to enter IMC due to one of several factors, internal pressure to get home, or "get-home-itis," and external pressure created by the presence and/or influence of passengers.

This first group, who lacks the ability to discriminate weather conditions, is consistent with the first part of the definition of judgment by Jensen & Benel (1977), the intellectual ability, or the capacity to "sense, store, retrieve, and integrate information." The authors refer to Van Dam, who terms this a "discriminating ability" (cited in Jensen & Benel, 1977). The second group is consistent with the second part of the definition of pilot judgment referred to as motivational tendencies. This is the motivation to choose and execute a suitable course of action within a given time frame, or what Van Dam terms the "response pattern" of the pilot. The response pattern includes biases or heuristics that influence the decision making process of the pilot. The response is also influenced by the manner with which the pilot copes with the risks inherent in the flight situation.

The role of other occupants must also be explored as a factor in VFR into IMC accidents. Research in related arenas such as social psychology (Asch, 1951, 1955; Milgram, 1964, 1974), driving (Arnett, Offer, & Fine, 1997; Baxter, et al, 1990; Doherty, Andre, & MacGregor, 1998; Preusser, Ferguson, & Williams, 1998; Regan & Mitsopoulos, 2001), and teams in a commercial aviation cockpit (Chidester & Foushee, 1988; Costley, Johnson, & Lawson, 1989; Foushee & Manos, 1981; Goguen, Linde, & Murphy, 1986; Kanki, Lozito, & Foushee, 1989; Ruffell Smith, 1979) have shown that the presence of and the interactions with other people in social situations can and do affect ones actions. In the GA domain, passengers may influence pilot decision making. Interestingly, research has found that passengers are more frequently present in accidents involving VFR into IMC accidents than during other types of GA accidents (Detwiler et al, 2008; Goh & Wiegmann, 2001a). The role of passengers in this type of accident must be explore before we can begin to understand how to prevent these types of accidents. Additionally, both the higher rate of fatal accidents and higher death toll associated with VFR into IMC makes this problem an even more pressing concern for study.

CHAPTER 2: WEATHER

At the most basic level, pilots must understand when they can and cannot fly based on the weather conditions. The basis of this determination is the broad categories of visual and instrument conditions (VMC/IMC), which is classified according to ceiling and visibility minimums. Rather than simply following the rules associated with flying in VMC or IMC, pilots are required to have an in-depth understanding of weather as it relates to aviation. Weather is neither stationary nor binary, it is ever changing, and understanding it requires and relies upon a fundamental knowledge of weather theory. Weather theory describes the basic concepts that can be used to understand why, when, and how weather phenomena (cold fronts, storms, etcetera) change and move. The knowledge of how these weather systems change and move result in the VMC/IMC determination. Weather information can be obtained in many different formats, potentially affecting its interpretation and use. In order to understand the pilot's decision making process, a basic understanding of how the pilot thinks about weather as it relates to aviation is necessary. This understanding requires a basic knowledge of weather theory, weather phenomena, weather classification, and the way pilots obtain weather information.

2.1: Weather Theory

The most basic understanding of weather theory requires understanding certain fundamental concepts. Weather theory basics begin with the atmosphere, a layer of air that surrounds the earth and rests on its surface (Flight Standards Service, 2003). There are several layers of the atmosphere that are defined by the distance in which they extend from the earth and their associated properties. The layer closest to the earth's surface where the majority of the weather phenomena and flying (especially general aviation) occurs is the troposphere. This layer begins at sea level and extends to 20,000 feet over the north and south poles and up to 48,000 feet over the equator. Differences in the height of the troposphere between the equator and the poles are a result of a change in weather during the summer and winter months that leads to uneven heating. This uneven heating can also be found at different times during the day and results in changes due to the type of surface. Different surfaces absorb and reflect different amounts of the sun's radiation. For example, there are differences in the absorption of heat in plowed fields, forests, and bodies of water (Figure 4; NASA, 2009). Land areas absorb much more heat than bodies of water but are still not able to absorb all of the radiated heat during the peak hours of the day. This leads to the earth absorbing the additional radiation, which is later emitted from the earth's surface at night. Water surfaces do not absorb as much heat as land because they reflect some of the solar radiation. Therefore, temperatures during the day are more stable because less radiation is being absorbed, resulting in less heat emitted during the night.

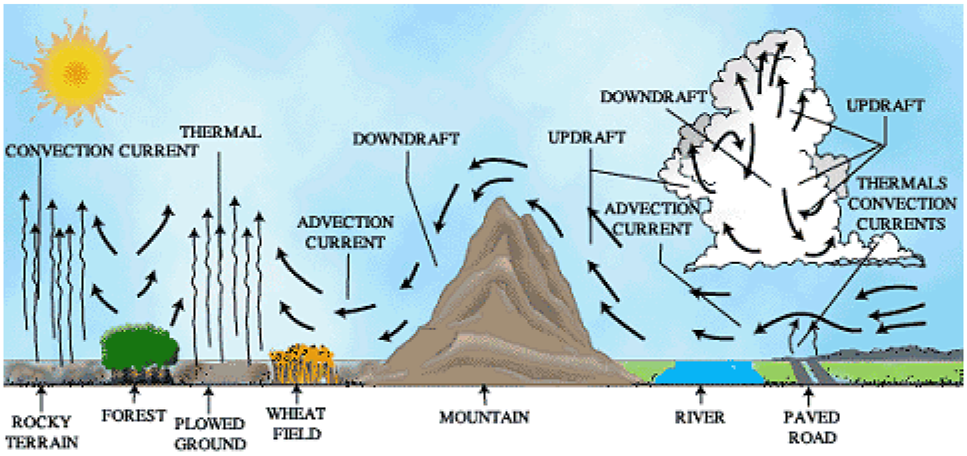


Figure 4: Air Current and Heating Effects on Local Circulation

One additional concept related to the differences between bodies of water and land is the concept of moisture. Moisture is one of the four key atmospheric properties. Moisture refers to the presence of some state of water, and can occur in many states (solid, liquid, gas). The most important concept when dealing with moisture is molecular saturation, or the maximum amount of moisture that a molecule can hold. If the air is saturated, it can no longer hold additional water vapor, resulting in excess moisture and therefore, some form of clouds or precipitation. There are two main ways that saturation can be measured, relative humidity (RH) and temperature-dew point spread (Lankford, 2001). RH is the percentage of saturation in a molecule. Therefore, if the air is completely saturated and can hold no additional moisture, RH would equal 100%. If the molecule is only holding half of its molecular capacity, it would have an RH of 50%. The capacity for air molecules to hold water vapor increases with temperature, resulting in a decreased RH and saturation with an increase in temperature. If the same molecule with a RH of 100% increases its temperature, it will have more available space for additional molecules, resulting in a decreased RH%. The temperature-dew point spread calculates saturation using the difference between the temperature and dew point. Temperature is the measure of the average speed of molecules, and dew point is the temperature at which air becomes saturated (Lankford, 2001). If the temperature and dew point are equal, precipitation (fog) is almost guaranteed, but as the difference in these values increase, precipitation becomes more and more unlikely (very unlikely with a six degree difference between temperature and dew point).

The movement of air is not only a product of moisture and temperature, but both the pressure and density of the air, the final two important atmospheric properties. Pressure is the force of the air, or how many air molecules exist above the point of measurement.

Therefore, as you gain altitude and the air above you decreases, so will pressure. These two properties of air have a direct relationship with one another, but an opposing relationship to the two previously discussed properties, temperature and moisture. These four properties have interacting qualities and behave in predictable ways. As pressure and density decrease, temperature and moisture increase. As molecules warm (temperature increases) the increased heating leads them to move farther apart from one another (density decreases), resulting in the ability to hold more molecules (moisture increases) with less pressure on the surface (pressure decreases), resulting in rising air. In general, warm air tends to rise and has low density and low pressure, and cooler air tends to descend, with high density and high pressure.

How air moves leads to the discussion of general circulation theory. This is the theory that explains the differences in pressure due to the unequal heating of the Earth's surfaces. As previously described with the changes in the troposphere due to heating differences, heating also has similar effects on pressure. The Poles are surrounded by an area of high pressure (cold air) and the equator by areas of low pressure (warm air). The low pressure in the equatorial regions allows higher pressure to travel in from the Poles, resulting in cooling of the air near the equator, making it sink towards the earth as it becomes denser. These wind patterns occur in each hemisphere approximately three times, and the circulation pattern is termed Hadley's cells (Figure 5; http://universe-review.ca/option2.htm). This is the central formula for air circulation, but there are many more factors that lead to changes to this basic pattern.

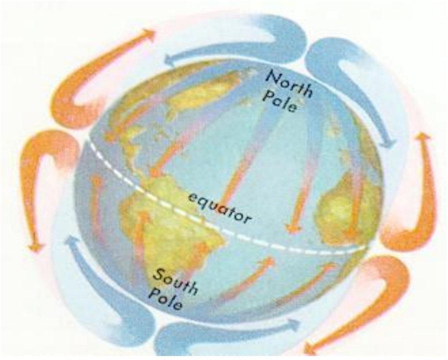


Figure 5: Global Circulation Patterns

These changes occur as a result of widespread changes to the atmosphere's general air movements by the Coriolis effect, pressure gradient force, or the frictional force. The Coriolis effect is due to the rotation of the Earth. In the Northern hemisphere, it results in a deflection of the wind clockwise in a high density area ("high") and counterclockwise in a low density area ("low"). This pattern is reversed in the Southern hemisphere. In general, highs are typically areas of dry, stable, descending air, bringing clear weather, and lows are areas of moist, unstable air, bringing stormy weather. The second factor is the pressure gradient force, which is caused by areas of different pressure. Pressure differences results in wind that typically wants to blow from areas of high pressure to areas of low pressure. A third factor, frictional force, is the difference between the moving air and the ground that slows the wind at or near the surface. This force acts opposite to wind direction and increases with rugged terrain.

These changes in the movement of air can lead to differences in two main types of motions in the atmosphere, horizontal movement (wind) and vertical movement (currents). These changes are due to heating differences, density and pressure, resulting in changes to wind direction and speed. In general, winds flow from areas of high density and pressure to areas of low density and pressure, and are minimized by the force of friction around objects.

Friction tends to increase with terrain changes, and this results in decreased wind speed with rougher terrain. These changes result in predictable patterns of wind changes around mountains and mountain passes (venture effect, mountain wave, standing wave), the sea and surrounding land (sea breeze), and mountains, valleys, and canyons (valley wind, gravity wind, drainage wind; Figure 4).

This discussion of the movement of air can refer to either small parcels of air (as previously mentioned) to larger bodies of air with similar weather features. These large bodies of air are termed air masses. The characteristics of air masses are a function of the temperature and moisture, which are largely determined by its geographical origin. Air masses that originate near bodies of water, as indicated by the phrase 'maritime,' (maritime polar and maritime tropical) have a high moisture content, and can be contrasted with those originating from land, which is termed 'continental' (continental polar and continental tropical) with a lower moisture content. The second half of the phrase for the type of air mass indicates the temperature from which it is located, with 'polar' (continental polar and maritime polar) indicating a cold air mass, and 'tropical' (continental tropical and maritime tropical) indicating an origin in warmer weather. Each has typical weather characteristics, with the moisture content of the air masses that originate around water (maritime) being a key ingredient in hazardous weather flying, while cold weather air masses (polar) have a high potential for icing, and warm air masses (tropical) have a high potential for thunderstorms (Figure 6).

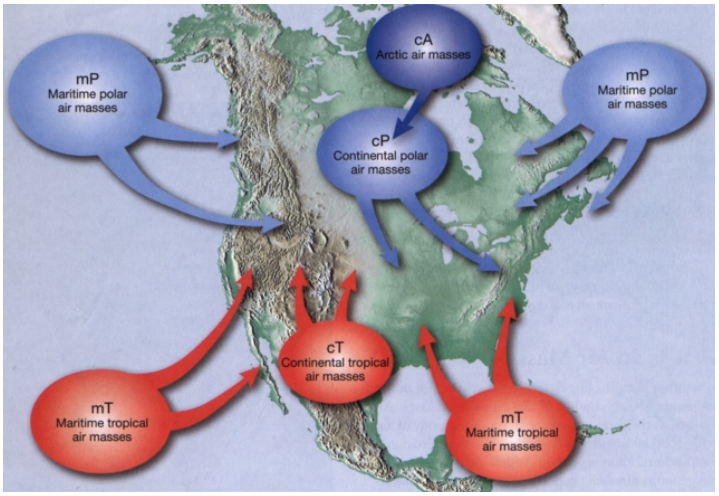


Figure 6: Air Mass Type and Location

As air masses move, they occasionally collide with one another. This is termed a front, of which there are four basic types; cold front, warm front, stationary front, and occluded front (AOPA, 2009) (Figure 7; Miller, 2002; Climate & Weather, 2010). During a cold front, cooler air is pushing warmer air out of the way due to the density of the air. Cold fronts consist of dense air, which makes the front stay towards the ground, sliding under the warmer air and forcing less dense air upwards. This upward flowing air results in rapidly decreasing air, creating clouds and leading to showers and thunderstorms when adequate moisture is present. While the front is passing, visibility will be poor, temperature and dew point will drop rapidly, and winds are variable and gusty, often resulting in violent weather. During a warm front, warm air slides over the cold air, displacing the cooler air. This type of front is typically less severe than a cold front, but can cause low ceilings and poor visibility. This is usually accompanied by light to moderate precipitation, most often in the form of drizzle, rain, sleet, or snow. Warm fronts generally bring low ceilings, rain, and poor visibility. This is in comparison to cold fronts that bring sudden storms, gusty winds, turbulence, and even hail or tornadoes, and can move twice as quickly. During a stationary front, two air masses meet but both are relatively equal, and neither displaces the other. This may result in a mixture of the effects caused by of cold fronts and warm fronts. During an occluded front, a fast moving cold air mass overtakes a slow moving warm air mass, and the leading edge of each occupies the same location. This results in weather similar to a warm front as it approaches, followed by weather from a cold front as it passes, resulting in a potentially severe weather pattern.

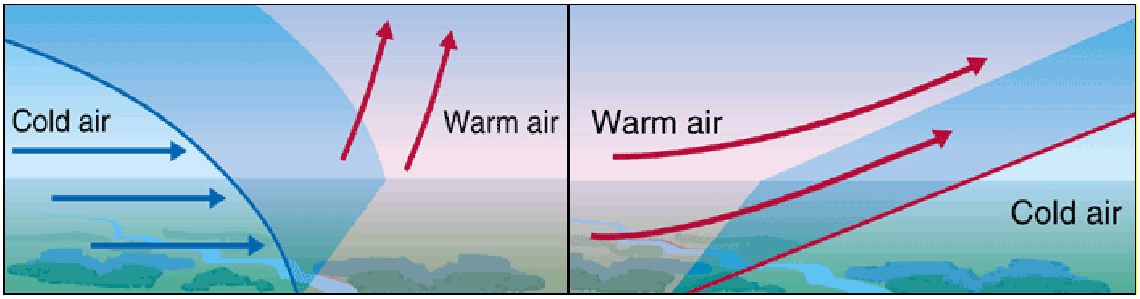


Figure 7: Cold Front (Left) and Warm Front (Right)

Although air can move singularly or in large masses, in general, air can be either stable or unstable. The stability of the air is the tendency for air to be displaced in the atmosphere. Stable air has a tendency to remain stationary and resist movement, while unstable air easily rises or falls. The air may become unstable in one of two ways. The air can be warmer than the surrounding air, causing it to rise (irrespective of saturation). Or, it can rise as a result of the saturation of the air. Generally, if rising air is colder and less dense than the surrounding air, it is stable. If the air is warmer and denser than the surrounding air, it tends to be unstable. Stable air results in generally calm weather, usually with poor visibility and precipitation. Unstable air results in generally poor weather conditions, often with turbulence, thunderstorms, and severe precipitation, but with good visibility.

2.2: Weather Phenomena

The basics of weather theory are important to understanding the weather phenomena that we are all familiar with in our daily lives but are paramount for an aviator to fully understand before a decision concerning his or her safety should be made. Pilots come into contact with common weather phenomena on a daily basis, including precipitation, thunderstorms, windshear, clouds, and turbulence. All of these may lead to decreased visibility and affect the safety and outcome of a flight.

Precipitation forms when there is excess moisture in the air and molecules are already saturated, leading to excess water vapor in the atmosphere being released. This excess water vapor can be released from clouds in either a solid or liquid form from clouds as rain, snow, ice (or similar variants) develop. Precipitation is distinguished from other types of weather phenomena in that the released water vapor must reach the ground. Different types of precipitation can lead to different changes in visibility. For example, rain reduces forward visibility, but visibility remains good both downward and on the sides. Visibility is typically referred to as a measure of the distance at which objects can be seen, and in aviation is referred to in statute miles (sm), or a typical mile.

Clouds are similar to precipitation in that they both are formed as a result of saturated air. Clouds are formed from heated water vapor at the surface of the earth rising and cooling to its dew point, therefore becoming saturated. A number of factors can be an impetus for the cooling process of rising air, all of which are due to the lifting action of the saturated air. There are several types of lifting mechanisms by which clouds are formed, and include orographic lifting, conventional lifting, convergence or frontal lifting, and radiative cooling. Orographic lifting occurs as a result of air that is forced to rise due to elevated land, conventional lifting occurs due to the heating of the warmer, lighter air at the ground surface interacting with the surrounding cooler air, convergence or conventional lifting occurs at the point where two air masses meet and interact, and radiative cooling occurs when the cooling and expulsion of heat from objects results in changes to temperature at different times of the day (radiative cooling).

Clouds are categorized according to their appearance, how they are formed, and the height at which their bases form (Lankford, 2001). Based on appearance, the clouds can be either curly (cirrus), spread out (stratus), or "heaped up" (cumulus), with the addition of a measure of high height (alto) or the attribute of being rainy (nimbo). The development of the clouds can be either horizontal (stratiform) or vertical (cumuliform). Stratiform clouds are associated with a stable air mass and consist of small water droplets. They typically have poor visibility, a widespread cloud mass, steady precipitation, and rime icing. Cumuliform clouds develop into rising mounds, domes, and towers, and are associated with an unstable air mass. They are characterized by good visibility, turbulence, localized cloud masses, showery precipitation, and clear icing. A third type is neither classified as horizontal or vertical but by consisting of high clouds (cirroform). Clouds can also be described by the height at which they form: low clouds (up to 6500 ft.), middle height (6500-20,000 ft.), high clouds (greater than 20,000 ft.), and clouds with vertical development (bases near surface and tops of cirrus). Four types of common clouds are presented in table 1 (Lankford, 2001; NASA, 2009) with a summary of all the previously discussed classifications regarding cloud type based on its development, appearance, and height, along with typical characteristics.

Table 1: Cloud Type Description

Cloud Type	Development	Visual Appearance	Height	Additional information
Stratus	Horizontal	Spread out	Low	Little to no turbulence, hazardous icing conditions if temp is at/below freezing, greatly reduced visibility if fog/precip present
Cumulus	Vertical	Heaped up	Low	Shallow layer of unstable air: some turbulence, no significant icing
Cumulonimbus	Vertical	Heaped up + high	High	Unstable air throughout, violent turbulence, usually icing
Cirrus		Curly	High	No signif icing; turbulence in dense, banded cirrus, composed of ice crystals; warm frnt sign

The lowest height at which clouds are present is the cloud ceiling. Therefore, if the first layer of visible clouds is a stratus mass at 5000 feet, the cloud ceiling would be 5000 feet. This cloud mass can also be categorized based on its coverage of the sky. Cloud coverage is the fraction of the sky that is obscured by clouds. It can be measured by eights of the sky. If the cloud cover is less than 1/8th covered in clouds, it is termed clear, if 1/8th to 2/8th of the sky is covered this is referred to as few, 3/8th to 4/8th of the sky is scattered, 5/8th to 7/8th is broken, and 8/8th is overcast. These general terms are frequently used in pilot briefings.

A weather phenomena resulting from unstable air is turbulence, which can result in sudden changes in altitude or attitude. The effect of turbulence can be categorized as light, moderate, severe, or extreme. This ranges from light turbulence indicating slight, erratic changes in altitude and/or attitude, to extreme turbulence, which leaves the aircraft structurally damaged, and nearly impossible to control. Turbulence has three main causes. Mechanical turbulence is caused by topography, or changes in wind due to buildings, mountains, or any other man made or natural features. A second type, wind shear, is the result of winds from different directions making contact with one another to create movement of the wind in various directions. This type results in sudden, drastic changes in windspeed over a short time period, and can be quite severe. A third type, convective turbulence is caused by the lifting action of air, and is often associated with thunderstorms.

Thunderstorms are the result of either a cold front pushing into a warmer air mass with a lot of moisture (frontal thunderstorm), daytime heating (air mass thunderstorm), or as a result of a storm inside a solid mass (embedded thunderstorm; AOPA, 2009). In each of these cases, an initial lifting mechanism is required. This can occur due to a number of factors: a frontal surface, sloping terrain, or surface heating (Lankford, 2001). This initial phase is the cumulus stage and is associated with cumulus clouds and large updrafts that may extend from the surface to several thousand feet (Figure 7a). Another requirement is unstable air, leading to the formation of the cumulus clouds. The reason for the occurrence of thunderstorms is the need to reduce the heat in the air. The updrafts that occur during this first stage results in cool air that was cooled from the rising air, that was previously warmer than the surrounding air.

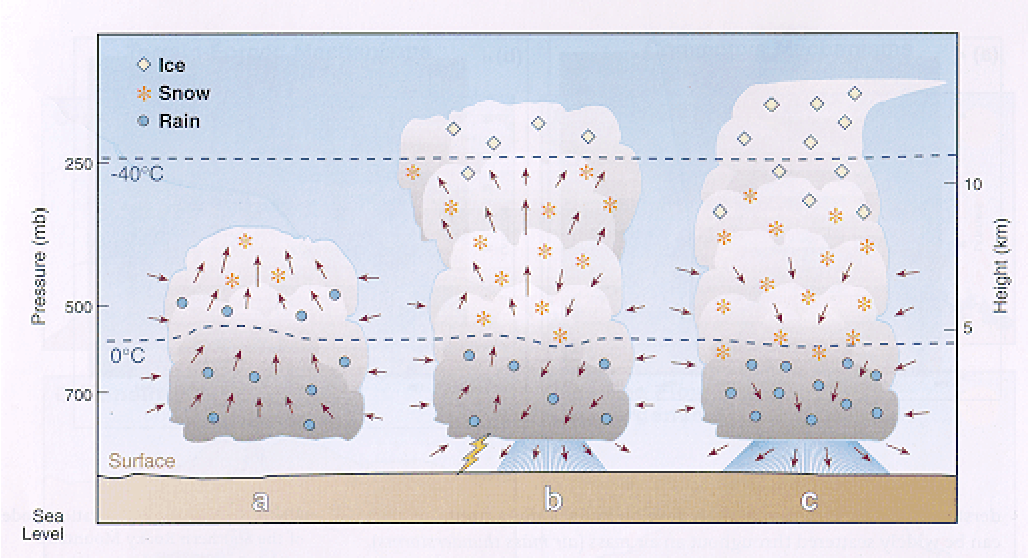


Figure 8: Lifecycle of a Thunderstorm

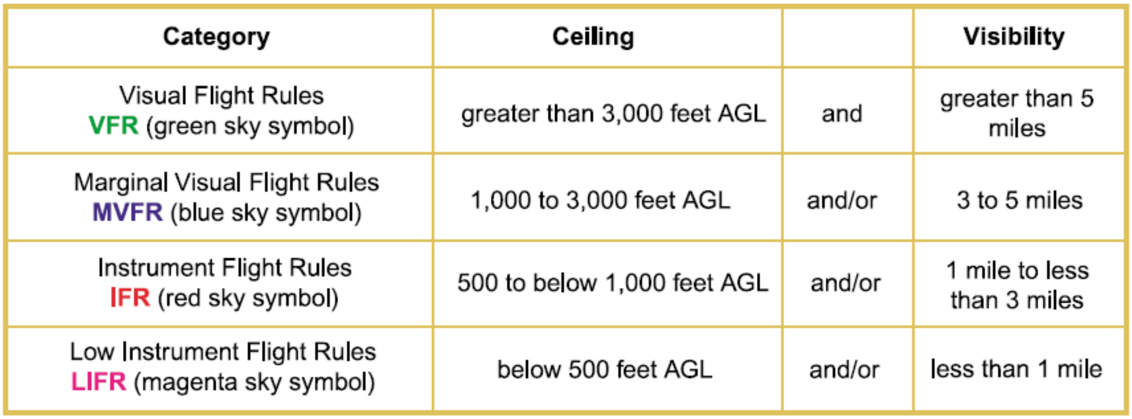
The second phase in the thunderstorm lifecycle is the mature phase, as characterized by a difference in the temperature, and an increase in the weight of water drops and ice particles. The weight of this falling precipitation reduces the upward motion of the air, and results in an increased downward motion of air, known as a downdraft (Figure 7b). This stage is the most intense, and is characterized by the visible electrical discharge (lightening), and the expanding gasses that occur with the lightening (thunder). This stage officially begins when rain falls, and ends when the supply of warm, humid updrafts to fuel the thunderstorm is cut off, and the rains stop. The last stage of the lifecycle is the dissipation stage, characterized by weak downdrafts and stratiform clouds (Figure 7c; Figure 8).

2.3: Weather Classifications

Meteorologists take into account how weather interacts to create ceiling and visibility, the two main factors used to determine weather classification. Table 2 (Parson,

2010) describes the weather minimums based on flight type for both ceiling and visibility. For pilots without an instrument rating, a minimum of marginal VFR (MVFR) is required for flight. This means that the ceiling must be at a minimum of 1,000 feet with three miles of visibility. However, flying into MVFR is generally considered ill advised by many pilots, who personally require VFR minimums to fly. VFR requires a 3,000 foot ceiling and five or more miles of visibility. IFR and low IFR (LIFR) are only permissible for instrument pilots, who may fly in weather with a ceiling of less than 1,000 feet and less than three miles of visibility.

Table 2: Weather Minimums by Flight Type



Category	Ceiling		Visibility
Visual Flight Rules **VFR** (green sky symbol)	greater than 3,000 feet AGL	and	greater than 5 miles
Marginal Visual Flight Rules **MVFR** (blue sky symbol)	1,000 to 3,000 feet AGL	and/or	3 to 5 miles
Instrument Flight Rules **IFR** (red sky symbol)	500 to below 1,000 feet AGL	and/or	1 mile to less than 3 miles
Low Instrument Flight Rules **LIFR** (magenta sky symbol)	below 500 feet AGL	and/or	less than 1 mile

2.3 Weather Sources

Weather information is available both pre-flight and in-flight. There are four main types of weather observations, surface, upper air, radar and satellite (Flight Standards Service, 2003). Surface weather observations are compiled from one of any number of ground stations, automated weather observing systems (AWOS), and automated surface observing systems (ASOS). Upper air observations are collected from either pilot reports of in-flight weather (PIREPs) or radiosone, the weather observations made from sounding balloons. Radar observations are of three types, NEXRAD, also known as Doppler radar, terminal radar, and Federal Aviation Administration (FAA) airport surveillance radar. Satellite observations are a fourth type of observation, and weather information is received from two weather stations that orbit over the earth near the equator.

The four types of observations provide different ways to capture weather information in order to compile a complete weather picture. The surface observations provide local weather conditions concerning wind, visibility, weather phenomena, dew point/temperature spread, and altimeter readings. The upper air observations provide information about what pilots will encounter at an altitude of up to 10,000 feet, including temperature, humidity, pressure, wind, and weather phenomena, resulting in nearly real time reports from other pilots. Radar observations provide the pilot with information about wind, precipitation, and general weather movement. In addition to radar, satellite observations provide a "big picture" view of weather patterns. These four information sources can be combined to provide forecasters with a way to describe and predict current and future weather changes.

Pilots receive weather information both pre-flight and in-flight. Prior to takeoff, pilots receive this information in the form of a weather briefing. There are three main briefing formats, an outlook, abbreviated, or standard briefing. Outlook briefings are used primarily to determine weather condition for a flight from one to several days in advance. An abbreviated briefing can be helpful to update a previous standard briefing with more current weather information. A standard briefing (Table 3) is a full briefing that contains any relevant information about adverse conditions in the area, recommendations concerning VFR flight, an overview of weather movements, detailed current conditions (ceiling, visibility, temperature, winds), en route forecasts based on the flight plan, a destination forecast, winds and temperature aloft, Notices to Airmen (NOTAM), Air Traffic Control (ATC) delays, and any other pertinent information.

Table 3: Standard Weather Briefing Components

Standard Weather Briefing:
• Adverse conditions • VFR flight not recommended • Synopsis • Current conditions • En route forecast • Destination forecast • Winds aloft • Notices to airmen (NOTAM) • ATC (Air Traffic Control) delays

Weather briefings come in either a printed or graphical format. Printed formats contain weather information about a specific airport or weather station including METARs, TAFs, FTs, or SAs. METAR is the Aviation Routine Weather Report, and includes standard information about current weather conditions at a particular airport. A TAF is the Terminal Area Forecast, which forecasts or predicts future weather conditions at a specific airport. FTs or Terminal Forecasts provide a forecast of weather information about a particular airport (terminal). The SA is a Surface Area report that describes the weather on the surface at an airport weather station or other weather facility. These formats generally provide information concerning ceiling, visibility, and winds.

PIREPs are Pilot Reports that give nearly real time weather reports that include weather information and any significant weather phenomena from pilots who have just flown through the area. These reports can be used to augment other weather sources that might be outdated or incorrect and provide for a more accurate weather picture in a specific area. NOTAM is the Notice to Airmen that may be added to the end of the SA or given separately, and include information about updates or changes to the normal procedures at an airport, with runway changes or closures.   RAREPs or Radar Weather Reports are reports issued by radar stations concerning precipitation and thunderstorms in an area.

Radar is typically used for the separation of aircraft, but can also be used to determine general weather system trends. Radar works by broadcasting a small pulse of microwave energy into several directions, which bounces back to the station when it refracts off an object. This provides information about precipitation, but is limited in that it will only detect liquid forms of precipitation and therefore will not detect all types of clouds. Radar information is typically gathered from either an approach tower or a control tower. Approach towers give weather information immediately for relatively small areas, in comparison to control towers that provide information for more extended areas, using WARP (Weather and Radar Processor) to compile information from one or more NEXRAD (Next Generation Radar) sites. Both Approach and Control towers display precipitation based on a numbered system that indicates the severity of the precipitation, from light to extreme (light precipitation is only available at approach towers).

The graphical form of weather information from radar is the radar summary chart, which provides information about the location and strength of precipitation. Other reports that provide information in a graphical format are the Surface Analysis Charts, Weather Depiction Chart, and the low level significant weather chart. The Surface Analysis chart provides weather information about atmospheric pressure patterns, frontal movements, and areas of high and low pressure systems that have already occurred. The Weather Depiction Chart is a simplified Surface Analysis Chart that contains information on prior frontal activity and allows the pilot to quickly scan for weather trends. All three of these methods provide the weather information for current weather trends, which means that once the weather data is reported, the weather information is already outdated. In comparison, the low level significant weather chart is the forecasted or predicted weather for a region.

Pilots typically tend to use more than just the weather briefing from the FAA to prepare for a flight. Many private companies offer computerized services tailored to pilots, and mainstream weather sources (ie: weather channel) can be useful for creating a full picture of the weather. These pre-flight weather sources are supplemented by updated in-flight weather. Weather information should be constantly updated to reflect any changes to weather systems that may occur once a pilot is in flight. This in-flight information is available is in several formats, either graphically using one of a number of GPS-type services (Datalink, handheld GPS devices), or through weather reports that are broadcasted through radio frequencies (Flight Watch or PIREPs), or through contact with ATC controllers.

The knowledge of weather systems and the interpretation of the sources of weather information provide a big picture view that assists the pilot in making weather-related decisions concerning his or her ability to fly. How this information is used is dependent upon both individual and group factors. These factors lead to a unique interpretation of weather information, which is then used when determining how to best utilize this interpreted information. The combination of weather information and individual and group factors result in a decision concerning any weather the pilot might experience.

CHAPTER 3: INDIVIDUAL FACTORS

3.1: Expertise

Expertise is defined as "the skill of an expert, or one who is skillful and well-informed in some specific field (Parson, 2010)." Optimally, experience is correlated with certain measures of knowledge or skill and represents the qualifications of the pilot. Measures of pilot experience have typically focused on certain pilot and flight experience variables, such as total flight hours, recent flight hours, instrument time, ratings and certificates. Other pilot-related factors have been explored as well, including demographic variables such as age or gender, risk-taking measures such as previous accident involvement (discussed in section 3.5) and countless others. Although the conclusion that these measures can be used to determine pilot proficiency is a reasonable one, some measures are much more accurate determinants of expertise than others. Global measures of expertise do not directly relate to more specific measures of expertise. This means that the time spent in the aircraft does not directly relate to the pilot's ability to identify weather cues. More specific measures, rather than total flight hours, have been found to be more accurate in the prediction of expertise.

3.1.1: Measures of Experience

Measures of flight experience have been investigated by a number of researchers who have focused on both flight time and licensure. Flight time can be measured in a number of ways, as total flight hours, recent flight hours, pilot in command (PIC) hours, cross country hours, or IFR hours. Measures of licensure include both the number and type of ratings and certificates achieved by the pilot. Both have been explored extensively in aviation studies.

A recent study by Detwiler et al (2008) used GA data gathered by the National Transportation Safety Board (NTSB) and the FAA to compare VFR into IMC (VFR-IMC) accidents to non-VFR into IMC accidents. The median flight hours of the accident pilots showed that all measures of flight hours were lower for VFR-IMC pilots except time as pilot in command (PIC). This includes fewer total flight hours (731 vs. 758), and fewer simulated (10 vs. 46) and actual (62.5 vs. 76) instrument time. Recent flight hours, however, showed little difference for the previous 30 (10 vs. 12) and 90 (23 vs. 29) days. The authors also found that the VFR into IMC accidents had a significantly higher percentage of pilots with only a private pilot's license (69.5% vs. 51.2%), less instrument ratings (33% vs. 45.8%), and less certificates (two or more: 10.9% vs. 9.3%). In relation to the flight hours, these ratings and certificate measures are not particularly surprising, given the connection between instrument time and instrument ratings (Table 4: reference for summary information).

Table 4: Summary of Expertise Variables

Study, description	Type of study	Sample size	Flight Hours	Ratings/Certificates
Detwiler et al. (2008) VFR into IMC vs. non VFR-IMC accidents	NTSB/FAA accident database 1990-2004	N=609 VFR-IMC N=15,825 non-VFR-IMC	**Total:** 731 vs. 758 hrs. **Last 30 (90) days:** 10 (23) vs. 12 (29) hrs. **Instrument (simulated):** 10 vs. 46 hrs. **Instrument (actual)**: 62.5 vs. 76 hrs.	**PPL:** 69.5% vs. 51.2% **IR:** 33% vs. 45.8% **1:** 89.1% vs. 80.7% **2:** 9.8% vs. 16.5%
Goh & Wiegmann (2001) VFR into IMC vs. non VFR-IMC accidents	NTSB/FAA accident database 1990 - 1997	N= 409 VFR-IMC N=409 non-VFR-IMC chosen w/ stratified sampling method	**Total:** 580 vs. 900 hrs.	**PPL/student only:** 76% vs. 58% **IR:** 32% vs. 46%
NTSB (1989) VFR into IMC vs. GA accident pilots* or all active GA pilots'	NTSB/FAA accident database 1983 - 1987	N= 361 VFR-IMC accidents N= 10,818 GA accident pilots* N= active GA pilots in 1984'	**<100 hrs:** 9% vs. 14%* **100-199 hrs**: 17% vs. 9.5%* **Total**: 52% had less than 500 hrs. **Instrument time:** 57% less than 20 hrs.	**IR:** 23% vs. 70%

*VFR into IMC studies are listed first in the results sections

These results are generally supported by earlier studies such Goh & Wiegmann (2001) and the NTSB (1989) report on VFR into IMC accidents. Both of these studies utilized the same database maintained by the NTSB/FAA but focused on different time periods. The study by Goh & Wiegmann was quite similar to that of Detwiler et al (2008). The authors found a similar link between less flight hours for VFR-IMC pilots (580 vs. 900 hrs.), less advanced ratings (PPL or student license only: 76% vs. 58%), and fewer instrument ratings (32% vs. 46%). The findings from the NTSB report also indicated a lower rate of instrument ratings as compared to the total GA population (23% vs. 70%). For GA VFR into IMC accident pilots, the data indicate a low rate of total flight hours (52% had less than 500 hrs.) and instrument time (57% less than 20 hrs.).

This low rate of total flight hours has been quantified in the overall aviation population by Hunter (1995a, 1995b) in a survey mailed to a random sample of aviation pilots. Results from over 6,700 pilots concluded that private pilots flew approximately 30 hours per year (median), which translates to roughly 2.5 hours per month. Similar rates were found in New Zealand by O'Hare & Chalamers (1995) with 22 hours as the median total hours per month for private pilots. The authors found that the majority of these pilots flew very few hours, with a few GA pilots flying quite frequently.

This lack of experience has been linked with an increased tendency of pilots to enter and continue through deteriorated weather conditions. Studies have found that the less flight hours a pilot had, the longer and farther the pilot tended to fly into the weather (O'Hare & Chalamers, 1999). This finding was replicated in Burian et al (2000), who found pilots in the 25th percentile of experience continued into deteriorated weather further than pilots in the 75th percentile of experience.

These results lead us to the conclusion that in comparison to other types of pilots, GA pilots typically have limited overall and recent flight hours, and less certificates and ratings. This is particularly true of GA pilots involved in VFR into IMC accidents or incidents (not including recent flight time, which is common to all GA pilots). This lack of experience has been linked to an increased likelihood of VFR only pilots entering adverse weather conditions, leading to the conclusion that these pilots may lack the experience necessary to identify important weather cues. In addition to these flight experience variables, other characteristics can be used to indicate exceptional expertise. Certain characteristics of experts are common across different professions and areas of expertise. These characteristics can be used to determine the coping mechanisms used by experts and how performance as differs from (and is usually superior to) those with less experience.

3.1.2: Expert Characteristics

The differences between experts and novices have been explored in a number of widely varying domains, including physics (Chi, Feltovich, & Glaser, 1981), chess (de Groot, 1978), auditing (Bedard, 1991; Bonner & Pennington, 1991), medicine (Elstein, Shulman, & Spraka, 1990), firefighting (Klein, Orasanu, & Calderwood, 1993), sports (Abernathy, 1990), air traffic control (Redding & Cannon, 1991), and GA pre-flight decision making (Wiggins et al, 2002). The common thread among experts in different domains is that experts exhibit certain characteristics that enable superior performance. Although many individual differences exist between experts, the following can be seen as characteristics or generalizations about experts that indicate their expertise in a given field.

One of the first generalizations that can be made about experts is that their representation of information, both the content and organization, differs from novices. It is generally believed that experts rely upon an organized body of conceptual and procedural knowledge that can be accessed rapidly during decision making. Experts organize this information into categories that are typically semantically or principle-based, while novices focus more on surface features (Glaser & Chi, 1988). The organization of this information determines "the quality, completeness, and coherence of the internal representation, which in turn determines the efficiency of further thinking" (Glaser, 1987, p. 84). This organization of information is refined over time, due to both chance experiences and deliberate practice. The repetition and fine-tuning process leads to an enhanced and improved representation of the information, which, in turn, leads to several benefits.

The first benefit is an improved ability to determine the typicality of the situation. The individual's experience with certain tasks allows the expert to understand how the situation typically plays out, which makes identification of abnormal situations quicker and easier. When these non-typical situations occur, the expert has the advantage of being able to look to a wide knowledge base of previously encountered situations. The pattern matching ability is termed pattern recognition, and provides the expert with the ability to quickly and efficiently match the situation to previously encountered situations. This allows the expert to determine what the problem is and how to solve it.

Improvements in knowledge organization have also been linked to improvements in performance. One by-product of the better organization of knowledge is improved memory recall, leading to the ability to retrieve information quickly and efficiently. This increased ability to retrieve information is also associated with a decrease in cognitive effort, in part due to the increased automaticity of the task. Automaticity is one characteristic of expertise originally thought to be a product of pattern recognition and direct access of action (Glaser, 1987). However, this conclusion has been revised, and now proposes that expertise is instead characterized by actions that are contextually based and intuitive (Fitts & Posner, 1967; Simon & Chase, 1973), which involves planning, reasoning, and anticipation (Benner, 1984; Dreyfus & Dreyfus, 1986).

The improvements in memory recall lead us to question if the differences between experts and novices involve task-specific competencies or if expertise is the result of improvements in general functioning. Ericsson & Lehmann (1996) investigated the general mental competencies of experts and novices, and made three main conclusions based on their findings. First, measures of basic mental capabilities are not valid predictors of whether an individual attains an expert level of performance. Second, the area for which the individual is an expert is typically very domain specific with little transfer to other areas. Third, any beneficial attributes of the individual are usually acquired during training, and are not due to superior general functioning. These conclusions lead to a rejection of a general memory ability, and instead lend to the opinion that expert memory performance is the result of domain-specific experience. Improved performance is therefore particular to the type of activity only, due to what is termed skilled memory (Chase & Ericsson, 1982).

The theory of skilled memory proposes that an individual rapidly encodes material in long-term memory (LTM) by associating it with pre-existing knowledge and patterns instead of relying on what is typically used in the situation, which is known as working memory (WM or short term memory). Therefore, the inherent limitation of WM (a limited amount of information that can be processed at one time) is circumvented by utilizing long-term memory (LTM) in some of the tasks that would have originally relied on WM (Kelley, 1964). This leads to superior functioning that exceeds the functioning typical of WM.

An additional difference between expertise levels is the strategy employed when solving a problem. Experts typically tend to take more time when they are first given the problem in order to fully understand the situation and the inherent constraints (Glaser & Chi, 1988). They use this time to build a mental representation of the task, which is later used to solve the problem. In contrast, novices are more worried about how to solve the problem, potentially missing some of the information that they could have gathered had they fully explored the problem before attempting to solve it.

A similar theme can be found in the differences between experts and novices in their scan patterns and information gathering. Results from studies examining the scan patterns of experts and novices (Bellenkes, Wickens, & Kramer, 1997; Kazarskis, Stehwien, Hickox, Aretz, & Wickens, 2001) have generally concluded that experts typically had shorter dwell times (time spent looking at instruments) and more total fixations. This leads to the conclusion that experts were able to determine what information they needed in a specific situation, and make a rapid assessment of that information during the scan of their flight instruments. This conclusion is also supported by research on pre-flight information gathering. One such study investigated a computerized system with weather and flight information on a number of hierarchically linked screens (Wiggins et al, 2002). Results showed a more focused pattern of information gathering for expert pilots than for novices. The experts spent more time on specific screens of interest, in comparison to novices who spent less time on a larger number of screens. The successively viewed screens also support the conclusion for a lack of focused search pattern. Experts viewed screens more often that were related to one another (such as two screens depicting weather information), while novices viewed successively un-related screens (such as weather information followed by aircraft capabilities).

In relation to piloting skill, all these general characteristics lead to improvements in the organization of knowledge required during piloting. This does not mean the expert pilot has superior memory or intelligence, rather it is through their extensive experience that they have managed to circumnavigate the requirements for working memory, resulting in superior performance. Their expertise also leads to the ability to recognize when the flight controls are not at their typical levels, and to identify when differences occur. When problems do arise, the pilot has a large base of knowledge concerning similar problems and solutions for those problems they have utilized (both successfully and unsuccessfully) in the past. He or she is then able to match certain characteristics of the present abnormal situation with other situations encountered in the past, leading to quicker and more efficient problem solving. Each of these characteristics for which the expert may possess leads to improvements in the outcome of any situation.

In addition to the previously mentioned general characteristics, research by Kochan, Jensen, Chubb & Hunter (1997) and Jensen (1995) added a few notable attributes specific to the expert pilot. The first is that the pilot is constantly working to improve his or her already superior skill, due in part to an extreme motivation to learn all that is possible about aviation. The expert aviator is also able to maintain an extreme focus, but this focus can be switched when new information requires. The expert is exceptionally aware of all that is going on around him or her with respect to the flight, such as other aircraft, weather patterns, and any terrain enroute. This aviator possesses extreme skill in problem solving, is easily able to come up with contingency plans, and does so as part of normal flight procedure. The expert is also an excellent communicator and keenly aware of his or her own limitations and the limitations of his or her aircraft.

Although the benefits of experience can have a large impact on performance, it is not always the case. A review on expert decision making found that expert judgments were typically unrelated to the amount of experience of the decision maker (Chase & Simon, 1973), and highly variable among a group of experts (Ericsson, Krampe & Tesch-Romer, 1993; Shanteau & Stewart, 1992). Instead, as previously mentioned with respect to memory differences, it is believed that expertise is domain limited and highly specific to particular aspects of the task. This task-specific experience has been found to be a better predictor of performance, but only moderately so (Bedard, 1991). When the expertise is not task specific, or when new tasks are encountered, this can reduce the expert to novice level performance.

Other limitations of experts include excessive confidence, and the ability to push themselves beyond the optimal stopping point. They may also fail to recall certain features of a situation and overlook details. It is also possible that due to their reliance on a wide memory bank of typical problems, they might have trouble adapting to any changes that do not fit inside one of the previously patterned situations. Any of these potential limitations may be a detriment to the benefits of a rich body of experience that can be looked to by an expert. The benefits from experience do not necessarily improve performance in a linear fashion, as would typically be thought. Therefore, it is important to understand how pilots develop expertise and how and when performance benefits result.

3.1.3 Development of Expertise

The differences between experts and novices have been widely studied and have typically been found to be quite clear. How the novice progresses to an expert has been theorized to be just as clear cut, and has been explored in a number of models. The foremost of the models that tracks the development of expertise includes those by Fitts & Posner (1967), Anderson (1982, 1983), and Dreyfus & Dreyfus (1986a). Unlike the progression in these models, certain types of performance that are infrequently used do not necessarily follow this linear progression towards expertise. Therefore, to determine the progression of expertise, the area of interest and the frequency of use of the information and/or skills should be taken into account. These models provide the basis for determining how and when certain types of expertise are gained, and the markers of performance for each level of expertise.

Fitts & Posner (1967) created a three stage model to describe the progression of expertise. In their first stage, the early or cognitive stage, the individual often develops a rudimentary approximation of the skill. This stage typically involves the novice attending to many cues in the environment because they are not yet aware of what cues to focus on. During this phase, new habits are added to a collection of old habits. The second stage, the intermediate or associative stage, is marked by the use of these newer habits, which are then incorporated into patterns of behavior. Errors are gradually reduced through this process of trial and error. The third and final stage, the autonomous phase, is where the skill becomes an extension of the individual, and very little thought is required to complete the task. The individual is now able to complete many tasks at once, because this new automaticity allows the expert to be involved in other cognitive and/or perceptual processes. This skill continues to improve in the form of both increased speed and accuracy for the task, but the performance benefits level off, and now gradually improve with time.

Anderson's model of skill acquisition (1982, 1983) posits a three stage model that is based on the model by Fitts & Posner (1967). The first stage is the declarative stage, where the individual learns facts about the process, and due to their inexperience, the individual must rehearse these facts in working memory to be able to utilize them later on. The second phase is the knowledge compilation phase, where the knowledge of the necessary facts (declarative information) is transferred to knowledge of the procedures, or the knowledge of how to use the facts. The last phase, the procedural phase, involves a 'tuning' of the information to ensure that it is applied in the proper situations. This fine-tuning process is also accompanied by an additional benefit, a speeding up of the processing of information.

In an additional model, Dreyfus and Dreyfus (1986) designed a five stage process for the development of expertise. The first of the five stages is the novice stage, where the individual has very minimal, if any, experience in the chosen field. The novice is limited to very basic rules and facts, and this knowledge is context-free. In the second stage, the advanced beginner stage, the individual has improved their understanding to include contextual information. This is due to their experience with real-world situations, and their knowledge of more advanced rules and facts. The third stage is competence, where the lack of context becomes problematic in a real-world environment. The individual therefore learns to see the situation in terms of the most important facts that can be used to determine goals and plans. The fourth stage is proficiency, where the individual is able to understand the typicality of the situation. No deliberate decision-making process happens and the individual recognizes similarities from past events that lead to anticipation and action for the present event. The final stage is expertise, which is marked by an intuitive grasp of the situation. The expert no longer makes conscious decisions, rather the individual's skill becomes an extension of their self.

All of these models can be categorized according to three distinct phases. The beginning phase is characterized by the individual learning facts and information about the skill they will be acquiring, with the individual being highly error prone during this phase. The intermediate phase(s) include(s) a re-organization of the information, with an improved understanding of the relationship between the information and its application. The last phase consists of an increase in speed and efficiency, with the process becoming more automatic, with the expert being able to simultaneously perform other tasks.

The problem with these models is that the gradual progression from novice to expert does not apply to every area where expertise can be attained. In aviation for example, piloting skill, or the ability to handle the controls of the plane, can be thought of as a gradual progression. This skill is consistently practiced each time the pilot flies. This is not the case in other areas of flight where pilots need to gain experience. In the area of weather decision making, the pilot may not be continually faced with experiences where they can improve their knowledge and understanding of weather conditions. This may lead one pilot with 300 hours to make the same bad decision that a pilot with only 200 flight hours would make in the same situation. The pilot with 1,000 hours may have the same amount of experience and interaction with adverse weather situations as the pilot with 200 hours, providing the same level of knowledge and expertise for an adverse weather situation.

A special vulnerability in aviation is thought to exist around the 100 to 300 hour mark (Craig, 2001; Olsen & Rasmussen, 1989; Telfer, 1989). At this point in their flight careers, pilots have just attained their pilots' license and no longer have the experience of a flight instructor to rely on as they did during training with that instructor in the cockpit. The pilot is now responsible for their own decisions in the cockpit, but without the relevant practical experience of more seasoned aviators. This period of trial and error will lead to an increase in the knowledge base of the pilot but may lead to several opportunities for the pilot to make an error during the decision process.

In total, this journey from novice to expert has been found in some fields to require up to ten years. Expertise in areas with gradual progression, such as chess, have been found to require a minimum of 10 years or more of full-time experience (Ericsson & Lehman, 1996), and this requirement was found to be consistent in a number of other domains, such as performance in sports, as well as the arts and sciences (Simon & Chase, 1973). Expertise in aviation has been quantified in a number of studies as 1,000 total flight hours (Wiggins & O'Hare, 1995; 2003). As previously mentioned, measuring expertise in aviation should be based on a number of variables, and 1,000 total flight hours may result in expert piloting skills, but not expert judgment in weather situations. Therefore, many studies have instead focused on more specific measures of experience to determine weather decision making, such as cross-country flight hours (Wiggins & O'Hare, 1995) or recent flight experience (Wiegmann, Goh, & O'Hare, 2001).

In the case of weather decision making, exposure to different weather situations can be a factor in weather decision making. Training that introduces and teaches pilots the importance of weather cues has provided beneficial results (Wiggins & O'Hare, 2003b). This might be particularly useful to pilots because the success of any training program requires feedback in order to be effective. Feedback results in cognitive processes that are more efficient and eventually automatic (Bloom, 1985; Hayes, 1981). In environments with poor or nonexistent feedback, learning will be delayed or nonexistent. Therefore, a flight environment where the pilot is exposed to and taught about different weather conditions will result in a pilot that is much more prepared when faced with adverse weather than a pilot who did not have this experience.

3.1.4: Situation Assessment

Situation Assessment can be defined as the process used to achieve, acquire, and maintain a state of knowledge (situation awareness). Therefore, the process used to acquire the information about the knowledge is situation awareness, and the actual knowledge that has been acquired is situation assessment. Goh & Wiegmann (2001b) extended this concept of situation assessment to aviation to describe the trend of inexperienced GA pilots entering adverse weather conditions (Goh & Wiegmann, 2001b). They proposed that the inexperience of the pilots involved in these accidents could be attributed to poor awareness of the hazards involved in adverse weather situations, an inability to recognize and/or interpret changes in weather conditions, particularly gradually changing conditions. According to their theory, the situation assessment hypothesis, pilots risk entering and/or pressing on into adverse weather because they do not accurately identify the weather conditions. This is due to a lack of knowledge about weather conditions. Therefore, it can be stated that if the pilot was aware of the weather conditions, the pilot would not have entered the adverse weather and would not have been involved in VFR into IMC accidents.

Evidence to support this theory comes from an experiment by the same authors who measured pilot's estimations of weather condition in addition to a number of other factors (self-appraisal of judgment and skill, frequency of risk taking behavior, confidence) during a simulated cross country flight (Goh & Wiegmann, 2001b). The authors found that pilots with more accurate assessments of the visibility conditions chose to divert from the adverse weather more frequently than those pilots with less accurate assessments of the weather conditions.

3.2 Decision Making

Decision making theories can be broken down into different schools of thought that have evolved over time to become more applicable to both the decision maker and the decision task. The earliest models of decision making were created to describe the choices of an idealized decision maker. According to this theory, the decision maker decided on a choice by selecting one option from a number of alternatives in order to determine the optimal response (Wickens & Hollands, 2000). This is termed the classical model of decision making (CDM). Later CDM theories sought to describe why people make less than optimal decisions due to the use of heuristics and biases.

The second major school of thought is the information processing model of decision making. This model looks at how information is processed by the human, and seeks to describe and understand the potential limitations that can occur at each stage. The third is the naturalistic decision model, which looks at the decision making of an experienced decision maker in a realistic environment with little time to make a decision. Improvements of this model from earlier models of decision making describe the decision making process in the environment which the decision typically takes place.

3.1.1: Classical Decision Theory

Classical Decision Theory refers to the collection of models of uncertainty, risk, and utility that dictate the optimal choice from many alternate options. The optimal choice is defined by an underlying model, and choice is determined by an explicit rule (Beach &

Lipshitz, 1993). Early decision making theories can be broken down into two main models that describe decision making, rational (also termed normative models), and descriptive models. These models either prescribe what an idealized decision maker should do in a specific circumstance (rational or normative models), or describe what people typically do, but only in a limited number of decision making situations (descriptive models). The earlier decision making theories are typically defined by three phases. The first phase involves the acquisition and perception of information or cues relevant to the decision. Next, the decision maker generates and selects hypotheses about the meaning of cues in relation to the current state. Finally, a choice is selected based on the inferred state and the costs and values of different outcomes.

The earlier rational or normative model revolves around the utility, or overall value of each choice, and the utility of each choice by the decision maker. There are three main theories that dominate the rational models. The first is multiattribute theory, which employs a utility function to describe the many attributes or features of a single object. The two other rational theories are applicable in a gambling type situation in which the decision maker has more than one option with an associated probability and importance (expected value theory) and a situation where the decision maker relies on the subjective probability and value for each option to make their decision (subjective expected utility theory).

The descriptive decision making models evolved based on a few key characteristics of how decision makers actually makes a decision, and in doing so violates some of the principles of rational decision making. The first is that the rational consideration of all potential outcomes and options is too time consuming for the decision maker. Therefore, people generally rely on simpler means of selecting an option from a number of choices.

One way that people tend to do this is to employ satisficing, which is the practice of choosing the option that is good enough for the current situation, instead of expending additional energy to determine the best possible option.

In addition to satisficing, people typically employ heuristics or biases, a simplifying strategy that makes it easier for the decision maker to choose one of many alternatives. Heuristics and biases are typically very effective at reducing workload, and in the majority of situations tend to be beneficial, but can also lead to a number of systematic flaws or problems. The limitations that result from heuristics and biases are specific to certain stages in decision making. For example, the problems common when receiving and using cues are different than those found during either the process of hypothesis generation, evaluation, and selection, or action selection (Wickens, Lee, Liu, Gordon-Becker, 2004).

Limitations that occur during the process of receiving and using cues include the ability to attend to only a limited number of cues, an exaggeration of the importance of the first cues and an inattention to later cues, an added importance to cues that are more salient (bright, loud, flashy, centrally located), an overweighing of unreliable cues, and a difficulty in processing negative evidence (absence of symptoms). Limitations occurring during hypothesis generation, evaluation and selection are the ability to generate a limited number of hypotheses, an increase in hypotheses that have been considered recently or frequently (available hypotheses selected first), an increase in generation of hypotheses when the pattern of cues "looks like" (is representative of) an example situation, an overconfidence in hypotheses that are brought into working memory, an underutilization of cues once a hypothesis has been generated or chosen (cognitive tunneling), and the use of additional cues only to confirm hypotheses, even when disconfirming information may be more diagnostic. Limitations occurring during action selection include a limitation in the number of action plans that can be utilized in working memory, additional availability effects in the selection of outcomes, and the influence of the presentation of information on a person's judgment (framing bias). Both judgment, and certain types of framing, such as sunk cost, will be discussed in more detail in the motivation section. Taken as a whole, these limitations can be used to understand the human decision making process and can be useful in understanding behavior in a variety of contexts.

3.1.2 Information Processing Model

The information-processing model was developed by Wickens (1984; 1987) to describe humans' decision making process. As can be seen in figure 9 (FAA Human Factors Web Course), the decision maker first retrieves sensory information (stimuli) from the environment through the senses. This representation of information is held very briefly in the short-term sensory store, and then is integrated to form elements that become meaningful through the process of perception. This information is recognized through a matching process that utilizes previous memories that are stored in long-term memory, which interacts with information that is currently being viewed in the environment (working memory). Once the individual has identified the object, there are two options, they may either delay the response or make a choice concerning a course of action. If the individual chooses to delay the response, the memory will be stored temporarily in working memory, the short term memory for objects and events (a few minutes per example), and is also referred to as short term memory. If the object is held in working memory, a number of potential outcomes may occur. A response may be generated in a relatively short time frame, the information may be forgotten, or the information may be transferred to long-term memory. If a response is the chosen course of action, the response is executed, and information concerning the chosen response is provided to the individual through the use of feedback. The process of feedback can assist the individual in understanding the impact of the response, and provides insight that the individual can use again in similar circumstances. This information about a response to the present situation (and many past situations) make up the knowledge stored in long term memory.

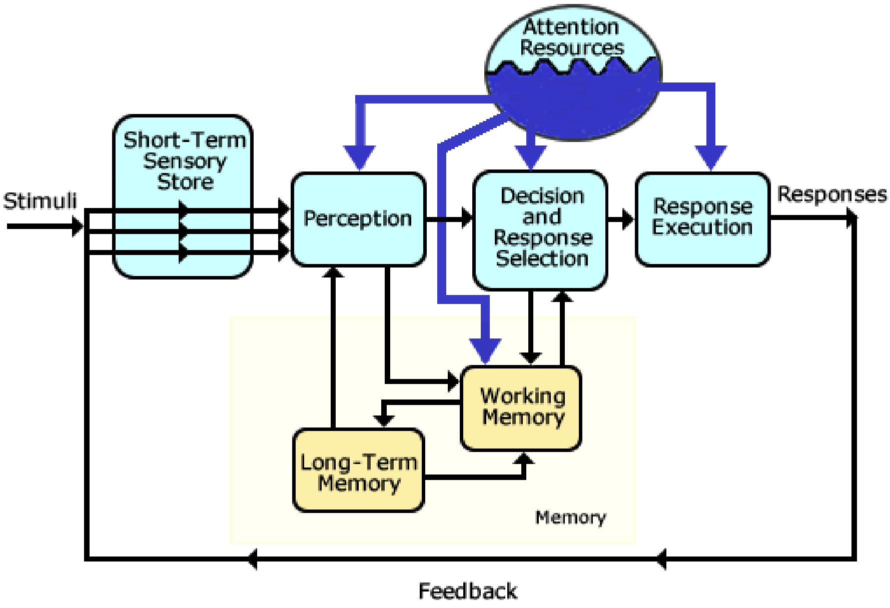


Figure 9: Wickens' Model of Human Information Processing

During any of these stages, problems or breakdowns in the decision making process can occur. For example, early on, certain elements in the environment with attention-seeking properties receive more attention than others elements. Therefore, if there are two objects and one has any combination of a number of certain attributes that draw attention to that object (bright, shiny, loud, etcetera), that object will be more likely to be attended to than one with less attention grabbing properties. This results in the individual either completely ignoring the second object, or overvaluing the information received from that first object. The attention resources category, which represents the limited mental capacity of the human to attend and coordinate to their actions, can lead to problems as well. The individual is only able to attend to a limited number of inputs at a given time. If there are more inputs than the individual can manage, potentially useful information or inputs are lost. Additional problems can occur due to limitations in working memory. The problems typically found as a result of working memory are related to its limited capacity, which leads additional information that cannot be processed to either be forgotten or remembered incorrectly. Many more problems can occur during this process, see Classic Decision Theory, 3.1.1.

Each stage in this process is the result of three attributes, the capacity of the stage, the length of time it can hold information, and how that information is represented in memory. The capacity of its stage is mediated by the sensory modality. There are many modalities for which information can be received, it can be visual, auditory, tactile, or through the sense of smell. It is believed that more information can be processed if it is received through multiple modalities. Therefore, an individual can process more information if it is retrieved through both auditory and tactile channels. However, similar modalities can interfere with the understanding of the information, leading to decrements in one or both of the inputs. The second attribute, the length of time the information can be held, is demonstrated through the use of working memory, which represents the time until information is forgotten. The final attribute is how the information is coded or represented in memory. For example, the representation of information in the short term sensory store can be coded in terms of its physical features.

3.1.3: Naturalistic Decision Making

Decision making research evolved from the early theories characterized by quantifiable probabilities to decision making in situations involving outcomes with unknown probabilities. This next phase of decision making is characterized by decisions made in a complex, dynamic, real world environment filled with uncertainty, termed naturalistic decision making (NDM). NDM asks how "experienced people, working as individuals or groups in dynamic, uncertain, and often fast-paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organization in which they operate," (Zsambok, 1997, p.5). This definition emphasizes the importance of context, where the decision maker cannot rely solely on routine activity or thinking.

NDM is characterized by eight characteristics: an ill structured problem, an uncertain dynamic environment, shifting, ill-defined competing goals, an action/feedback loop, time stresses, high stakes, multiple players, and organizational goals and norms (Klein, Orasanu, & Calderwood, 1993). The ill-structured problem requires the decision maker to generate hypotheses about what is currently happening and develop appropriate options. The uncertain dynamic environment results in an imperfect environment with incomplete information that is dynamic and changing. The shifting, ill-defined goals result in many, potentially conflicting, goals that may be the result of several purposes. The action/feedback loop provides many opportunities for self-correction by the decision maker that may occur during an action sequence, requiring a sequence of events, each with its own feedback mechanism. Time stresses occur in realistic environments and may result in exhaustion and loss of concentration on the task at hand. High stakes are typical of situations that occur in non-laboratory settings where the impact of the decision may have life threatening results. Multiple players represent a situation that involves more than one person, whether it is in a team setting or involves the interaction of any person with the decision maker. Organizational goals and norms represent the values, goals, and rules that are a necessary part of interacting with any organization.

Earlier publications on NDM (such as Klein et al, 1993) characterize expertise as a factor secondary to the eight characteristics. Later works on NDM (Zsambok, 1997; Pruitt et al, 1997) emphasize the role of the decision makers' experience on the decision making. More specifically, Zsambok (1997, p.4) stated, "NDM is the way people use their experience to make decisions in field settings." Pruitt et al (1997) furthered this viewpoint when they stated that the primary factor defining NDM studies is expertise. Many (e.g., Lipshitz et al, 2001) believe that experience can be equated to the setting where the decision occurs. Therefore, the context shapes decisions through the constraints and affordances that the situation provides. In addition to both context and expertise, NDM is characterized by a more extensive pre-decision making process. The additional time spent prior to making the decision is used to completely understand and assess the situation, working forward from what is currently known rather than focusing on how to achieve a desired end state. This is in comparison to a typical CDM situation, where the focus is on assessing potential options to determine how to achieve a specific goal.

Recognition Primed Decision Making

Although there are many models that fall within the NDM framework, the 'prototypical' NDM model is Recognition Primed Decision Making (RPDM) (Lipshitz et al, 2001). In comparison to the more complex, non-routine tasks typically found in NDM, the RPDM model describes more simple, routine tasks that can be easily matched to previous situations. RPDM was developed after the authors (Klein, Calderwood, & Clinton-Cirocco, 1986; Klein, Calderwood, & Macgregor, 1989) conducted cognitive task analyses (CTA) of expert commanders in order to understand how firefighters handle time pressure and uncertainty when making decisions. Contrary to what they expected to find, and most surprising, was that the firefighters rarely generated more than one option when making decisions. Rather, they employ satisficing (Simon, 1955), or employing the first option that generates a 'good enough' solution, rather than taking the time to find the best option. The focus of RPDM is on an experienced decision maker, who has the ability to generate a reasonably good first option. When the first option generated does not prove to be adequate for the situation, alternate options are generated and evaluated serially to determine their applicability and acceptability for the current situation.

The most important (and most recognizable) feature of RPDM is that during this process of evaluating alternatives, the current situation is 'matched' to previous situations that the decision maker has experienced. These situations and the corresponding decisions are stored in memory and each time the decision maker comes across a similar situation those previous experiences are drawn from memory. This situation assessment phase is just one part of RPDM. The other half is the mental simulation portion (Klein, 1993) which is used to evaluate potential courses of action.

There are three separate forms of RPDM, which vary from very simple to more complex. In the simplest course of action, the decision maker assesses the situation and executes the initial option identified (Lipshitz, 2001). If no simple match can be found, the second and third variations are employed, and mental simulation is utilized. The second variation is a story building strategy used to mentally simulate the events that occur just prior to the situation (Pennington & Hastie, 1993; Klein & Crandall, 1995; as cited in Lipshitz et al, 2001). The third variation is termed progressive deepening, where mental simulation is used to picture the course of action, to see if the strategy has the intended consequences or any unintended consequences (De Groot, 1965; cited in Lipshitz et al, 2001).

For the majority of the time, recognitional strategies are used (versus the more time consuming analytical strategies). Klein (1993) summarized the findings of five studies in separate domains, from firefighting to tank platoon leaders to design engineers. The results show that this is true for even difficult cases. The more experienced decision makers showed higher rates of recognitional decisions. For example, in a study comparing novice and expert fireground commanders, 58% of experts versus 46% of the novices used recognitional decisions. However, this rate is much lower than experts with over 20 years of experience who were found to use recognition-based in 80% of decisions. This rate also varies based on task type. For decision makers in strategic positions, analytical-based strategies are more frequently used. In general, recognitional decision making occur more frequently when the decision maker has more time pressure, is more experienced, and deals with less stable conditions. In relation to pilot decision making, pilots typically use pattern matching first, and then if no 'match' is available, they then utilize the analytical methods (Barnett, Stokes, Wickens, et al, 1987). The more experience a pilot has, the larger the body of knowledge from which to draw, and therefore, more recognitional based decision making occurs.

3.1.4: Aeronautical Decision Making/Judgment

Aeronautical decision making (ADM) and judgment have been defined differently over the years, and are generally thought to be related but not identical. ADM encompasses the decision making process that is utilized by pilots during flight (Harris, 1994). Some researchers (Lester, Diehl, & Buch, 1985) consider it to be the final stage in pilot judgment in which the pilot must choose one from a number of potential options. In contrast, judgment was previously thought of as a relatively stable trait found in the best aviators, either as an instinctive quality they possessed, or as an ability that was developed and refined as a result of many years of experience in a variety of flight situations (Buch, 1984). These conclusions have been disproven, mainly due to a number of successful attempts at improving pilot judgment in a variety of flight training environments for newly licensed pilots (Diehl, 1990). As researchers have gained a greater understanding of how to train judgment, there has also been an increased understanding of pilot judgment.

The earliest well-documented research on pilot judgment was a study conducted by Jensen & Benel (1977) which sought to investigate the current state of knowledge of judgment (in a number of different fields) with the aim to apply that knowledge to aviation. From their review of the relevant literature, the authors defined judgment as a two part process consisting first of the ability to discriminate and determine all information relevant to the task at hand, and the ability to respond with motivation appropriate to the situation. The first part of this process consists of relatively simple perceptual judgments, such as determining weather conditions at a particular airport prior to takeoff. The second involves cognitive judgments in which the pilot determines how to best utilize the previously gathered information of the first stage during the selection phase. During the second phase when the pilot is making a pre-flight go/no-go decision, he or she will take into account not only the weather conditions (perceived during the first stage), but also a number of other factors, which could potentially include personal values, an emotional response, and social pressures.

Given this definition and explanation of judgment, evidence that supports the importance of this topic comes from the study by Jensen & Benel (1977). The basis of their research is the analysis of five years of accident data (1970-74) that revealed 80% of the accidents were attributable to pilot error. Of that percentage, faulty pilot judgment errors occurred much more frequently in fatal accidents (52%) than non-fatal accidents (35%). This research prompted a number of studies focused on faulty decision making and pilot judgment in order to determine if training could lead to improvements in judgment and subsequently, performance.

Research by Berlin, Gruber, Holmes, Jensen, Lau, Mills & O'Kane (1982b) added to this body of knowledge by creating a manual for the student and instructor in order to determine the effectiveness and practicality of pilot judgment training. These manuals were later updated, but were mainly focused on the three main parts of the decision making process: the pilot, the environment, and the aircraft. In a typical flight situation, the pilot should be aware of how these three main concepts influence his or her performance in the cockpit. This includes recent sleep patterns, stress, and physical ailments (the pilot), the weather fronts and adverse weather conditions in the area (the environment), and the capabilities of the plane in various situations and conditions (the aircraft).

The manuals were used to demonstrate judgment concepts through situational exercises, the five hazardous thought patterns of pilots, the modes of pilot error (six ways), the poor judgment chain, and the use of the judgment profile. Examples of the hazardous thought patterns that typically lead to accidents were given (anti-authority, external control, impulsivity, invulnerability, macho), with ways to improve upon these behaviors for a variety of flight situations. The judgment profile was used to determine the capabilities and limitations of each pilot taking the test. Additionally, the judgment chain was discussed in order to demonstrate how errors generally occur in a sequence, and methods the pilot can use to break the chain.

Berlin, Gruber, Holmes, Jensen, Lau, Mills & O'Kane (1982a), Buch (1984), Telfer & Ashman (1986), and Diehl & Lester (1987) tested versions of these manuals in a variety of flight training programs (Diehl, 1990). Results showed significant improvements in correct decisions for the group of pilots receiving judgment training in all studies. The benefits of this training varied from a 9% to 46% improvement over the control condition, who received no judgment training. These results were typically the result of an observational flight, during which pilot judgment was evaluated. In one such study, an experimenter posed as a passenger was tasked with determining if the newly-licensed pilot performed any of the twelve behaviors that constituted "good judgment" (Diehl & Lester, 1987, pg. 6-7). These behaviors typically include items that covered pilot activities that occur during all stages of a VFR flight.

The wide range of improvements between the judgment studies can mainly be attributed to a number of factors surrounding the flight training and both student and instructor characteristics. The study that found the largest improvements over a control group was a highly structured program with extremely motivated students and instructors at a military flight school, a 46% improvement over a control group. The lowest rate of improvements, 9%, was found in an unstructured program with less motivated instructors who received no monetary incentive for performance, with students who were recreational pilots with no plans to become professional pilots.

Other methods have been used to evaluate pilot decision making, such as questionnaires utilizing scenarios in which the pilot is asked to choose the best option from a number of potential outcomes. There have also been various models utilizing acronyms (e.g., DECIDE, PAVE, S-D-R-V) that have been taught to pilots for use in-flight during aviation situations or crises. For example, the DECIDE model stands for Detect, Estimate, Choose, Identify, Do, and Evaluate. The pilots were taught to use this acronym during any situation requiring "use of their cognitive abilities." This model was tested during a simulated flight in which the pilot was presented with three unexpected conditions, failure of the attitude indicator, carburetor icing, and deterioration of weather conditions. The results of using the tool was not overly positive, but the author (Jensen, 1988) concluded that it showed great promise as a tool for teaching judgment to inexperienced pilots. An additional focus of ADM studies includes the level of expertise of the pilot, and the use of other models of decision making, such as naturalistic and recognition-primed decision making.

3.4: Motivation

It is perplexing to learn that intentional VFR into IMC accounts for 76% of all accidents (Goh & Wiegmann, 2001). This high rate of deliberate VFR into IMC encounters suggests that the vast majority of GA weather accidents are intentional, whether due to the actions or inactions of the pilot. However, a separate study instead suggests that only 24% of weather-related encounters are due to motivation, and 52% of the incidents or accidents are due to a lack of appreciation of the weather (Shappell et al, 2010). The large disparity between these two studies about the number of accidents attributed to deliberate VFR into IMC raises questions about the nature of the pilot's motivation to continue into IMC and any differences in the two studies that could be affecting the results.

The first study (Goh & Wiegmann, 2001) was based on the analysis of the NTSB and FAA database. These authors compared VFR into IMC accident data to GA accidents not caused by VFR into IMC (all other GA accidents). Motivation of the pilots in this study was determined by the NTSB investigators determination, and their assigned categorization (continued, inadvertent, attempted, performed, intentional, initiated, encountered, and unclassified) of the type of VFR into IMC. In these studies "unintentional" VFR into IMC was represented by the inadvertent and encountered categories and "intentional" VFR into IMC was classified by all other categories.

As is unfortunately the case, VFR into IMC accidents frequently result in fatalities (80%), which leaves no survivors or cockpit voice records to provide the needed information to aid during the accident investigation. This is a common issue for GA accident investigations due to the smaller, lower-technology airplanes flown in GA (as compared to commercial aviation for example) that do not come equipped with recording equipment, such as the black box. This, and the high fatality rate of VFR into IMC accidents, makes it extremely challenging, if even possible, to determine the cause(s) of these accidents. Therefore, data surrounding this type of accident can be missing or incomplete, not giving a full picture of the occurrences that preceded the crash or the motivation of the pilot. This results in a severe limitation in the conclusions that can be drawn from captured information and the generalizability of the results to the greater GA population.

The second study (Shappell et al, 2010) was conducted in order to understand weather-related GA encounters based on interviews with pilots who had recently had a weather-related incident or accident. The 25 weather interviews were conducted with pilots who requested a weather-related flight assist from Air Traffic Control (ATC). These weather encounters included not only VFR into IMC, but also many other types of weather encounters such as thunderstorms, icing, turbulence, and marginal VFR (MVFR).

The pilots in this study were contacted after the incident/accident and later interviewed to determine what factors played a role, and what methods they used to survive the incident or accident. At the time the pilots were interviewed, they had already gone through proceedings with the FAA to determine if any actions were to be taken against them. Therefore, the pilots did not have a legal or procedural reason to modify information concerning their weather encounter in any way, and all participation was voluntary.

One of the major limitations is the generalizability of the results in this study. Although information received during interviews is usually as thorough and as accurate as possible when investigating accidents and incidents, the small sample size, the method of recruitment, and the requirement for voluntary participation, could have resulted in a sample of pilots unlike those found in the GA accident data (NTSB/FAA). The first major factor is the method of recruitment. As mentioned earlier, the pilot participants had contacted ATC for assistance when encountering problems in-flight. Therefore, it can be reasoned that pilots who failed to contact ATC on that one occasion (which resulted in an accident/incident) may demonstrate a pattern of certain behavior that typically lead to weather and/or other types of adverse flight events. These pilots must also have agreed to be interviewed for this study, resulting in a self-selection of pilots who were willing to discuss the event with the authors. Additionally, the small sample sized results in a reduced ability to generalize the results to the larger GA population.

Although no definitive answer as to the true number of motivation-related VFR into IMC accidents exist, we do know that motivation does have an impact on VFR into IMC and other types of weather-related incidents and accidents. Although these studies vary widely in their estimation of the number of motivation-related accidents, even at the lower figure, motivation still has a large impact on GA aviators. What is lacking is an insight into the reasons why VFR into IMC, particularly motivation-based accidents, occurs. The following sections explore some of the motivation-based theories that have been applied to aviation situations to describe motivation in the cockpit, including sunk cost, prospect theory, and plan continuation errors.

3.4.1: Sunk Cost

Sunk cost describes the psychological process where as more time and effort are invested into achieving a goal, an individual will be more likely to expend additional resources in an effort to try to meet that goal (Arkes & Blumer, 1985). This has been described as "throwing good money after bad," meaning that any additional efforts an individual makes to achieve the goal would not be taken had a prior investment not been made. This change in behavior due to the initial investment has been shown by the authors in several everyday situations, including theatre tickets, investment strategies, and vacation and dinner plans. Examples of this theory are exemplified in everyday decisions, such as choosing to go to a football game in bad weather because the ticket had already been purchased, or continuing to put money into a rundown apartment that requires more money to fix it up than it's worth. Sunk cost has been implicated in more extreme situations, such as Congress continuing to fund a project that is worth less than the additional investment it will require to finish (e.g., the Tennessee-Tombigbee Waterway project, 1981; cited in Arkes & Blumer, 1985, p. 124-125).

The theory of sunk cost has also been applied to aviation weather decision making. In this context, a pilot who encounters weather 15 minutes into an hour-long flight will be less likely to continue the flight than the same pilot who encounters weather after 45 minutes into the flight. According to this theory, the pilot that had invested more time and money into the hour flight (encountering weather after 45 minutes) would turn around less quickly than the pilot who encountered weather earlier (after 15 minutes). The pilot would consider the time and money expended for this flight a sunk cost, with the goal of minimizing potential losses. Although this theory has been applied to other situations successfully, and seems logical for the present problem, the findings indicate contradictory results from what would be expected according to sunk cost.

One study in support of sunk cost theory was conducted by O'Hare, Owen & Wiegmann (2001b). During the first part of their study, the authors analyzed a database of cross country GA flights to determine if there was a difference in crashes due to human factors (termed "controllable exposure to risk" or CER) and those resulting primarily from non-human related factors, or mechanical failures (termed "externally driven" or ED). The authors found that there were two types of CER, or human driven accidents, weather-related and those due to loss of control. The loss of control accidents typically occurred earlier on in the flight (49.7 nm) than either the human or mechanical related. However, the interesting difference is between the weather-related accidents, which are generally attributed to the pilot entering adverse weather conditions, and the equipment-related factors, which should occur randomly at unexpected points throughout the flight. The weather-related accidents occurred much later in the flight (92.5 nm) than the ED (78.1 nm).

The second part of the study involved two simulated experimental flights on a laptop computer, a "scud-running flight," where visibility and cloud ceiling deteriorated over the course of the flight, requiring the pilot to fly close to the ground to continue the flight. The second, VFR on top, indicates a situation that required the pilot to fly above the clouds in order to continue the flight. Weather in the 'VFR on top' flight deteriorated twice the distance into the scenario than the scud-running scenario, resulting in a 44% continuance rate versus a 17% continuance rate. The results from the first part of the study, the database analyses, indicate that weather accidents occur further into a flight than would randomly occur. These results are supported by the findings from the second part of the study which indicate that when pilots enter deteriorated weather further into a flight, they continue more frequently.

An additional study by many of the same authors (Wiegmann, Goh & O'Hare, 2001a) tested the sunk cost hypothesis during a simulated flight using a flight simulator. For this study, the authors tested this theory using two scenarios that were identical except for the time into the flight the weather was encountered. In the first condition, the pilot encountered the weather 15 minutes into a one-hour flight, as compared to 45 minutes into the same flight. The authors found that those pilots who encountered the weather earlier flew longer and farther into the weather than the pilots who encountered the weather later. This finding contradicted previously studies, but was later followed by, and supported later studies with similar results.

A study by Saxton (2008) investigated motivation as measured by financial incentive (base payment plus the option of an additional "bonus" in external motivation condition), and time into scenario before encountering deteriorating weather. The deteriorated weather occurred at either 25% of the distance into the flight, or 75% of the distance into the flight (12 vs. 30 minutes into a 42 minute flight). Irrespective of the financial incentive, Saxton found that pilots who encountered weather later into the scenario continued further than those who encountered the weather earlier. A suggested explanation for these results is that the pilots who had received the deteriorated weather earlier decided to "take a look" in order to explain the contradictory weather information that they had received in the pre-flight briefing. The contradictory results of these three studies lead to the conclusion that sunk cost theory is not supported in aviation VFR into IMC scenarios. This is particularly the case for the more recent studies that used flight simulators to determine this effect on aviators' decision making.

3.4.2: Prospect Theory

Prospect theory addresses the relationship between risk and outcome. Kahneman & Tversky (1979; 1984) state that people do not think of a decision in terms of the final or intended outcome, but rather in terms of prospective gains or losses from some reference point. The authors summarize the human response to a decision in terms of a value function. This function prescribes a steeper curve for losses than for gains, meaning that a loss will have a greater impact than would a gain of the same magnitude. Therefore, this theory implies that people are inherently risk averse when looking at a situation from a gains perspective and risk seeking when looking at the situation from a loss perspective.

Both the reference point and the frame from which the situation is viewed affect the decision outcome. The reference point is the starting point which the individual views the situation, and can be affected or changed based on the framing, or the viewpoint of judging the situation. A frame can be either positive or negative, the positive highlighting the advantages and the negative highlighting the disadvantages for a set of options. For example, a pilot on his way to meet friends for the weekend who encounters weather below VFR minimums can frame the continue/divert decision in one of two ways. He may emphasize the anticipated loss, such as wasted money (fuel, aircraft rental), and time lost (negative frame), or he may emphasize the anticipated benefits, such as not jeopardizing his life or his aircraft (positive frame).

This frame can be, and has been, experimentally manipulated. A pilot can be assigned a frame that describes the information they are given in either a positive or negative light, highlighting either the positive or negative aspects of a given situation. During an experiment by O'Hare & Smitheram (1995), pilots were asked to make a decision about whether they would continue or divert during a hypothetical flight scenario. They received the basic initial information about the flight scenario, either positive or negative information concerning the flight (experimental frame), and were asked to make a decision about whether they would choose to continue the flight. The authors found that the experimentally manipulated frame (the positive or negative information given to the pilots) was found to be effective in changing the pilots continue/divert decision. Therefore, the pilots who received information about the flight that emphasized the positive aspects of diverting chose to divert more frequently, and the pilot who received information emphasizing the negative aspects diverted less frequently. These results do not remain consistent when applied to a pilot's natural decision frame in a real world setting. Therefore, a pilot who was assigned the positive frame experimentally will be much more cautious in weather situations than a pilot who would normally frame the decision using a positive frame.

3.4.3: Other Theories

Plan Continuation Errors

Additional theories have been used to describe the motivational aspects of pilot decision making. The investigation of what is now termed plan continuation errors (PCE's) resulted from a trend found in Part 121 (scheduled air carrier) aviation accidents first examined by the NTSB (NTSB, 1994). Of the decision errors in the analysis, approximately

65% of the flights were found to have similar characteristics. These flights could be identified by the pilot's decision to continue with an original course of action despite the presence of information that would have resulted in the evaluation and selection of an alternate course of action (Orasanu, Burian, Fischer, Martin, & McCoy, 2000). Later analyses were performed to determine the accuracy of this trend and its incidence in other types of aviation. Results showed that PCE's occurred in approximately 63% of GA accidents (Orasanu et al, 2001; cited in McCoy & Mickunas, 2000). Additionally, these accidents were the result of an average of seven separate errors by the pilot.

Additional research into the cause of PCE's detail a more accurate picture of the pilot who commits this type of error. This pilot tends to fixate on the original course of action, blinding them to the changing situation and the need for an update in their outdated plan. This leads to the conclusion that PCE's typically refer to an error of omission, a failure to take a necessary action, rather than an error of commission, resulting from an improper action. Therefore, PCE's are predominantly found later into the flight, during the approach and landing phases (Orasanu, Martin, & Davidson, 2001). These events are quite similar to, and have commonalities between, incidents and accidents involving "get-there-it is" or "pressing on," indicating that the pilot continued past a point in the flight where it would have been optimal to either divert or change their plan. This description of PCE's is quite applicable to VFR into IMC accidents, which results in the pilot failing to take action to prevent flying into adverse weather, or failing to change course once adverse weather is encountered.

3.5: Risk Management

Although the definition of risk varies by source, risk can generally be defined as a combination of the severity of outcome and the likelihood that an injury will result. One field that studies how individuals manage risk is risk management, and is common to any situation involving inherent risk. The literature on risk suggests there are two parts to any decision involving risk, the perception of risk and the tolerance for that risk (Hunter, 2002). During the first part of the process, risk perception (or hazard assessment), the individual will perceive certain elements of the risk and correctly determine that a risk exists, or they may fail to notice it entirely. The second part involves risk tolerance, which has been described as a relatively stable level of risk that an individual will tolerate over time and across different situations, potentially similar to a personality trait. A study looking to understand the relationship between risk perception and risk tolerance found that the two are related but separate constructs. Hunter (2000b) found that the pilot's risk tolerance was negatively related to risk perception. Therefore, the tolerance of higher levels of risk was associated with a lower perception of risk.

During a VFR into IMC situation problems may arise during either the risk perception or risk tolerance stages. During risk perception, the pilot may incorrectly determine that the weather conditions have deteriorated. Or, it is possible that they have correctly determined the weather condition during the first stage, and instead made an unsafe decision when choosing to continue despite the adverse weather. The problems that arise may result from any of a number of factors, such as a lack of experience during risk perception, or an overconfidence in personal abilities, leading to risk tolerance that places the pilot in unsafe situations. Although risk tolerance and risk perception seem to be quite similar, these two factors have been found to be only slightly related, suggesting separate constructs (Hunter, 2002).

3.5.1: Risk Perception

Risk perception is "the subjective assessment of the probability of a specified type of accident happening and how concerned we are with the consequences. [Including] … the evaluations of the probability as well as the consequences of a negative outcome" (Sjoberg, Moen, & Rundmo, 2004, p.13). Improper risk perception may be attributable to improper risk and/or hazard perception. To differentiate the two, a hazard is the source of danger and is classified according to severity of the outcome, and risk is the probability of suffering a loss (O'Hare, 1990). An individual may properly understand the potential sources of danger for a given situation (hazard), but fail to understand the level of risk involved for that hazard.

Risk can be considered either objective or subjective. Objective risk is the actual risk in a situation, as determined by experts in the field of interest. Subjective risk is the risk perceived by the individual and consequently, may differ quite substantially from the objective risk. This difference between what the individual perceives and the actual, objective, level of risk can be due to a number of factors, either knowledge or motivated-related, and the result of either conscious or unconscious processes. Some researchers believe that risk cannot be categorized using this sweeping generalization. They believe that risk is inherently subjective and specific to the individual rather than a measure that can be broadly applied to any situation, irrespective of the individual involved.

O'Hare (1990) tested both risk and hazard assessment when developing and utilizing a questionnaire tailored to the GA pilot population. The Aeronautical Risk Judgment Questionnaire (ARJQ) measures hazard perception, risk awareness and pilots' perception of their abilities and risk-taking propensity (O'Hare, 1990). The hazard awareness measures were used to determine if the pilot could correctly determine, and was aware of, the likelihood of certain types of accidents and incidents (based on causal factors, phases of flight, and fatality levels). Risk awareness measures were used to determine the pilots' knowledge of the level of risk associated with a number of aviation and non-aviation related activities. Additional measures were also explored using this questionnaire. Personal invulnerability was tested by asking the likelihood of becoming involved in a number of specific types of accidents, both for the individual pilot taking the test, and for any other GA pilot. The difference between these two questions was computed to determine a measure of personal invulnerability. A higher score, or greater difference, denoted a pilot who believes they have a much less chance of becoming involved in an accident than other GA pilots. Self-judgment was determined by the pilot rating their level of skill and judgment in comparison to a pilot of similar experience. In addition to the questionnaires, a subsection of the pilots completed a computerized one-hour simulated flight with three in-flight decision points where the pilot was asked to rate their ability to handle the situation, and their level of uncertainty, confidence, and the degree of risk involved in their decision.

The findings from this study indicate that pilots have a relatively low level of hazard and risk awareness. The mean hazard estimate rating for the pilot error category was significantly lower than the NTSB figures (57.4% vs. 79.9%), meaning that pilots underestimated the involvement of human error in aviation accidents. However the accuracy of pilots improved when they were asked about the occurrence of weather-related accidents and incidents.

The self-appraisal of abilities and judgment for pilots is generally optimistic, and the most unrealistic in young, inexperienced pilots. This optimistic bias can be seen not only in younger pilots, but pilots of any age who have just received their license. Younger pilots rated their skill and ability as highly as did older pilots, and newly licensed pilots rate themselves as highly as pilots who have had their license for much longer. Comparatively, measures of personal invulnerability and risk were lowest in older pilots. Judgment and skill were correlated, but not with pilot's rating of their willingness to take risks during flying. The author notes that this finding of individuals believing that they are better than the average (in terms of both skill and safety) is common and paralleled in other fields, such as driving.

The simulated flight revealed additional insights to the information gained from the questionnaire. The flight consisted of deteriorating weather and several decision points where the pilot was asked if they wanted to continue with the flight. Those pilots who chose to continue with the simulated flight past the decision points were more likely to be younger and had more flight hours than the pilots who diverted (in comparison to the lower recent flight hours for questionnaire pilots). These pilots rated themselves as more willing to take risks, had higher scores on measures of personal invulnerability, and had less knowledge of the phases of flight when accidents occur. Overall, these results are disparaging. They provide a look at GA pilots who often underestimate the risks in the aviation context and overestimate their own ability, skill, and judgment in handling those risks.

An additional study by O'Hare focusing on GA pilot risk taking found that pilots who continued into adverse weather during a simulated flight differed in risk perception than those who diverted (O'Hare & Wiegmann, 2003). The pilots who diverted from the adverse weather rated the risk of continuing as higher than those pilots who chose to continue. However, those pilots who chose to continue rated continuing as the more risky alternative (compared to diverting), but still chose to continue. These findings are similar to the results found by Hunter (2002) during the evaluation of a risk perception and risk tolerance questionnaire. His results also concluded that pilots with a low perception of risk were involved in more hazardous events, but the significance of this effect was low. This is significant because his study involved a wide range of pilots (backgrounds, licenses, flight hours) who visited the FAA homepage.

To understand why risks are not perceived accurately it is important to understand the perception of risk. The inaccurate perception of risk, also considered the difference between objective and subjective measures of the risk, can be considered due to a number of factors, including characteristics of the activity and the method of processing the risk (Fischhoff et al, 1978; Slovic & Weber, 2002). Fischhoff and colleagues (1978) explored the relationship between the perceived benefit of various activities (nuclear power, bicycles, general aviation, x-rays, etc) and risk. They asked participants to rate each activity on a seven-point scale for each of the nine characteristics listed in figure 10 (Fischhoff et al, 1988). These characteristics include the voluntariness of the activity, the impact of an adverse effect (chronic/catastrophic; severity), the emotional reaction of the individual to the event (common/dread), the state of knowledge about the risk (to science), the immediacy of the effect, the controllability of the result, and the newness of the activity.

The figure below displays the average ratings for two of the 30 total items rated. On the left (solid line) is the x-ray, a relatively well-known and acceptable risk that can be compared with a technology considered to have an unacceptable level of risk, nuclear power (dashed line).

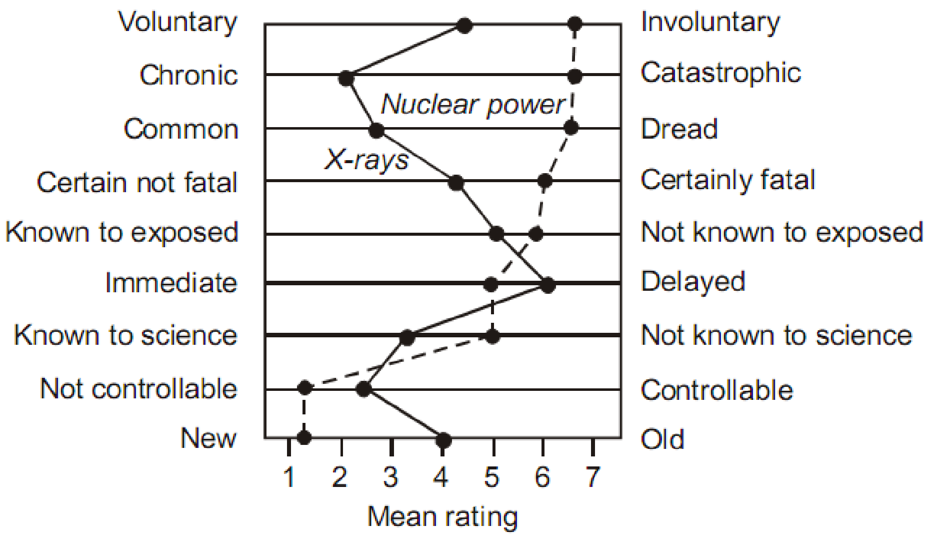


Figure 10: Characteristics of Perceived Risk for Nuclear Power and X-rays across Nine Risk Characteristics

Results from rating the 30 activities/technologies indicate that perceived risk is correlated with dread and severity. This was not true for the other seven characteristics, including voluntariness, which was previously believed (although not experimentally proven) to influence the perception of risk. Other studies have explored this factor and found opposing results (Rotter, 1954, 1966, 1975).

The voluntariness of an activity has also been referred to as locus of control. There is often a tendency for people who think that they are in control of a situation to perceive less risk in a situation, and are therefore more likely to take more frequent and larger risks.

The locus of control scale can be determined by the degree to which the individual believes that the outcome of a situation is under their personal control (Rotter, 1966). The individual can be either internally or externally oriented. This internal versus external orientation can vary based on the individual and the specifics of the situation. On one end of the locus of control scale is the internally oriented individual who believes that most situations are under their personal control. This is in contrast to someone who is externally oriented and believes that most situations in life are out of their control. Pilots typically fall into this first category, and this type of individual who actively tries to manage their situation has higher scores on measures of internal locus of control (Hunter, 2002a; Wichman & Ball, 1983). For example, someone who is driving a car would perceive the risk of driving to be much smaller than if they were a passenger in the same situation (McKenna, 1993). This illusion of control can lead to taking additional risk and an unrealistic and overly optimistic viewpoint of the situation.

An additional factor that influences risk is the overall benefit of the activity, which decreased the perceived risk. Therefore, as the severity of an adverse effect and the dread associated with that activity increased, the perception of risk associated with that activity increased. The common-dread factor is defined as "a risk that people have learned to live with and can think about reasonably calmly, or it is one that people have great dread for on the level of a gut reaction." This emotional aspect of the perception of risk is also described by Slovic & Weber (2002) as a separate processing system that is used when making decisions concerning risk.

Many authors suggest that there are two different ways that information is processed when making decisions, an automatic, faster, unconscious route, and a rule-based, effortful route (Chaiken & Trope, 1999; Epstein, 1994; Sloman, 1996; Slovic, Finucane, Peters, & MacGregor, 2003). The first, automatic route relies upon expertise and the associations for those experiences, which are linked to the emotions and feelings about whether the choice is a good or bad one. This system transforms uncertain information in the environment to affective responses, termed risk as feeling, which can be seen in the fear, dread, happiness, and any other emotion that an individual feels during a given situation (Loewenstein, Weber, Hsee, & Welch, 2001). This is in comparison to the rule-based system, which relies upon knowledge of algorithms and rules, requiring conscious processing of information (similar to normative models of decision making). Holtgrave & Weber (1993) explored the impact of the different decision making routes. Their findings indicate that a model that incorporates both the affective mode (emotional aspect), and the knowledge of the consequences (probabilistic information of outcomes) results in the best fit for predicting health and financial information. This indicates that although the more rational, reasoning-based information provided the best fit for data from the health and financial fields, the affective data from a model by Slovic et al (2003) that provided information similar to the nine characteristics by Fischhoff et al (1988) was useful in explaining additional variance. These results indicate that both processes are utilized during decision making involving some aspect of risk.

3.5.2: Risk Tolerance

After the risk has been perceived by the pilot, the pilot will make a decision based on the level of risk that he or she deems appropriate for the given situation, their level of risk tolerance (Hunter, 2002b). This acceptable level of risk varies depending on the situation, the potential outcomes, and most importantly, differences in the individual and what they deem acceptable. This level of risk has been described as a relatively stable level of risk that the individual will tolerate over time and across different situations. Many have created theories and explanations for why risk tolerance varies from person to person. Several notable theories include implicit risk theory, risk homeostasis theory, zero risk theory, the threat avoidance model, and hazardous thought patterns.

Risk attitudes are generally domain-specific, and the aversion and tolerance of risk is limited to the area of interest (Hanoch, Johnson, & Wilke, 2006; Weber, Blais, & Betz, 2002). Therefore, studies in the aviation field will provide more insight into pilot behavior due to the specific nature of risk tolerance. Aviation studies have previous utilized questionnaires (Hunter, 2002b, 2005; Lopes, 1987; Pauley, O'Hare, & Wiggins, 2008), and the implicit anxiety test (IAT) (Greenwald, McGhee, & Schwartz, 1998; Pauley & O'Hare, 2008; Pauley et al, 2008) to understand risk tolerance.

The Hazard Assessment Scale (HAS) (Hunter, 1995) was commonly used among these studies to determine pilots' previous accident and incident involvement. Results from Hunter (2002b, 2005) measuring risk tolerance did not find that hazardous event involvement was related to risk tolerance. Instead, the cognitive skills and the individual experiences determine risk tolerance and place pilots at risk for accident involvement. Pauley, O'Hare, & Wiggins (2008) found promising results using a measure of risk tolerance previously validated using incident and accident involvement, as captured using the HAS questionnaire. The motivational theory of risk tolerance developed by Lopes (1987) was based on individuals' preference for either opportunity for gain or the threat of a loss. The opportunity for gain is defined as the opportunities associated with the beneficial aspects of a situation, which can be compared to threat, which is defined as those negative aspects of a situation representing losses to the individual. Pilots were considered risk tolerant if the level of opportunity was a significant predictor of the decision to take off, rather than potential gains. These two features were varied over a number of situations that the pilot was then asked to rank. During the last phase, pilots were asked to fly a simulated flight.

Results from this study indicated that all pilots were significantly influenced by threat and not opportunity, indicate risk aversion. The higher the level of threat, the less likely the pilot would be to continue the flight. Of the 27 pilots who participated in the study, only two were considered risk tolerant. These two pilots had been involved in significantly more hazardous events than the risk aversive pilots, approximately double the number of incidents (Figure 11; Pauley et al, 2008). For these two pilots, there was a weaker relationship between threat and the decision to take off, meaning that threat was less of a factor influencing their decision. The results did not show any differences between age and experience in risk taking behavior. The small percentage of risk tolerant pilots limited the authors' ability to conduct statistical tests, however, the results still show quite large differences between the two groups. They note that this small percentage of pilots in the current study that are risk tolerant (7%) is similar to the percentage of risk tolerant pilots in other studies (4%) (O'Hare & Chalamers, 1999; Hunter, 1995).

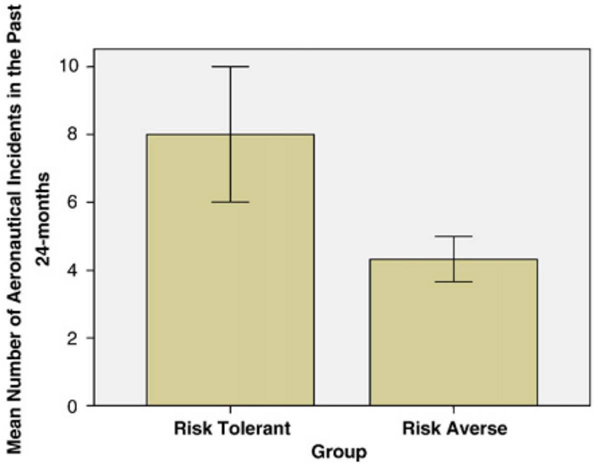


Figure 11: Involvement in aviation incidents by risk tolerant and risk aversive pilots

A second set of studies by Pauley, O'Hare, and colleagues (Pauley & O'Hare, 2008; Pauley, O'Hare, Mullen, & Wiggins, 2008) focused on understanding risk tolerance by measuring implicit attitudes, or the "introspectively unidentified (or inaccurately identified) traces of past experiences that mediate favorable or unfavorable feeling, or action toward social objects" (Greenwald & Banaji, 1995; p.8). Implicit attitudes are important because an individual may not be consciously aware of their true feelings toward a situation, and the unconscious processes may be unknowingly influencing their behavior. Support for this theory can be seen in RPDM, which focuses on pattern matching and recognition processes that take place subconsciously, or implicitly (Klein, 1993), and physiological data (heart rate) showing a relationship between anxiety and the decision to divert during an adverse weather simulated flight (O'Hare & Wiegmann, 2003).

The Implicit Anxiety Test (IAT) measures implicit anxiety by using the association between two target concepts and two attributes. The theory behind the test is that people tend to pair attributes and concepts together faster when they are similar, for example, flowers and happiness, rather than opposing concepts, such as flowers and unhappiness. If the combination produces a mismatch or anxiety between the two concepts, reaction time will increase. Implicit anxiety is determined by the variable D. D is calculated by the difference between the average reaction time of compatible and incompatible blocks, divided by the standard deviation of all responses. In general, negative D scores indicate a stronger implicit association.

For the studies by Pauley, O'Hare, and colleagues (Pauley & O'Hare, 2008; Pauley, O'Hare, Mullen, & Wiggins, 2008), the IAT was used to measure the association between afraid (scared, anxious, etc.) and unafraid (relaxed, calm, etc.) words, and their association with ten pictures of VMC and IMC weather conditions. The authors created compatible (IMC/afraid, VMC/unafraid) and incompatible (IMC/unafraid, VMC/afraid) blocks to determine differences in response time, which were later used to compute a D value. Negative D scores indicate that participants held a stronger implicit association between IMC and being afraid and VMC and feeling unafraid. Therefore, a risk tolerant individual would have a lower (potentially negative) D score than someone who is risk averse. Results indicate that the majority of pilots implicitly associated adverse weather with feeling anxious or worried. Implicit association decreased as individuals were involved in more weather-related hazardous events. Therefore, the individuals who had been involved in more incidents or accidents felt less anxiety when encountering adverse weather conditions. The authors conclude that these results indicate a relationship between implicit associations and risk-taking behavior.

In addition to the emotional or implicit aspect of risk tolerance, other more stable characteristics or traits are associated with risk tolerance. The thought patterns of aviators who possess specific qualities, termed hazardous attitudes, are expected to accept a higher level of risk and/or more frequent risks when making decisions. The five main types of hazardous attitudes that are associated with accidents are anti-authority, external control, impulsivity, invulnerability, and macho (Buch & Diehl, 1984). Anti-authority represents an attitude of resentment towards any authority that tries to dictate their activities or impose rules and regulations. External control (also termed resignation) represents the feeling of a lack of control over a situation or their own life. Impulsivity represents someone who acts quickly, without the adequate forethought. Invulnerability represents an attitude where the individual believes that nothing could ever happen to them. Macho represents an attitude of superiority, with an emphasis on ego and proving their worth. Each of the five hazardous attitudes was found to be distinctly different from one another, and was determined to be a separate construct (Lester & Bombaci, 1974). Of these five hazardous attitudes, invulnerability was the most frequently occurring hazardous thought that was associated with risky decision making in the aviation context, it was the predominant attitude in 40% of the pilot participants. Invulnerability was followed by impulsivity at 20%, and macho at 14%. Anti-authority and resignation occurred infrequently.

Since these earlier studies, several researchers have found a sixth measure should be added to the original five to capture the attitudes of pilots more precisely. The additional hazardous attitude of deference was proposed by Telfer (1986, 1989). Deference occurs when an individual relinquishes power to a peer, authority figure, or any other person, resulting in a change in decision making. This factor can be traced back to early studies of social psychology that experimentally explored the effects of deference in a group setting (Asch, 1956; Milgram, 1964). A second, but similar, sixth hazardous attitude was proposed by Murray (1999) who suggested the addition of loss of face. Face is the individual's assessment of the way in which others view that person (Redding & Ng, 1982; cited in Murray, 1999). When face is challenged, the individual is challenged with a negative emotional response, including shame, worry, feelings of uneasiness, anxiety, embarrassment, and tension (Goffman, 1967; Redding & Ng, 1982). In order to reduce these feelings, the individual will perform certain actions to reduce this emotional discomfort, resulting in potentially risky behavior and loss of face. Loss of face has been noted to be especially prominent in the aviation community, which generally tends to attract individuals with similar personality traits, particularly younger males with a propensity for risk-taking behavior. The adverse effects of the presence and/or input of other people during the decision making process can lead to riskier decisions. It therefore becomes important to understand how decisions change and evolve with the presence and influence of others.

CHAPTER 4: MULTI-PERSON/INTERACTION FACTORS

The personal characteristics of an individual and a situation shape behaviors, decision making processes, and actions. When others are added to the situation, so too are additional variables, influencing the individual decision making process, behaviors and actions. The result of this influence is expressed in any number of ways, depending not only on the individual factors, but the interaction with and influence of the additional parties present. This change in behavior due to the presence and influence of others has been confirmed by early social psychology research in group settings, accident statistics suggesting its occurrence and prevalence in certain situations, and the more applied experimental situations in real-world settings. Applied research on interpersonal interactions have extended to applications in commercial aviation in the form of crew resource management (CRM) and in programs for newly licensed teenagers learning to drive. A more recent focus, particularly in GA, is the effect of a passenger in a GA cockpit. Although the impact of interpersonal relationships in the GA cockpit have been explored by analyzing accident reports, experimental research directed at these interactions has yet to be conducted.

4.1: Social Pressure and Influence

Influence has been primarily studied in group settings by social psychologists with a focus on interpersonal interactions. These studies indicate the extent of influence on an individual's behavior in a group setting. Research on these interactions have been supplemented by a focus on the effectiveness of specific methods used to induce behavioral change. Theories describing these methods include conformity, persuasion, and obedience, which can occur in typical, everyday situations, or situations involving potentially extreme outcomes. This potentially wide range of situations include anything from a group project at work, a psychology experiment, the identification of a suspect in a witness lineup, or interactions between pilot and co-pilot during a flight maneuver. The underlying theme in these scenarios is the same, people's behavior can, and typically is, swayed by their interactions with others in some form. Given this wide breath of research and applications, social pressure or social influence may also explain pilot flight into adverse weather. Social pressure in GA can occur when a passenger encourages the pilot to continue flying to the intended destination despite the weather conditions. The pilot may conform due to the passenger's insistence and/or pressure on arriving at the destination at the scheduled time.

Social influence can typically be categorized into one of two main types, informational or normative social influence. Informational social influence occurs when information from others results in a change in behavior. For example, pilot A see pilot B take off in marginal conditions, leading to pilot A believing that flying in those marginal conditions is safe because pilot B attempted it. However, pilot A may not have even considered that pilot B may have made a poor decision or is more capable of handling those conditions due to experience and/or training. In comparison, normative social influence occurs when an individual modifies his or her behavior to fit with the social norms or unwritten rules of social interactions. When the individual does not conform to the established social rules, he or she may experience a sense of discomfort. In order to minimize these unpleasant emotions, people often modify their behaviors and decisions to adapt to the social norms.

Influence may occur in either an indirect or direct format. Indirect social influence, of any type, occurs when the presence or actions of another induces a change in behavior without a request. This is in comparison to the direct form of influence, which occurs as the result of a request to perform some action through any number of means. Indirect methods range from social facilitation, the least intrusive form of social influence resulting from merely the presence of others, to conformity, whereby a change in behavior occurs due to the effects of differing viewpoints by group members. Direct methods range from compliance, following orders generally due to a request from someone in authority, to persuasion, which occurs as the result of encouragement or reasoning with the individual by a separate party.

4.1.1: Indirect Methods

Social Facilitation

Merely the presence of others can result in changes to behavior. This effect is termed social facilitation and was first described over 200 years ago (Zajonc, 1965). Social facilitation can result in either positive or negative effects, depending on the situation, the individual, and their task. In general, social facilitation leads to the enhancement of a dominant response. This is beneficial for certain tasks, such as those involving memory, vigilance, and even motor responses. The negative effects of social facilitation occur when the individual is learning new material. Beneficial effects in a learning situation occur if others are engaged in the same activity, and the individual can observe, and then mimic, the correct behavior and actions.

Some researchers disagree with the basic premise of social facilitation, that the mere presence of an audience is sufficient for social facilitation to occur (Baxter et al, 1990). Some have proposed that the presence of others increases arousal, which then leads to the effects of social facilitation (Zajonc, 1965). Other authors have instead suggested that social facilitation occurs when an individual believes that their behavior will be evaluated, resulting in arousal and enhancing dominant responses (Cottrell, 1968, 1972). An additional conclusion is that audiences are distracting, and the competition between the task and the audience is arousing (Sanders & Baron, 1975). Irrespective of the reason behind social facilitation, marked changes in behavior do occur as the result of solely the presence of others. At the most basic level, social facilitation is the first step in understanding how decision making is changed by the involvement of others, either those present in the same room or those influencing the decision making process.

Conformity

Conformity is a change in behavior due to real or imagined pressure from another person. A frequently cited study by Muzafer Sherif (1935) tested the autokinetic effect, a visual phenomenon where a stationary point of light appears to move but does not. In this study, the participant judged how far the light had moved, when in reality the light remained stationary. Participants were placed in a group setting and each person gave their response separately, but in front of all other group members. Sherif found that the responses of individuals in the group setting eventually converge to a single rating, representing a mid-point or average for the group. The individuality of these group members disparate responses were lost. Interestingly, after the group separated, individual participant ratings remained at this center point rather than reverting back to their original response pattern. Although Sherif's group effect was impressive, the study was critiqued for the ambiguity of the task, and the lack of a concrete "answer," resulting in subsequent research with outcomes that could be objectively measured.

The subjective studies of visual phenomena by Sherif led to studies with an objective outcome by Solomon Asch (1951, 1955). The original studies by Asch involved a group of eight people who were tasked with determining which of a set of three lines matched the length of a fourth line (Figure 12). Although this may seem like a basic length discrimination task, there was one participant who was unaware that he was faced with a group of seven cohorts who were hired to consistently choose the same incorrect response as each other. Therefore, the true goal of this study was to determine how often the subject chose the incorrect answer, and instead conformed to the incorrect response of the group. This landmark study was later revised to include different conditions with variations to the total numbers of cohorts, the presence or absence of dissenting cohorts, and varying discrepancies between the actual line length and the incorrect majority response. Surprisingly, this simple task with a clear and obvious correct response resulted in conformity for 32% of all trials. For these studies, 25% of the participants did not conform for any trial, 75% conformed at least once, and 5% conformed for all trials. These results were surprising to the researcher as well, who predicted a far lower conformity rate due to the obvious correct response for the task.

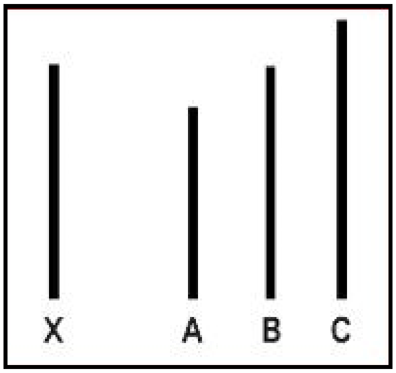


Figure 12: Solomon Asch Line Discrimination Task

The presence of dissenter(s), individual(s) who gave the correct answer, in the group greatly reduced the influence of the other group members on the subject as it gave the individual an "ally" within the group. This is seen in the error rate, which dropped from the 32% seen in the original study to 10% when an additional naïve subject was present in the group and further to 5% if there was a dissenter who chose all correct answers. An additional experimental manipulation was the number of dissenters in the experiment, which varied from one to sixteen people. Asch found that larger majorities of four to sixteen cohorts did not produce greater effects than a majority of three. This effect was dramatically reduced when the number of other "subjects" was reduced from three to one. The mean number of errors decreased from an average of 4.0 errors with three cohorts to 1.53 errors with two cohorts, and .33 with one cohort, compared to a baseline error rate of .08. Even with only one cohort present, the error rate was over four times as high as the baseline error rate.

The presence of just one dissenter greatly decreased the probability that an individual would conform to the group response. Asch found that a group of three unanimous cohorts was more effective in producing a conformity effect than a group of eight cohorts with one dissenter. Different variations in the arrival and departure of the dissenter and the correctness of their answer resulted in a change to the error rate of the subject. In all these conditions, the presence of a dissenter or an "ally" greatly reduced the influence of the group on the subject to conform. This finding is important because it shows that it is not the number of people present, but rather if an "ally" is among them.

Additional conditions by Asch included variations between the length of the correct line and the line chosen by the group. Asch found that the difference between the two, whether large or small, produced the same rate of errors. However, the method of yielding did change. As differences between the actual line length and the group answer increased, more "compromise" errors occurred, which split the difference between the correct answer and the response of the group, rather than the participant noting the incorrect response.

4.1.2: Direct Methods

Compliance

Compliance is a form of social influence that occurs when one alters his/her behavior in response to a direct request. There are many techniques that are used to induce compliance, the most common are the foot-in-the-door technique, door-in-the-face technique, and the low-ball technique. The foot-in-the-door technique involves a small initial request, followed by a second larger request, usually after some time has passed (Freedman & Fraser, 1966). One theory used to explain the effectiveness of this technique is self-perception theory, which asserts that after agreeing to an initial request, an individual attributes the commitment to internal factors about themselves, particularly the beneficial attributes. The attempt to maintain the positive sense of self leads the individual to continue to comply with future requests. The door-in-the-face-technique involves a very large request, typically found to be unreasonable and subsequently rejected, followed by a much smaller request. The large difference between the initial and subsequent request results in the norm of reciprocity, and people typically feel obliged to make a concession to match the concession made by the solicitor. The low-ball technique is seemingly the opposite of the door-in-the-face technique. Using this technique, one initially commits to a deal that seems too good to be true, but only after accepting does he or she learn of the additional stipulations or costs. Due to the original commitment, the individual feels obligated to uphold the bargain, and is therefore less likely to break the commitment than if asked directly.

An article exploring the use of these various tactics in the aviation context used the critical incident method to conduct interviews with pilots about a prior weather encounter they had been involved with (Paletz, Bearman, Orasanu, & Holbrook, 2008). The Alaskan pilots interviewed were asked to recount at least one weather-related incident of their choosing that challenged their skills as a pilot in command. The themes of these interviews were then grouped according to similar features. Of the 28 interviews conducted, 24 described a situation involving social pressure. Eight of the pilots described at least one case of foot-in-the-door or normalization of deviance**,** and five described at least one pressure related to self-consistency pressures/impression management.

Examples given by the interviewed pilots for informational social influence include a situation in which they felt safe to fly because they had observed other pilots flying in the same area and/or under the same conditions. Foot-in-the-door examples include the request by a manager to "go take a look" to determine actual weather conditions. Some of these requests were innocent, as information concerning the weather can be inadequate, however, it was noted that in other times this was used as a ploy to get the pilot to take off and then continue through deteriorated weather conditions. The third type commonly seen is the normalization of deviance, which is the incremental acceptance of lower levels of safety. This acceptance of lower standards for weather conditions may eventually lead to complacency, often resulting in dangerous situations. This may occur after pilots are faced with deteriorated weather that persists for several days or weeks, leading the pilot to take off in conditions that they would normally not deem acceptable.

Self-consistency, as related to self-perception theory, is the need to maintain the self-image and beliefs consistent with the individuals' perception of self. Similarly, impression management is the pressure to avoid social disapproval and failure. These two taken together may result in a passenger who wants to fly to their destination, a pilot who is aware of this, and acts to fulfill their wishes. Even though the passenger might not state directly the urgency of arriving at their destination, the pilot may still be aware of this, and responds accordingly. The pilot might be faced with a potential loss of face if they had to tell the passenger that they would not be able to conduct the flight.

These examples of influence methods depict the Alaskan pilot managing not only adverse weather conditions, but also social pressures in the cockpit (Paletz et al, 2008). It is interesting to note that when asked to describe a situation involving weather, the vast majority of the pilots described some form of social influence. This fact speaks to the importance and prevalence of social influence within an aviation environment.

Persuasion

Persuasion, a form of normative social influence, uses reasoning for the purpose of changing the attitudes and/or behavior of another person. One common persuasion theory, the social judgment theory (SJT), states that a person judges a persuasive message based on the difference between their own position on an issue and the communicator's position. The theory outlines three judgment categories: the latitude of acceptance, the latitude of rejection, and the latitude of non-commitment. The latitude of acceptance and rejection result in the immediate acceptance and dismissal of the action or request. The latitude of non-commitment is the neutral zone, a "gray" area between the latitude of acceptance and the latitude of rejection. In this zone, the situation highly influences the actions and outcomes and what the individual is willing to accept. Therefore, if an individual receives a request that falls into the latitude of rejection, it will be dismissed immediately. However, if that same request for a different individual falls in the latitude of non-commitment, situational variables and persuasive means may be used to convince the individual to agree to the request. SJT makes practical sense because it describes how a persuasive argument is received and explains the individual differences in the ability to be persuaded. Each pilot has his or her own different experiences, capabilities, and acceptable levels of risk, all of which can modify how the message is perceived and the "zone" in which the persuasive message falls.

A study exploring the reasons why pilots would take off into bad weather conditions indicated that pilots would be more willing to take risks if the proposed flight was for a medical emergency (an angel flight), when going home for the holidays, or when performing search and rescue flights (Driskill, et al, 1998). In comparison, the situations that the pilot would choose not to perform a risk (rated the lowest) were flying home after a day away, visiting friends, or receiving an instrument flight check. These relatively unimportant reasons for taking a risk were all rated as a 1.5 or less, as compared to the highly rated reasons, which ranged from 75 to 88. These results indicate support for separate latitudes of acceptance, with the higher rated risks indicating a neutral or "gray" zone where an individual might accept additional risk due to differences in situational and/or other personal factors.

Obedience

Obedience can be defined as the change in behavior due to a direct request from someone in authority. One of the most widely recognized experiments on obedience is by Milgram (1963, 1964). Milgram's original study involves a subject brought in for a "memory experiment" to determine the effect that punishment had on a memory task. In this experiment the subject of interest is the learner, who is working with the experimenter to dupe the true participant, the teacher. The goal is to determine the level of shock the participant would be willing to administer when instructed by the experimenter. The shock is considered the punishment, and is administered each time an incorrect answer is given by the learner. The level of shock increases in intensity with each additional incorrect answer by the confederate. To add to this situation, an experimenter is encouraging the subject to continue to administer shocks to the confederate with a series of increasingly strongly worded prompts that correspond to the increase in shock voltage. In this original study, there is no visual or auditory input from the learner except when 300 and 315 volts are reached, and a banging on the wall is heard. Once 330 volts was reached, there were no additional responses from the learner. At the maximum of 450 volts, the experiment was concluded.

When commanded by the experimenter, all participants continued to shock the "learner" until reaching 300 volts, at which point 17% refused to continue. In total, 65% of the participants continued to shock the learner until reaching the maximum of 450 volts. Additional conditions of the experiment were added to the original study. The proximity of the subject to the learner and the proximity of the experimenter to the subject were manipulated to determine its effect on conformity. The first variable of interest, the proximity of the learner to the subject, was manipulated from the original condition with the subject in a separate room from the learner, without auditory or visual information (no A/V). Subsequent conditions include the added component of verbal protests by the learner (A only), and an increased proximity (a few feet) of the learner to the subject, who could both be seen and heard during the experiment (A+V). A fourth condition required the subject to physically hold down the learners hand once the learner refused to participate in the experiment after reaching 150 volts (A+V+touch). In each of these cases the subject's increasingly close proximity to the learner and increased awareness of the outcome makes him more aware of the situation that he is responsible for causing. Milgram mentioned that the subjects showed escalating unease with the increased proximity of the learner, and many times were found to distance themselves from the situation by avoiding visual contact with the subject in the later conditions. Even with these changed, the percentage of fully obedient subjects, those who continued until the 450 voltage shock was given, decreased over the conditions: 65% for no A/V, 62.5% for A only, 40% for A+V, and 30% for A+V+touch.

The second type of relevant condition is the proximity of the experimenter to the subject. There were only two conditions for this second type of experiment. The first is a new "baseline" condition, where the location of the experiment was moved to a more modest looking location in the basement of the same building. This condition was similar to the voice feedback only condition, with the additional mention of a heart condition at certain voltage levels by the learner. The result was a slight chance variation. This condition is in comparison to the seventh experiment, where instead of the experimenter sitting just a few feet away from the subject, the subject only had contact with the experimenter via telephone during the experiment. In comparison to the baseline condition, where 26 subjects obeyed completely, only nine of the subjects completely obeyed in the distanced experimenter condition. What can be gained from the studies by Milgram is the large role of someone in authority (the experimenter) on the individual's decision to continue the ill-advised, and potentially physically harmful, electrical shocks.

Another well known study is the Zimbardo prison study (Haney, Banks & Zimbardo, 1973). This study placed normal college students in a prison environment, half randomly assigned to the role of prisoner and half as guards. What was originally planned as a two-week study had to be shortened to less than a week due to unexpected consequences. The students assigned to the position of guard exhibited aggressive behavior towards the prisoners, and the prisoners exhibited docile conformity to the wishes of the guards. Although at first glance, the actions of the prison guards might seem to be the main finding of interest, the actions of the prisoners exhibited a disturbing and fascinating look into an extreme case of conformity. As the experiment progressed, the prisoners had stopped requesting better conditions or responding to the unpredictable actions of the guards. The prisoners even went as far as turning on the one prisoner who was still standing up to the guards after all others had complied completely. The prisoners instead failed to initiate any action, wandering around in a zombie-like state, and complied with any request made by the prison guards.

The willingness to comply with requests from an authority figure can be extended to the multi-piloted aircraft cockpit. An NTSB study of aviation accidents from 1978 to 1990 determined that 80% of the accidents involved a monitoring/challenging error by the non-flying crew members, which in 81% of these cases was the first officer. Of these accidents, Tarnow (2000a, 2000b) concluded that excessive obedience was implicated in as many as 25% of the civil aviation accidents. The determination of the monitoring/challenging error versus the excessive obedience error was the impact of the error. Therefore, a first officer who failed to warn the captain of a missed engine light that resulted in the primary cause of an accident would be determined an excessive obedience error. However, in that same example, if the engine light was only considered a secondary cause of the accident, and not directly contributing, then the error would be considered a monitoring/challenging error.

The conclusions from the NTSB analyses by Tarnow (2000) concerning the high rate of obedience and monitoring/challenging errors is supported by flight transcripts of accidents involving social pressure. The flight recordings taken from two accidents resulting in social pressures involved failures in managing interpersonal relationship in the cockpit (NTSB 1979, 1980; cited in Kanki & Smith, 2001). In both accidents, the first officer was uneasy about the decision the captain had made but failed to express his concerns strongly enough to change the fatal outcome. One explanation for the reason why first officers may fail to speak up or adequately express their concerns when faced with a potentially life threatening error by the captain is the trans-cockpit gradient.

The trans-cockpit gradient is the working relationship in a dual pilot cockpit, and describes the difference in seniority and authority between the captain and the first officer (Edwards, 1975). The captain's designation as final authority over the aircraft is determined by the Code of Federal Regulations (CFR) (Tarnow, 2000a). This position typically requires seniority in the airline and a large number of accrued flight hours. This can be compared to the first officer, who typically has a third to a quarter of the flight hours of the captain, and far less time within the airline.

Many times this relationship between the first officer and captain is compounded by personality factors and leadership styles. An overbearing captain can result in a timid first officer not voicing their concerns adequately, or conversely, a captain can abstain from their role of authority, resulting in confusion and lack of proper coordination in the cockpit. Organizational norms also exacerbate this factor, as can be exemplified by an airline policy in the 1950's stating that the first officer may not correct errors by the captain. This thought process, and the associated organizational norms, has changed over the years due in part to aviation accidents that could be prevented by the first officer questioning the captain. This body of research, and the associated preventable accidents, resulted in an NTSB recommendation for assertiveness training to combat the problem of the trans-cockpit gradient (NTSB, 1989). This recommendation marked the beginning of crew resource management (CRM), which has evolved over the past 30 years, and is now a requirement for all commercial pilots (Kanki & Smith, 2001).

4.2: Communication in Teams

4.2.1: Crew Resource Management & Assertiveness Training

In some, the ability to speak up in difficult situations is a natural ability, but in others it requires practice and concerted effort, which can occur through the use of social skills and management training techniques (Helmreich & Foushee, 1993). Crew or Cockpit Resource Management (CRM) was created to address those issues, particularly for the aviators whose skills were lacking. CRM has progressed over five evolutions to become an integral part in commercial aviation training (Salas, Burke, Bowers, & Wilson, 2001). As the focus has changed over the years, there have been improvements in the communications of aviators during hazardous situations, and a decline in accidents attributable to CRM.

The focus of the first evolution of CRM was on fixing individual problems. This later evolved to the second phase, with a focus not only on the individual's problems, but on the dynamics within the cockpit. The third evolution expanded the scope to interactions within an aviation context, not solely on the aviators. This evolution created the understanding that CRM must include the interactions that aviators have with other individuals, such as with ATC, maintenance personnel, and other support personnel. The fourth evolution allowed for additional improvements, including tailoring and certifying (now a requirement for airlines) the CRM program to the company, and providing the aviator with the opportunity for review and feedback of their performance. The focus of the fifth and final evolution is the inevitability of human error, and the methods used to mitigate these errors. Error mitigation techniques include error avoidance, early detection of errors, and minimizing the consequences of CRM errors. Additions to this phase include the recognition and management of threats. This most recent evolution of CRM training built upon previous evolutions to create a pragmatic look at the way errors occur. Instead of trying to prevent errors completely, the goal is to minimize their impact. Therefore, when errors inevitably occur, they can be managed effectively, reducing their impact on safety and ensuring a safer flying experience.

Many studies have supported the contention that CRM training does improve teamwork in the cockpit (Fowlkes, Lane, Salas, Franz & Oser, 1994; Leedom & Simon, 1995; Smith-Jentsch, Jentsch, Payne, & Salas, 1999; Smith-Jentsch, Salas & Baker, 1996; Stout, Salas, & Fowlkes, 1997; cited in Salas, Fowlkes, Stout, Milanovich, Prince, 1999). A study by Prince & Salas (1993) identified seven key teamwork skills for aviators: communication, decision making, leadership, situation awareness, mission analysis, adaptability/flexibility, and assertiveness. One key area of interest due to its applicability to the trans-cockpit gradient and passenger pressure is assertiveness.

Assertiveness

Assertiveness is the ability to communicate ideas, feelings, concerns, and needs clearly and directly without being demanding or infringing upon the rights of others (Jentsch, & Smith-Jentsch, 2001). The attributes of a communication message exist on a continuum. On one end of the continuum are passive, indirect, statements that may only hint at the true purpose of the communication. At the opposite end of the continuum is an aggressive statement that provides a succinct and direct version of the communication, but does so in a negative manner, typically involving a degree of defensiveness, hostility, or imposition on others actions or point of view. Therefore, to be effective, assertiveness should fall in the middle of the continuum, providing the necessary information, but in a positive manner, without defensiveness or hostility.

Lorr & More (1980) propose that assertiveness as it is generally defined is too broad in scope, and instead should be conceptualized as a multidimensional variable with four parts or sub-sets, including directiveness, social assertiveness, defense of rights and interests, and independence. Directiveness is the ability to lead and influence others in tense personal statements that require action, initiative, and assumption of responsibility. Social assertiveness is the ability to maintain and engage with others successfully in social interactions. Defense of rights is the ability to stand up for one's rights and refusal to accept unreasonable requests. Independence represents the ability to actively resist conformity from themselves or others, and instead act on their own beliefs without the influence of others. The authors mention that each category of assertive behavior can be classified as both a skill and as a disposition, resulting in expected changes to behavior based on the situation and stimuli. Others (Gupta, 2004; Smith-Jentsch, Salas, & Baker, 1996) support the conclusion that team performance is a skill, and unlike disposition, should be trainable.

The authors researched a variety of CRM programs and found that assertiveness training is most effective when a behavioral role-modeling format is followed. This format includes the use of lectures and demonstration, with an emphasis on practice and performance feedback. The combination of practice and timely performance feedback during a simulated flight scenario are particularly effective at building interpersonal skills. The concept of assertiveness has been incorporated as a module into nearly every CRM training program in the last 30 years (Jentsch, & Smith-Jentsch, 2001). The requirement of recurrent training for commercial pilots includes a simulated flight addressing specific skills, that is taped and later reviewed for performance feedback (Baldwin & Ford, 1988; Jentsch & Smith-Jentsch, 2001).

CRM training has been applied extensively in the aviation field, with generally beneficial results. Salas et al (2001) conducted a literature review to determine the effectiveness of CRM training. Of the 58 articles reviewed, the authors noted a general lack of systematic investigation for the effects of training. The vast majority of the studies reviewed in this article evaluated the training based on some, but not all, of the training evaluation methods (reactions, learning, behavior, and results) described by Kirkpatrick's learning framework (Kirkpatrick, 1976). The authors concluded that if all four of these evaluation methods are not addressed, a comprehensive view of the effect of training is not possible to determine. Taking into consideration this caveat, and the results from a few studies finding that CRM training had no effect, the authors conclude that there is adequate evidence to support the effectiveness of CRM training. This is particularly significant given the current state of evaluation methods used by the reviewed articles. The results from the reviewed articles can be summarized into a few key findings: CRM training produces positive reactions, attitudinal change, and the desired behavioral change in the cockpit.

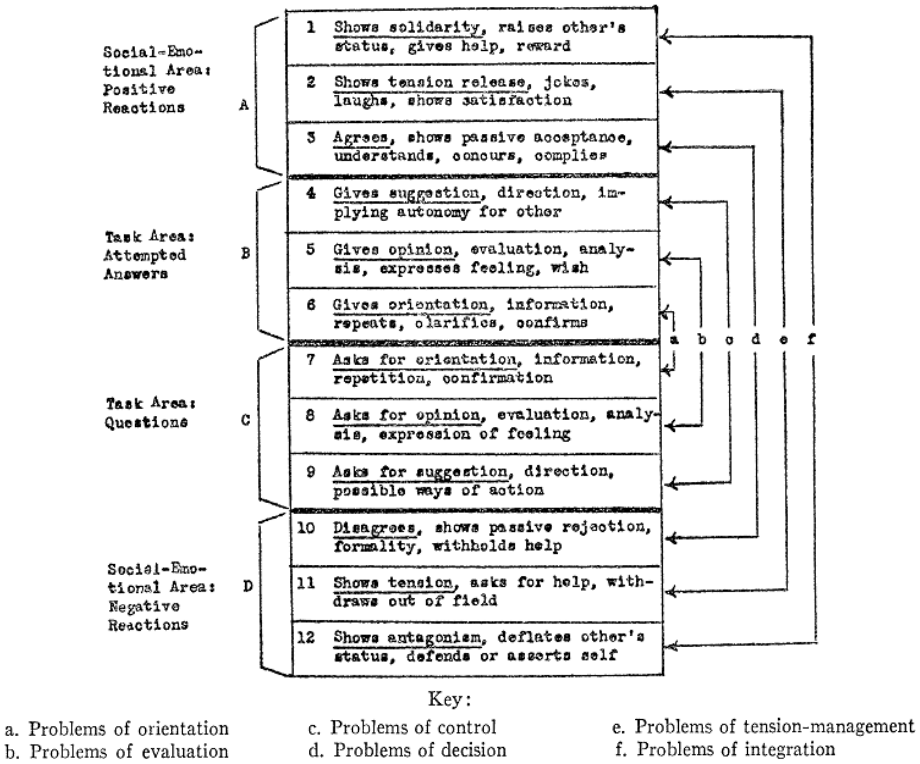
4.2.2: Communication Patterns & Coding

Communication measurement and analysis have provided researchers with an additional way to study performance in the cockpit. Two methods of analyzing communication content created by Bales and colleagues (Bales, 1950; Bales & Cohen, 1979) were used extensively to study group communication. The Interaction Process Analysis (IPA) and the System for the Multiple Level Observation of Groups (SYMLOG) have been widely used to classify the content of behavior, providing insights into the factors involved with and influencing group processes. Both IPA and SYMLOG have been used as a basis for several studies investigating the role of communication in a commercial aviation cockpit. The adapted communication coding methods have shown how differences in performance, error type, and rank influence communication patterns.

IPA is a communication coding method that can be used to determine the relevance and importance of each statement in relation to the problem-solving process (Bales, 1950). In order to determine the importance of each communication, the statement is classified according to a set of categories. The twelve categories are arranged as six complementary pairs that can be used to describe any interaction. These categories address problems of orientation, evaluation, control, decision-making, tension management, and integration using two diametrically opposing statements. In figure 13 (Bales, 1950), six and seven (a) both represent problems of orientation, but do so differently. Item six gives information that can be used for orienting, or understanding the problem or situation. Item seven, in comparison, asks for additional information to increase understanding. These opposite statements allow for a wide variety of actions.

When using IPA to code a conversation, each sentence will be coded as a separate entity, one of the twelve categories. For example, the phrase "Has anyone checked on the order status?" would be coded as category seven because it is asking for orientation, rather than giving information to orient others to the problem. If this statement is made in a group of more than two people, the statement will also be coded according to the direction of the statement. Therefore, the coding might be coded as category 7, with attendee 1 addressing attendee 3. The code that precedes and follows the code of interest will also be used to determine communication patterns. Over the course of a conversation or interaction, the amount and types of codes by person, their frequencies, and the codes that precede and follow it, all give insights into the interaction. Additionally, IPA provides information on the relationship between the communicators, the progression of the conversation, and the type of communication that occurs.

Figure 13: IPA Communication Categories



SYMLOG is similar to IPA in that it uses categories of opposing actions to capture communication within a group. In comparison to IPA, which categorizes information based on actions, SYMLOG uses descriptive terms to detail the underlying themes behind the action. Therefore, instead of using actions (ie: gives opinion, asks for suggestion), SYMLOG focuses on the qualities of the person and their communication, which may be either verbal or nonverbal. The behavior may be classified as one of a number of adjectives. P, or positive, can be used to describe as friendly statement/action; N, is negative and represents unfriendly; U, or upward, is also known as dominant; F, or forward, can be described as instrumentally controlled; and B, or backward, can be described as emotionally expressive. SYMLOG is a more recent coding mechanism, and has not yet achieved the level of interest of IPA.

Although many of the examples given by Bales (1950; 1979) describe a meeting or other type of group setting, SYMLOG, and IPA in particular, have been used in many aviation-related studies as the basis for understanding communication within a team. These communication coding techniques have been modified to better understand the cockpit dynamics in a commercial aviation setting. Variants of IPA and SYMLOG have been used by several researchers to code, and understand, the communications in a multi-piloted aircraft (Fischer & Orasanu, 1999; Foushee, Lauber, Baetge, & Acomb; 1986; Foushee & Manos, 1981; Straus & Cooper, 1989).

Straus & Cooper (1989) focused on communication patterns to determine how the differences in rank structure affect group communication. Communications by the crews (homogeneous and heterogeneous ranks) were coded into one of the three main groups of communication: task information statements (procedural information, opinions, acknowledgements), directive communications (commands, corrections, formal acknowledgements), and tension release (expressions of frustrations, embarrassment, task irrelevant comments). The communications revealed the task structure for performing certain actions by the pilot and co-pilot. The pilot gave more directives to the co-pilot, and the co-pilot gave procedural information, opinions about the task, and other types of information to the pilot. Non-task communications were higher for the pilot, possibly relieving tension through the use of nervous laughter, encouragements, and statements of frustration. The authors note one surprising finding, the expected effects of crew composition were not significant. The communications between homogenous crews (similar rank/status) were higher than heterogeneous crews (different rank/status), but the results were not significant.

An additional study focusing on the effect of role and status on pilot communication strategies utilized eight categories of communication; two classes were speaker-centered communications and six were types of requests (Fischer & Orasanu, 1999). The requests included commands, crew obligation statements, crew suggestions, queries, preferences, and hints. The two speaker-centered communications include permission-seeking questions and self-directives, indicating future actions. These communications vary according to the directness and explicitness of the statement and the action to be taken. Results from the study mirrored the findings from Straus & Cooper (1989) and indicated a different communication pattern between captains and first officers. Captains typically used commands, in comparison to the less direct method used by first officers (i.e., hints), which expresses the problem but suggest no solution. The communication patterns also differed based on risk and face threat (embarrassment) errors. In high-risk situations, communication becomes more direct, captains increase their use of commands, and first officers increase their use of crew obligation statements. High face threats by first officers often elicit an increase in hints by the captains, rather than their preferred communication method, commands. An evaluation of the effectiveness (rating based on both success and appropriateness) of the communications found that both the captains and first officers rated crew obligation statements as more effective than commands. Similar to the first part of the study, direct statements were rated as more effective in high-risk situations.

A similar study by Foushee & Manos (1981) coded communications into one of the following statements: crewmember observation, commands, inquiries, response uncertainty, agreement, acknowledgement, tension release, frustration or anger, embarrassment, and pushes (repetition of previously stated information). Results from the study shows that the low error crews communicated more overall. More specifically, crewmember observations, acknowledgements, and commands resulted in less errors, including flying (altitude errors, engine handling), operational (misreading instruments, mishandling of engines), and tactical decision (flap settings, braking) errors. In contrast, higher rates of errors are associated with an increase in response uncertainty, frustration/anger, and embarrassment statements. The increase in command statements associated with low error crews may indicate the effectiveness of commands, up to a certain point. If these statements indicate a behavioral style, then this behavioral style may lead to a submissive first officer failing to inform the captain of critical information.

Communication patterns are also dependent on a number of additional factors, including crew familiarity, similarity of speech patterns, and situational factors. Crew familiarity had a positive impact on performance and led to performance superior to that of unfamiliar crews, even with the highest levels of fatigue (Kanki & Foushee, 1989). This positive effect of performance on familiar crews can be at least partially attributable to speech patterns. The crews with homogeneity of speech patterns were characterized by a low occurrence of errors, as compared to high error crews that were marked by heterogeneous speech patterns (Kanki, Lozito, & Foushee, 1981). The homogeneity of speech was characterized by a predictability of the speech patterns that indicated a standard form of communicating. The authors concluded that the predictability of homogeneous speech patterns by crew members resulted in benefits to performance.

The findings from the studies of speech and content coding can be combined into a few general conclusions. First, the differences in communication patterns of captains and first officers support the trans-cockpit gradient theory. Second, high performing crews exhibit certain patterns and types of communication that differ from low performing crews. Third, the first two findings lead to the conclusion that communication coding is a valid means of understanding pilot behavior in the cockpit. Therefore, communication coding may be used to increase understanding in other sectors of aviation, or in other domains.

4.3: Passengers

4.3.1: Driving

A large percentage of the research addressing passenger influence in driving has focused on drivers younger than 25 due to their increased crash risk (Ulmer, Williams, & Preusser, 1997). This elevated crash risk is further increased when the young driver is accompanied by passengers who are peers (Drummond & Healy, 1986). This increased risk has been attributed not only to inexperience, but also to driver risk taking and peer influence (Mayhew & Simpson, 1990; Williams, Ferguson, & McCart, 2007). Williams et al (2007) mentions that young drivers are more susceptible to peer influence than older drivers because they are highly attuned to the behaviors of others, have a high need for social acceptance, and have underdeveloped self-regulation capabilities. These characteristics that lead them to be more risk-taking with peers also leads them to be risk-averse with other types of passengers. Drivers mentioned that they are more careful under certain circumstances, such as when they drive with parents and adults, and for males, when driving with a significant other (Arnett, Offer, & Fine, 1997; Preusser, Ferguson, & Williams, 1998; Rolls & Ingham, 1992; Ulleberg, 2005). An additional protective influence of older passengers, particularly older females, has been found, leading to a decrease in crash risk.

Due to the large influence of passengers on driving behavior, a number of research studies have focused on interventions that target teens faced with social situations and social pressure in driving situations. Before any behavioral change can occur, drivers should be made aware of how passengers can influence their behavior, whether it is the passenger persuading the driver to race their friend's vehicle, or if it is simply the presence of the passenger that results in a change of behavior (Williams et al, 2007). One training method, assertiveness training, has also been utilized in the driving sector where it has been recommended for use for passengers faced with an unsafe driving situation. Regan & Mitsopoulos (2001) adopted assertiveness principles by implementing a training program that uses a hierarchy of verbal statements to bring up the passengers safety concerns to the driver. This hierarchy of statements increases the strength of the wording to communicate an increased importance with each additional communication. Therefore, with each additional statement, the urgency of the demand is increased. The authors mention that the use of a hierarchy of communication will result in a desired effect more often than an initial blunt demand. This framework could also be applied in a reverse situation, when a passenger is pressuring the driver to perform some risky behavior, and the driver needs to be assertive enough to take a stand.

4.3.2: General Aviation

In comparison to other types of GA accidents, VFR into IMC accidents had significantly more passengers onboard (Goh & Wiegmann, 2001). The authors found that passengers were present in 54% of VFR-IMC accidents, which was significantly more than the 45% present in non-VFR into IMC accidents. Data analyses from a 14-year period by Detwiler et al (2008) confirmed this increase in passengers for VFR into IMC accidents. The authors found the fatality rates were significantly greater for VFR into IMC flight (1.57 fatalities per accident), as compared to non-VFR into IMC accidents (.33 fatalities per accident).

The motivation of the individuals in these samples is however, limited. These studies used accident reports from the NTSB/FAA database, resulting in a limited view to only the information that could be captured after the accident had occurred. Often, VFR to IMC accidents result in the death of the pilot, and no survivors or voice recordings can aid the accident investigation. Unfortunately, this is a common issue for GA accident investigations due to the smaller, lower-technology airplanes flown in GA that do not typically come equipped with a 'black box' (as compared to commercial aviation for example). Determining the cause of these accidents is extremely challenging, if even possible. Key information is typically scarce regarding pilot reactions in these demanding and stressful situations.

The results from Goh & Wiegmann (2001) & Detwiler et al (2008) suggest that the presence of a passenger does influence the decision making process in VFR into IMC accidents. These results are confirmed by the role of passengers in other domains, such as driving, which has found that both the presence and type of passenger influences the driver's risk taking behavior. Although many studies have experimentally explored driving risk taking behavior in relation to the passenger, similar studies in general aviation have yet to be conducted. Therefore, in order to increase our understanding of pilot behavior when faced with passenger influence and/or pressure, the problem must be explored experimentally. As such, the proposed study aims to provide a look at the role of social pressure and influence in the motivations and decision factors faced by pilots involved in VFR into IMC situations.

CHAPTER 5: METHODS

5.1: Participants

Participants for this study were recruited for both the role of the pilot and the passenger. A total of forty-five pilots were recruited to fill the role of the pilot, each participating in one of the three persuasion conditions. These pilots were recruited from Clemson University, flight clubs in the area, and local airports. There were two non-pilots recruited for the role of passengers who were present during the experiment (explained below). The non-pilots were chosen based on their expected effectiveness and availability.

The pilot demographic information for each of the three conditions is included below (Table 5). Age and measures of experience represent a wide variety of pilots. Age ranged from 18 to 77 years, and time since the pilot received their private pilot's license ranged from a pilot a month shy of his formal license to a retired military pilot who had received his license 52 years earlier. Due to this wide range of experiences, both the range and medians are given. The participants in the 'non-incentive' condition are older with more flying time than the 'positive' and 'negative' incentive conditions. These higher values can be attributed to two participants who had been flying for over forty years. Although the values of the 'baseline/non-incentive' condition are slightly higher than the other incentive conditions, the pilots from the positive and negative incentive condition are comparable to one another in both age and flight experience variables.

Table 5: Pilot Demographic Information

	Age	Time since received PPL	% PPL	% IR	VFR Hrs.	Total IFR Hrs.
Negative Incentive	41	6			555	46
	(26-62)	(0-40)	53.8%	46.2%	(142-22,000)	(10-4000)
Non-incentive/Baseline Condition	47.5	12.5			1200	175.5
	(19-77)	(1-52)	62.5%	62.5%	(0-13,4000)	(0-15,198)
Positive Incentive	42	4			218	15
	(18-66)	(0-25)	60.0%	33.3%	(9-8,000)	(0-1600)

5.2: Equipment and Weather Simulation

All data for the present study were collected in the Human Factors laboratory in Freeman Hall on the Clemson University campus. The laboratory was complete with a Dell Optiplex 745 with 2.4 GHz Intel dual-core processor and 3072 MB RAM. The desktop computer was connected to a 17” monitor and a projector. The projector was used to present the image of the out of cockpit view in front of the pilot and the monitor was used as a separate view of the instrument panel (Figure 14). The addition of extra RAM and an updated video card, the GeForce 8500, were added to the computer to support the high realism settings used in X-Plane. X-Plane is a flight simulation program that has different versions (home vs. FAA-approved) and add-ons that can be adapted for either home use for the PC-gamer or as a high-tech training tool used for pilot certification. For the present study, the home version was used with the addition of a yoke equipped with throttle and mixture switches and rudder pedals. The Cessna 172 Skyhawk was equipped with a Garmin 430 GPS device in the cockpit that assisted the pilot with navigation throughout the flight with the use of the 'direct-to' function. This function allowed the pilot to view the route from the departure to the destination which was depicted by a pink line in addition to their location along that route. Pilots who had deviated significantly from this route were asked by passengers about their location along the route in order to non-directly advise the pilot to regain proper course in order to ensure that all pilots received a similar weather encounter.

Figure 14: Weather Simulator Laboratory

A weather plug-in was added to X-Plane to ensure that the weather specifications of the scenario were enacted as designed, and the weather gradually deteriorated during the flight (plug-in created by Chris Johnson, University of Wisconsin-Madison; not currently licensed). The specifications used in the weather scenario were created with the assistance of meteorologists from an aviation-focused university. The scenario consists of a route with five measurable points where weather deteriorated. The deterioration in weather included decreased cloud ceiling and visibility, and terrain that crossed over several points of high elevation. As can be seen in the sectional charts in figure 15 (fltplan.com), and indicated with the beige mountains in contrast to the green relatively flat land, the rising terrain occurs early into the flight and continues until marginal conditions are encountered approximately halfway into the flight. The visibility and cloud ceiling specifications are located in table 6, which detail the clear progression from visual to instrument conditions. The weather conditions around KCKB, the departing airport, indicate high visibility and cloud ceiling, in contrast to the area around KOFP, the destination airport, which indicates severely deteriorated visibility and vastly lowered cloud ceiling.

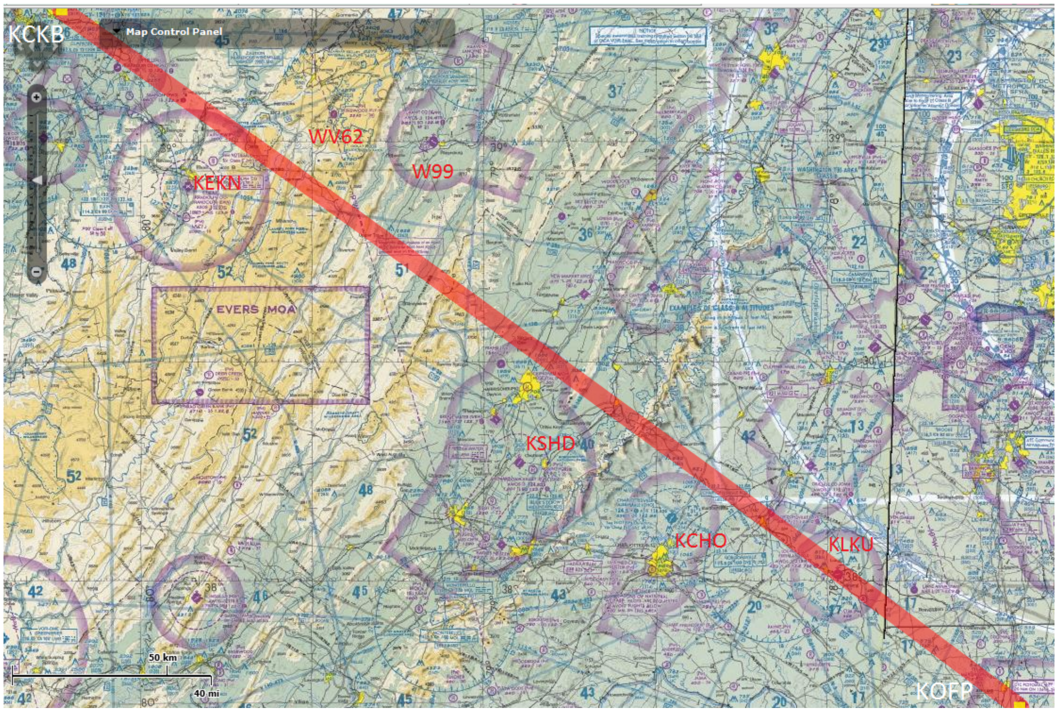


Figure 15: Sectional Charts KCKB-KOFP

Table 6: Airport and Weather information

Airport ID	Location	Airport Name	Classification	Airport		Weather	
				Distance	ETA*	Distance	ETA*
KCKB	Clarksburg, WV	North Central West Virginia	VFR	-----	-----	-----	-----
KSHD	Stauton, VA	Shenandoah Valley Regional	MVFR	89 nm	1:02	74 nm	:51
KCHO	Charlottesville, VA	Charlottesville-Albemarle	IFR	109 nm	1:13	99 nm	1:09
KLKU	Louisa, VA	Louisa County/Freeman Field	LIFR	132 nm	1:25	122 nm	1:25
KOFP	Richmond/Ashland, VA	Hanover County Municipal	LIFR	163 nm	1:42	153 nm	1:47

*= Estimated Time of Arrival (ETA): based on calculation from fltplan.com, an online flight planning software (7500 ft, 112 mph)

This weather scenario included approximately thirty minutes of visually clear conditions until the pilot was expected to reach deteriorating weather. This time period in the scenario allowed for ample time for the pilot to become accustomed to the aircraft prior to experiencing any adverse weather. This period is also advantageous to the passenger who was able to create a rapport with the pilot, leading to an increased familiarity and bonding with the pilot during this first part of the flight.

The weather at the departure airport (KCKB) was mostly clear and sunny. This weather continued until KSHD, where MVFR conditions will began approximately halfway, or 90 miles, into the simulation. The weather deteriorated as the pilot encounters IFR weather around KCHO, or approximately 110 miles into the simulation. It continued to deteriorate to LIFR conditions approximately 132 miles into the simulation around KLKU, and remain LIFR until reaching the destination airport.

Weather Factors

The focus of the weather simulation is on two main weather factors of interest, cloud ceiling and visibility. These two factors are the main variables used to determine weather categorizations for flight type (VFR, MVFR, IFR, LIFR), and have been found to be of utmost importance in pilot weather decision making. During the development of Weatherwise, a cue-based training program, Wiggins & O'Hare (2003) interviewed expert pilots and identified ten important weather cues that pilots utilize to make decisions concerning the weather. Of these ten cues, visibility and cloud ceiling received the highest ratings of importance and were rated as significantly more important by experts than by novices. An additional study by Knecht et al (2005) also focused on these two variables of interest when experimentally manipulating financial incentive. The authors concluded that visibility and ceiling were key components during the pilot's decision to take off into marginal weather conditions. These weather factors interacted with the financial incentive (the motivation), resulting in a decreased sensitivity to the weather conditions due to the bonus. The authors concluded from this study that for the pilots who were influenced by the bonus ("bonus susceptible pilots"), their normal baseline for weather conditions was lowered, and they were more likely to attempt a flight into bad weather.

These two studies show both the effect and importance of the two main weather factors of interest, ceiling and visibility, in a pilot decision making task involving motivation. Although these factors are quite important in any scenario involving aviation weather, many other weather factors play a role as well. These other factors have been addressed by the meteorologists during the creation of the weather scenario, and have been manipulated in order to create a weather environment with a full range of weather features. For the present study the additional variable of terrain was added to ensure that the pilot would not continue to descend as the cloud ceiling deteriorated. The addition of light wind was added to create realism to the scenario.

Adverse Weather Simulations

Given that this study involved a VFR into IMC scenario with the addition of a passenger, it is neither possible nor ethical to duplicate the same weather scenario over multiple conditions in a real flight environment. Therefore, the only option for studying this problem experimentally is to use a simulated environment. Simulation has been used successfully in the past to explore pilot decision making in adverse weather scenarios similar to the present one (Goh & Wiegmann, 2001b; O'Hare & Owen, 1999; O'Hare & Smitheram, 1995; Saxton, 2008; Wiggins & O'Hare, 1995). These studies show that adverse weather simulations provide physiological responses with similar patterns to those found during actual flight (Magnusson, 2002; Veltman, 2002), providing further support for their use.

The complexity of the technology used in these adverse weather studies varied considerably, ranging from a laptop computer (O'Hare & Smitheram, 1995) to an Elite flight simulator with a cockpit body (Saxton, 2008). Given the variety of advanced capabilities of the simulators used in these studies, it is interesting to note that widely available programs such as Microsoft Flight Simulator and X-Plane were frequently the method of choice for portraying weather scenarios. Their widespread availability and ease of use makes them the optimal choice for weather scenarios. X-Plane was chosen for the current study based on its advanced capabilities to design and manipulate weather during flight scenarios, its graphical realism, and widespread use by aviator and throughout the aviation simulation community.

5.3: Questionnaires

Pilots

Questionnaires will be administered both pre- and post-flight for pilots using an online survey tool, surveymonkey.com. Questionnaires were chosen to represent a wide range of factors that can affect the pilot, including demographic information and flight experience (Appendix A), and knowledge of weather conditions, previous accident involvement, risk taking behavior, decision making during flight scenarios, and assertiveness (Appendix B). A debriefing was conducted once the experiment and experimental questionnaires had be finished, and included questions pertaining to the effectiveness of the scenario, including both the simulator and passenger (Appendix C).

The first pre-flight questionnaire for the pilots, the demographic questionnaire, contained questions to determine the age, sex, and flight experience of the pilot. The flight experience variables include total flight hours, cross-country hours, instrument hours, recent flight hours, and certificates and ratings. Post-experimental questionnaires included questions pertaining to pilots' knowledge of weather conditions, determined through the use of ten weather photographs that represent a wide range of weather conditions, and had been used during previous research on the use of weather cues in an adverse weather scenario (Wiggins & O'Hare, 2003a).

Risk taking behavior was measured using two scales. The first measured risk by previous risk taking behavior, and the second and third measured the pilots' agreement with hazardous thought patterns characteristic of risky behavior, and their opinion of their own likelihood of being involved in an accident. The Study of Accidents and Incidents measured previous incident and accident involvement (O'Hare, obtained by request). This questionnaire asks the pilot questions concerning their previous involvement in a wide range of risky situations, from how many times they have been forced to make a precautionary landing to how many times they have flown into IMC without an IFR flight plan. The Aviation Safety Attitude Scale (Hunter, 1995 & 2005) consists of a total of 27 questions. This scale assessed the pilots' level of risk taking using statements such as "I like to practice stalls," and "If I had an accident, it would be the result of bad luck." This questionnaire consists of simple declarative statements that utilize a Likert scale to indicate agreement with the statement on a 1 (strongly disagree) to 5 (strongly agree) scale. Ten of the questions focused on the hazardous attitudes of pilots, and the remaining focused on the risks of aviation, the probability of being involved in an accident, and the pilot's perception of their own skill level.

Decision making was evaluated through the use of the Federal Aeronautical Decision Making/Judgment Questionnaire (Driskill, Weismuller, Quebe, Hand, & Hunter, 1998). This questionnaire consists of 51 short scenario descriptions, with four options that the pilot ranked from the best to worst case outcomes. This study tested "expert" versus "novice" pilots (less than 500 hours), but only found significant differences between the two groups on seven of the questions. Saxton (2008) implemented the same questionnaire in her study that experimentally explored financial incentive and pilot investment in the flight (i.e., sunk cost theory). She found significance in two of the four questions that were analyzed for differences. Due to the large number of items in the original study, only those questions that showed significant results in the previously mentioned studies were included in the current study.

The assertiveness scale by Lorr & More (1980) was the result of a review of a number of the most widely used and respected assertiveness scales to determine any commonalities that might exist between their methods of measuring assertiveness. The authors correlated a number of statements, such as "it's easy for me to make small talk with people I've just met," or "If I've been shortchanged, I go back and complain," with other statements and a number of constructs, or types of assertiveness. From these results, the authors concluded that there were four main types of assertiveness: directiveness, social assertiveness, defense of rights and interests, and independence. The final questionnaire included a total of 24 questions, which represent the eight highest correlated statements on each of the four main types of assertiveness.

Once the simulation is stopped and the accurate consent form is given, the pilots will be given a debriefing based in part on the debriefing used in Knecht et al (2008). This study focused on the importance of financial incentive during a pilots' pre-flight go/no go decision, and asked the pilot questions regarding the impact of the scenario, the different weather conditions, and the financial incentive. The questionnaire was updated to reflect the effect of social pressure on the pilot rather than financial incentive. Additional questions were added to determine the pilots' experience with simulation in general, with Microsoft Flight Simulator X, and with video games.

Passengers

Passengers will be given the same assertiveness scale by Lorr & More (1980) prior to the beginning of the experiment. Additionally, passengers will be given a passenger debrief at the conclusion of each trial. The majority of the questionnaire will pertain to the 30 trials where persuasion is being investigated, but will also contain general questions that relate to the two non-persuasion conditions. The questions will focus on the effectiveness of their persuasive message, and their performance in comparison to previous trials. This participant debriefing can be used in part to determine any differences that might occur due to the passengers' increased familiarity with both the experiment and the persuasion condition.

5.4: Design

The present study consisted of three experimental conditions. The pilots are told that the primary purpose of the experiment is to understand the role of pilot experience during a simulated VFR cross-country flight. The secondary goal is to determine how a passenger gains information about aviation during a simulated flight (in order to describe the presence of the passenger). The first condition will consist of a pilot with a non-incentivized passenger in the cockpit (baseline/non-incentive condition). This condition will consist of a passenger who will not attempt to persuade the pilot to either continue or divert from the planned route. This condition will be used to determine the percentage of time that pilots will typically enter IMC in this particular adverse weather scenario, and can be used as a comparison for the additional two conditions. The second condition will consist of a pilot with a passenger who encourages the pilot continues through the weather past the optimal decision point (positive incentive condition). This condition will consist of a scenario whereby the pilot has to fly the passenger to a job interview that afternoon in Richmond, VA. This incentive condition will create a plausible explanation for the reason for the passenger to pressure the pilot to continue through the weather. The third condition will consist of a passenger who encourages the pilot to deviate from the planned route to a safer course of action, either to an alternate airport or to the departure airport (negative incentive condition). The scenario for this condition is the same as the baseline condition, with the addition of a nervous passenger without prior experience in a small GA plane. This incentive condition will create a scenario that places pressure on the pilot in order to encourage them to divert from the adverse weather.

5.5: Procedure

The procedure for the experiment is depicted visually in figure 16. There is a different scenario for the pilot and passenger. Both of the scenarios are described below by participant type.

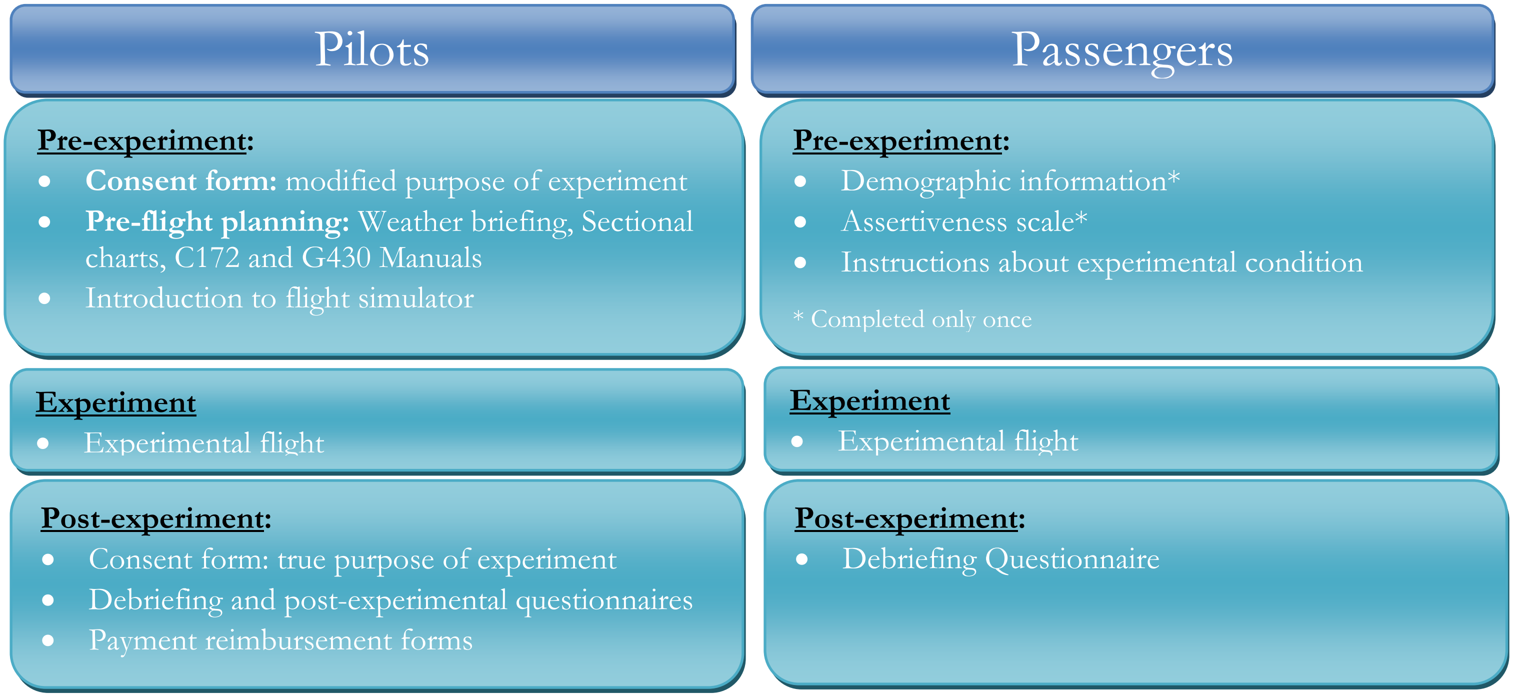


Figure 16: Experimental Protocol

Pilots

During the pilot's scheduled appointment, the pilot will arrive at the Human Factors Laboratory and read over the consent form, which describes the purpose of the study, including risks or discomforts, potential benefits, and contact information for the experimenters and the Institutional Review Board (IRB). The experimenter will discuss the informed consent with the pilot to ensure that the pilot understands and agrees with all the information and requirements of the study. The description of the study in the consent form will differ from the true purpose of the study. During this stage in the experiment, the pilot will receive the first consent form (Appendix F) detailing an experiment with a fictional purpose.

Once the pilot understands the consent form and any questions concerning the experiment are answered, the pilot will begin the pre-flight process. The pilot will be given the weather briefing (Appendix H), the applicable sectional charts, the manual that includes the operating instructions for the Cessna 172 Skyhawk (Cessna, 1971), and the applicable sections for the Garmin 430 GPS manual (Garmin, 2009; Introduction, Navigation, and Direct-to Navigation sections). The Cessna 172 was chosen due to its widespread use by GA pilots, during GA training, and because many of the pilots in the study may not be familiar with more technologically advanced aircraft. Similarly, the Garmin 430 is a basic GPS model that allows the pilot basic navigational functions without the added complexity of more advanced models.

After the pilot has familiarized himself with the pre-flight information, they will be given an overview of the weather briefing and operating conditions for the Cessna 172. They will be introduced to the flight simulator and given a brief explanation on both the use of the simulator, and the Cessna 172 and its equipment. They will be instructed that even though a passenger is present during the flight, that they should treat the flight as their first priority, as they would any other flight.

Once the pilot has indicated they are ready to begin, the pilot will start their flight on the runway at North Central West Virginia Airport (KCKB). As previously described, the scenario will consist of lowering ceilings, reduced visibility and rising terrain. Rising terrain is found at two location during the flight, between the first and second airports, and again (but slightly less so) between the second and third airports where MVFR is encountered. The pilot will then be exposed to one of the three experimental conditions (5.5: Design). The flight will be concluded by one of a few potential outcomes. The optimal decision is for the pilot to perform a change in direction in order to land at the departure airport or to divert to an alternate airport. The other undesirable outcome, from a flight safety standpoint, includes continuing into adverse weather, which may lead the pilot to crash the aircraft. The optimal decision point for the pilot to divert is prior to the pilot entering IFR conditions, sometime either before or shortly after marginal conditions (MVFR) are encountered. The pilot will be allowed to continue through the flight scenario until they either divert from the flight plan or crash the aircraft.

At the conclusion of the experiment, the pilot will be told the true purpose of the study and given the accurate consent form (Appendix F). At this point the pilot may wish to exclude their data from the study (as required by Clemson's IRB). If the pilot chooses to continue with the study, the pilot will complete the debriefing form and is asked to provide any feedback regarding the experiment and flight simulation. They will then be given the debriefing and experimental questionnaires using an online survey tool, surveymonkey.com. The pilot will complete the paperwork to financially compensate them for participating in the study.

Passengers

Passengers will be given the pre-experimental questionnaire (Appendix C) prior to any experimental involvement. These forms will be kept on file for all future trials. Their version of the pre-experimental questionnaire will consist of questions concerning the passengers demographic information in addition to the assertiveness scale by Lorr & More (1980), as previously discussed in section 5.3. The passenger will be introduced to the pilot once the pilot has completed their pre-flight briefing and has been introduced to the flight simulator. During the flight, the passenger will converse with the pilot, and additionally will remain silent concerning the flight and the weather conditions, or will persuade the pilot to continue or divert from the adverse weather (Section 5.4). Either the passenger will be given instructions to remain silent concerning the weather conditions (baseline/ non-incentive condition), to encourage the pilot to continue through the weather (positive incentive condition), or to encourage the pilot to remain safe and divert from the flight plan (negative incentive condition). The passenger will participate in the baseline condition prior to participating in any of the incentive conditions in order to become familiar with both the weather simulation and their expected role in the weather simulation. The participant will complete the incentive conditions only once they have expressed their comfort with the baseline condition and their understanding of what is expected during the incentive conditions. Both passengers will be given suggestions and examples for how to persuade the pilot during each of the incentive conditions, but no script will be given for exact phrasing of the persuasive message. After each experimental trial, the passenger will complete an online debriefing using surveymonkey.com to determine their comfort with the simulation program and condition, their perceived effectiveness, and any additional comments that they feel would be helpful when interpreting the data.

5.6 Analysis of Data

A visual representation of the variables of interest for the current study are located in figure 17. This diagram shows the primary focus of the present study, the effect of different types of persuasion on the pilot in an adverse weather simulation. A secondary focus of the study is the interaction between expertise and persuasion. These two main variables of interest will be investigated to determine their effect on an adverse weather simulation by looking at the continue/divert decision using distance into the weather. Supplementary variables of interest that are predicted to contribute to this decision will be investigated using questionnaires (risk taking, assertiveness, experience). These variables of interest are listed in. The method of analysis used to determine the significance of each variable of interest is given below, with a significance value of .05 used as the cutoff value for significance in the current study.

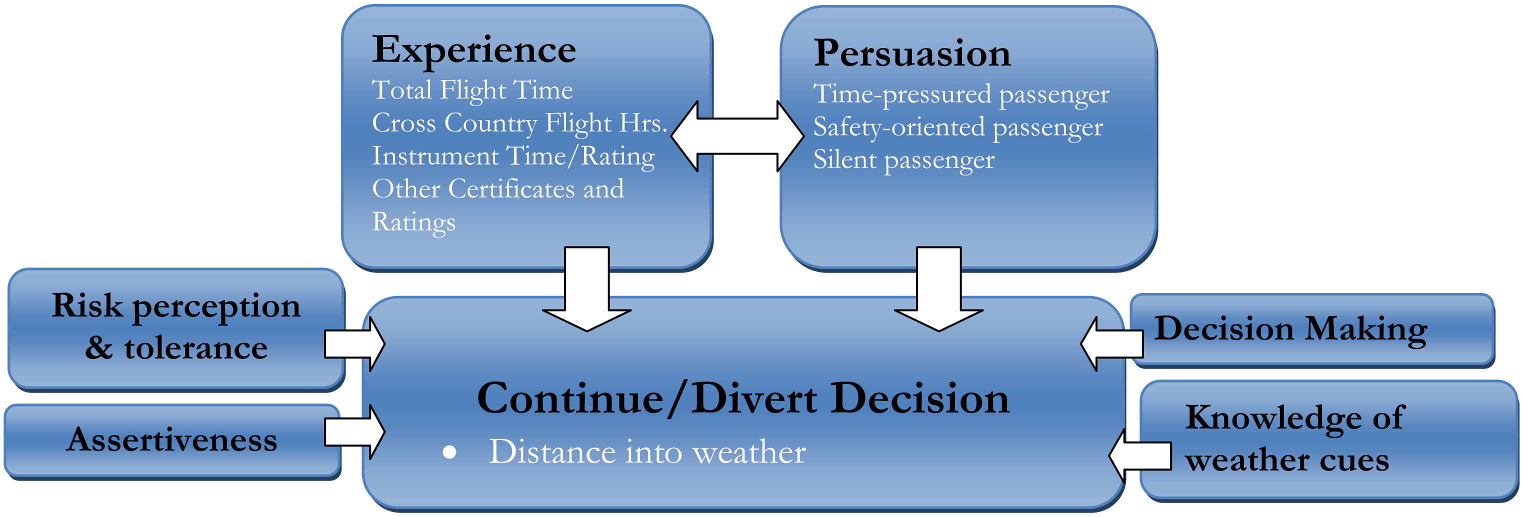


Figure 17: Visual Pictoral of Variables of Interest

Table 7: Listing of Variables of Interest

Independent Variables	Dependent Variables
Persuasion	**Continue/Divert Decision**
Baseline/non-incentive	Distance into weather
Positive incentive	
Negative incentive	**Questionnaires**
	Pilot knowledge of weather
Experience	Weather Photographs
Total hours	**Risk Perception/Tolerance**
Cross-country hours	Study of accidents and incidents
Instrument hours	New Hazard Assessment Scale
Instrument rating	Aviation Safety Attitude Scale
Certificates and Rating	**Decision Making**
Recent flight hours	Federal Aeronautical Decision Making/Judgment
	Assertiveness
	Debriefing
	Effectiveness of study

Variables of Interest

The main focus of the study is the effect of persuasion on the pilot in a weather decision making task. Therefore, the independent variable is the persuasion condition (non-incentive, positive incentive, negative incentive), and the dependent variable is the distance into the weather before diverting. Secondary variables of interest are the measures of pilot experience, (total flight hours, cross country flight hours, certificates and ratings, etcetera), pilot knowledge of weather conditions (photographs), previous accident involvement, hazard assessment, decision making, and assertiveness.

CHAPTER 6: RESULTS

Data from 45 participants were collected for the three incentive conditions: negative incentive (N=14), baseline or non-incentive (N=16), and the positive incentive (N=15) conditions. This data was analyzed using SPSS statistical software in three ways. First, the three incentive conditions were compared to determine if differences existed for time into the weather prior to either diverting or crashing. Second, distance into the weather was used to determine if differences existed between pilots who flew further versus diverted early. Third, pilot experience in the form of both VFR and IFR flight hours was used to determine differences for secondary measures of interest.

6.1 Incentive Condition

The average distance into the weather prior to turning around or diverting differed by incentive category. As was predicted, the 'negative incentive' condition continued an average of 32.3 statute miles (median=29.3), the 'baseline' condition an average of 46.8 statute miles (median=41.2), and the 'positive incentive' condition an average of 67.5 statute miles (median=72.7). Tests to determine if these values were significantly different typically require both the equality of variances and normality of the data. To determine the equality of variances between the three incentive conditions, Levene's test was performed. This test indicated that the variances were not significantly different ($p<.05$). The Shapiro-Wilk test was used to determine if the data represented a normal distribution, and if outliers were present in the data. This statistical test was chosen due to the smaller sample size requirements for the test. Results from both this test (using p<.05 for significance) and the box plot below, indicate that there was one outlier in the 'negative incentive' condition, which can be seen in the top left side of the graph in Figure 18. This outlier was then excluded from the data set and no additional outliers were found.

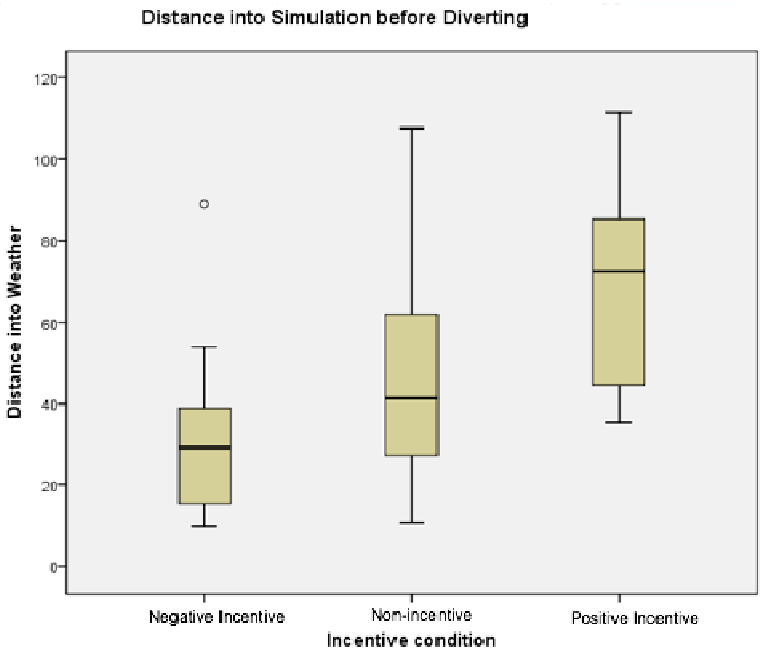


Figure 18: Boxplot to test for Outliers

As can be noted from Figure 18, the upper range for the baseline condition is large, mainly due to the presence of two pilots who had flown significantly farther than the other pilots in the group (Figure 19; see Appendix J for sectional map with final distance noted). The differences between the spread of the data by incentive condition, particularly in the baseline condition, indicate a potentially non-normal distribution. Therefore, a nonparametric statistic, the Kruskal-Wallis will be used to test for significance. Rather than using means to test for significance, this test uses ranked data to determine significance between groups.

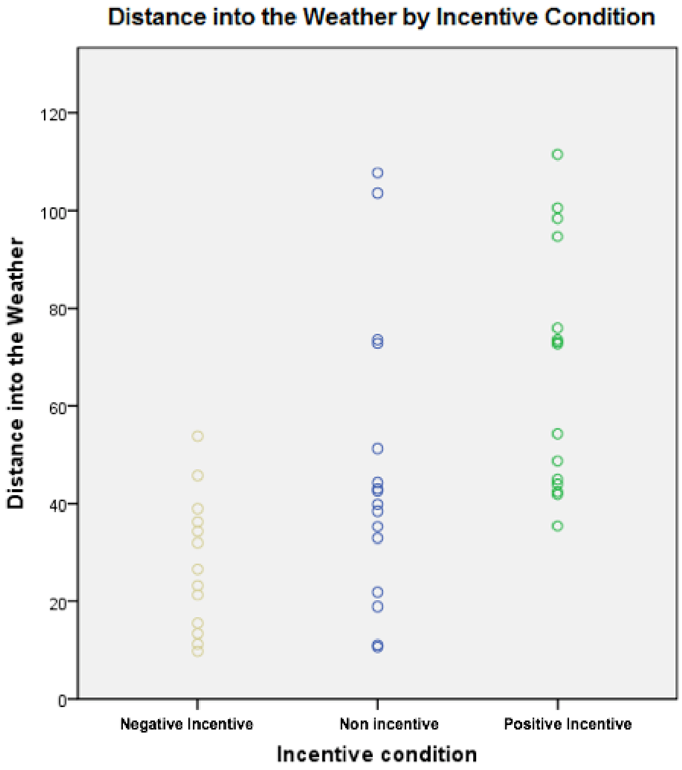


Figure 19: Incentive Condition by Distance into the Weather Distribution

Although the results from the Shapiro-Wilk test indicate no additional outliers in the data set after the outlier had been excluded, the data still did not appear to be normal. As a general rule, tests for normality are generally more reliable with larger sample sizes. Therefore, histograms for each incentive were created to us a visual, and additional, measure of normality. The histograms have an overlay of the normality curve (Figure 20) to show the difference between a normal distribution and the distribution of the current dataset.

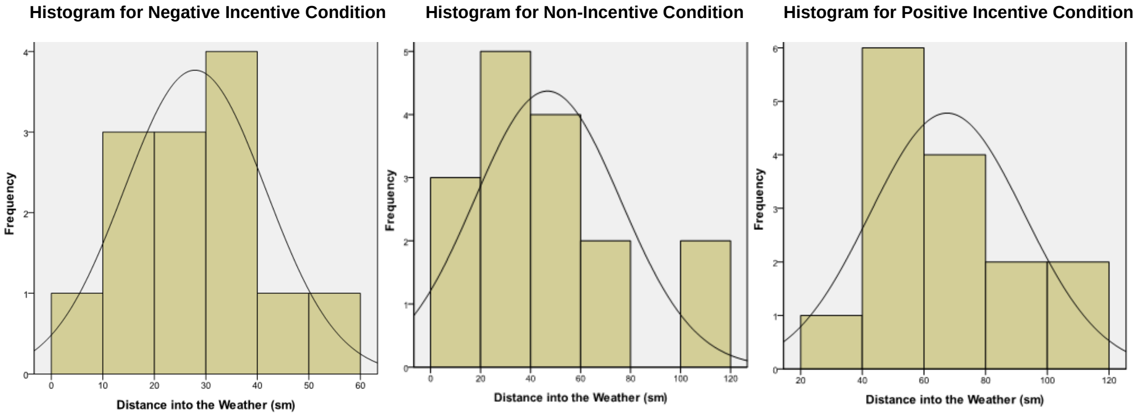


Figure 20: Incentive Condition by Distance into the Weather: Histogram with Normality Curve (In order from left to right: Negative Incentive, Non Incentive, Positive Incentive)

With the outlier excluded, the differences between the three incentive conditions remained consistent with the trend previously mentioned. An updated version of the data can be seen in figure 21 below. This graph shows that the average distance the pilots continued into the weather varied by incentive condition. The pilots in the 'negative incentive' condition were generally among the first to divert (as previously noted with the full sample), on average, 27.9 miles (median=26.6). This number can be compared to the 'non-incentive' and 'positive incentive' conditions, who diverted at an average of 46.7 (median=41.2) and 67.5 miles (median=72.7), respectively. The differences between the three incentive conditions were statistically significant. Post-hoc tests indicated that the differences between the 'negative incentive' and 'positive incentive' conditions were statistically significant ($p<.05$), and the 'baseline' and 'positive incentive' conditions were statistically significant ($p<.05$). The difference between the negative and positive incentive conditions was not statistically significant, but approached significance ($p<.10$).

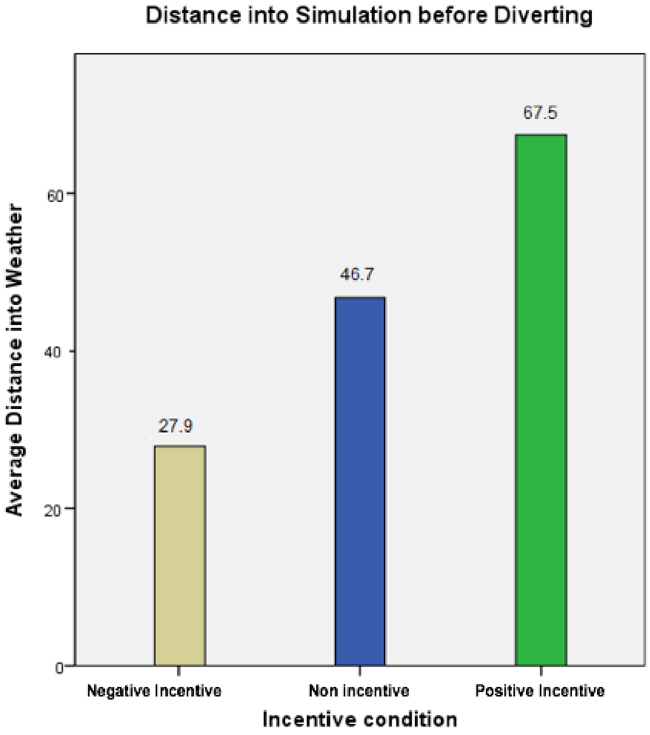


Figure 21: Incentive Condition Average Distance into the Weather (outlier excluded)

Weather Sources Usage

On average, pilots use 4.5 sources of pre-flight weather information. Most frequently these sources include Flight Service Station (FSS, 80%), the Weather Channel (68%), Direct User Access Terminal (DUATS, 64%), and the National Oceanic & Atmospheric Administration (NWS, 61%). Least frequently used are Pilots Automated Telephone Weather Service (PATWS, 15%), other pilots (18%), and commercial vendors (19%). Pilots also varied widely in their categorizations of weather conditions. As can be seen in table 8, in several of the photographs the estimations varied widely based on category, and all but one photograph was represented by each weather classification type.

Table 8: Weather Photograph Responses

	VFR	MVFR	IFR
Photograph 1	39%	52%	9%
Photograph 2	44%	49%	7%
Photograph 3	20%	48%	32%
Photograph 4	35%	12%	53%
Photograph 5	45%	9%	45%
Photograph 6	0%	41%	59%
Photograph 7	41%	45%	14%
Photograph 8	84%	14%	3%
Photograph 9	32%	52%	16%
Photograph 10	18%	63%	19%

Involvement in Accidents and Incidents

Pilots had been involved in an average of .15 accidents (range: 0-3), had flown into IMC when not on an instrument plan an average of .8 times (range: 0-6), and turned back or diverted due to weather an average of 2.5 times (range: 0-6).

6.2 Distance into the Weather

In order to determine if there were differences between pilots who diverted either early versus late, Spearman's rho correlation was used to determine if pilot differed based on their distance into the weather. Spearman's is similar to other nonparametric tests and uses ranked data rather than means, accounting for non-normal data distributions. Correlation analyses were performed for all demographic, flight experience, and questionnaire data. Additionally, Chi squared was used to test nominal data.

Demographic and Flight Experience

The basic demographic information, including age, gender (all males), and location of flight training were all non-significant based on the correlation analyses. Data split based on distance into the weather (bottom 33%, average/middle 33%, and high/top 33% for each incentive category) indicated a trend for several measures. The private pilot's license was found in increasing numbers as pilots continued into the weather further, denoting the absence of more advanced licensure (see Table 9). The measures for VFR, cross country, and pilot in command hours did not exhibit any noticeable trend. No trends could be found for measures of recent flight time, the 90 days VFR flight hours were included in the table for general reference. The instrument rating was highest for the pilots who continued the furthest into the weather, and instrument time, including actual, simulated, and total increased over the three conditions.

Table 9: Median Instrument Flight Hours and Licensure for Three Distance Conditions

	Shortest	Average	Furthest
VFR hours	890	236	530
Private Pilots License	47%	57%	73%
VFR hours: past 90 days	14 hr.	8.7 hr.	18 hr.
Instrument Rating	40%	36%	67%
IFR actual hours	3 hr.	5 hr.	20 hr.
IFR simulated hours	30 hr.	33.5 hr.	55 hr.
IFR total hours	33 hr.	48 hr.	84 hr.
Distance into weather	21.9 sm	42.8 sm	73.6 sm

Flying Information

No differences were found between the type of aircraft typically flown (primary/secondary aircraft) and how far the pilot continued into the weather. The aircraft were then categorized according to type (recreational: Cessna 172 and similar varieties, technically advanced aircraft, experimental, homebuilt, cargo/passenger), but no significant differences or tends were noted. Experience with the Cessna 172 was also not significant. The type of flying the pilot did (recreational, training, commercial, self transport, etcetera) only found one significant difference, self transport flying increased with time into the weather (r=.461).

Weather Sources Usage and Knowledge

Pilots were asked to indicate which pre-flight sources of weather information they used regularly. A significant negative correlation was found for the use of TWB (r=-.271) and the number of weather vendors used (r=-.289) for distance into weather, indicating a decreased usage of TWB and less weather sources overall as distance into the weather increased. The visibility and cloud ceiling personal minimums, and the variation in these minimums were found to be non-significant and without any trends.

Pilots were asked to indicate a weather classification and comfort rating for a series of ten photographs of varying weather conditions. Comfort ratings for all but photograph 1 were non significant, indicating an increase in comfort with photograph 1 associated with an increase in distance into weather (r=.299). Upon completion of the study, pilots were asked to estimate their distance from the destination and give a comfort rating at the time the simulation was stopped. These values were not significant nor displayed any trends.

Simulator Usage and Comfort

Measures for prior use of X-Plane or other simulation software did not differ based on distance condition. The pilot's familiarity with the area and/or route was not significant. The willingness of the pilot to continue through the weather due to it being a simulation and not reality was positively correlated with distance into the weather (r=.362). This finding indicates that the effect of the simulation was correlated with distance into the scenario.

Passenger Influence and Experience

Each pilot was asked to denote their total time spent flying with passengers, and the percentage of time spent with each of a number of different types of passengers. Both the total number of hours spent with passengers and the type of passenger did not exhibit significance or trends. Questions asking the pilot to indicate the influence of the promptings from the passenger were also not significant.

Questionnaires

The questionnaires used to determine pilots attitudes toward themselves and risk taking found two statistically significant differences. The first statement, "Aviation weather forecasts are usually accurate" was negatively correlated with a decreased distance into the weather (r=-.353). A second statement, "I know how to get help from ATC if I get into trouble," was also negatively correlated with distance into the weather (r= -.392). This indicates that as distance into the weather increases, agreements with these statements decrease.

The Aeronautical Decision Making (ADM) Questionnaire found a number of significant differences between the rankings of options for the scenarios. The first question reaching significance (Table 11) is related to the rankings from the scenario involving ATC. Significance was found for the correlation between the first option, "You are cutting it too close and elect to proceed to your alternate," as the first and fourth ratings. Therefore, as distance into the weather increased, this option was rated more frequently as either the first or fourth (last) option by pilots. Additional scenarios that were significantly correlated with distance into the weather include engine problems, health problems prior to flight, safe plane characteristics, and ground fog forming during a flight. Measures of assertiveness were found to be nonsignificant for all questions except, "I'll take a drink (or smoke tobacco or pot) when out with a group even though I really don't want to," (r=.333). Agreement with this statement was correlated with increased distance into the weather scenario prior to diverting.

Table 10: Correlations for Aeronautical Decision Making (ADM) Questions for Distance into the Weather

Scenario and Option (Significant numbered ranking is noted)	r=
After holding for 15 minutes you elect to proceed to your alternate, which is 45 minutes away and is reporting VMC. You receive a clearance and depart that hold. ATC calls you 15 minutes after you leave the hold to tell you that Approach has an open slot and could take you now if you would like to return.	
You are cutting it too close and elect to proceed to your alternate -1 / 4	0.332 / 0.345
You ask for vectors to a closer airport - 1	0.323
You ask ATC to stand-by while you review the situation and your status before making a final decision – 1 / 4	-0.364/0.338
You are cruising at 4500 feet on top of a thin haze layer with the outside air temperature at 65 degrees. It has been twenty-five hours since the engine was overhauled and the run-up check was well within limits. The engine slowly loses RPM with no indications of oil or fuel problems. You suspect carburetor icing and pull on the carb heat. The engine backfires, vibrates and loses RPM fast. You decide to:	
Pull out the mixture, stop the engine and check the fuel selector valve, mag switch settings and declare an emergency. - 2	-0.371
Push in the carb heat, keep the engine running and divert to the closest airfield. – 2 / 3	-0.31/0.311
Keep the carb heat on and see what happens. - 2	0.314
Push in the carb heat, keep the engine at idle, declare an emergency and ask for advice. - 4	0.313
You have paid for and been planning this flight to the Lodge Resort at the Lake for six months. The weather is forecast good VFR with a summer haze under 3000 feet and broken scattered clouds along the route of flight. The only problem is you know you have a minor summer cold. You can clear your ears and only feel a little achy with no headache. You decide to:	
Stick a menthol inhaler in your pocket, take no other medication and go. - 2	-0.484
You are looking for 172s to rent. You have decided the most important thing to look for in a rental plane is:	
A clean engine with clean oil. - 3	-0.332
Smooth skin, no dents or dings. – 2 / 3	-.366 /-0.348
It had rained all day, but the font pushed south of you and cleared the skies. You are out with two friends on a sight seeing trip to the hills 40 miles away and plan to be back before dark. With sunset still an hour away you notice ground fog beginning to form. You decide to:	
Call Flight Watch and cruise back home. - 3	0.384
Call on your home airfield's CATF to see if anyone is there and can tell you what the weather is doing. - 4	-0.333

6.3 Experience Factors

To determine the effect of experience, two main measures of experience were correlated with the data, VFR and IFR hours. VFR flight hours were used rather than time since receiving pilot license due to several pilots who had received their pilot's license decades earlier without a large number of total or recent flight hours. Therefore, VFR hours were more representative of experience. These measures were then correlated with the data using Spearman's rho. Nominal data was analyzed using Chi-squared.

Demographics and Flight Experience

As would be expected, flight experience variables were highly correlated with the majority of other flight experience variables. More specifically, VFR and IFR hours were positively correlated with one another, as were VFR and IFR hours with Pilot in Command hours, IFR hours (actual, simulated, total), cross-country hours, and a commercial pilot's license. VFR hours were positively correlated with recent VFR time (30, 60, 90 days), as was IFR hours and recent IFR time (30, 60, 90). Interestingly, having a PPL was negatively correlated with both VFR and IFR hours. Additionally, an instrument rating was not significantly correlated, either positively or negatively, with either VFR or IFR flight hours.

Flying Information

Flight type (self-transport, recreation, etcetera) was correlated with both VFR and IFR flight hours (Table 11). More specifically, VFR hours were negatively correlated with self transport (r=-.268) and recreational activities (r=-.279), and positively correlated with agricultural/aerial work (r=.305). IFR hours were negatively correlated with self-transport (r=-.356), and positively correlated with agricultural/aerial work (r=.372). Interestingly, negative correlations were associated with both VFR and IFR hours with self-transport and positively associated with agricultural/aerial work.

Table 11: Correlations for Flight Type and VFR and IFR Hours

VFR hours	**r=**
Check which of the following categories best describe your current flying activities: Self-Transport	-0.268
Check which of the following categories best describe your current flying activities: Recreational Activities	-0.279
Check which of the following categories best describe your current flying activities: Agricultural/Aerial Work	0.305
IFR hours	
Check which of the following categories best describe your current flying activities: Self-Transport	-0.356
Check which of the following categories best describe your current flying activities: Agricultural/Aerial Work	0.372

Weather Sources Usage and Knowledge

For VFR flight hours, the use of both TWB (r= .0351) and EFAS (r=.331) were correlated with increased VFR flight hours. Correlations between IFR flight hours and the use of DUATS (r=-.301) and PATWAS (r=.329) was significant. DUATS usage decreased with an increase in flight hours and PAWAS usage increased with IFR flight hours.

Table 12: Correlations for Weather Providers and VFR and IFR Hours

VFR hours	**r=**
What weather providers do you typically use? Transcribed Weather Broadcast (TWB)	0.351
What weather providers do you typically use? Pilots Automated Telephone Weather Answering Service (PATWAS)	0.325
What weather providers do you typically use? Enroute Flight Advisory Service (EFAS)	0.331
IFR hours	
What weather providers do you typically use? Direct User Access Terminal (DUATS)	-0.301
What weather providers do you typically use? Pilots Automated Telephone Weather Answering Service (PATWAS)	0.329

The personal minimums for visibility and cloud ceiling were only significant for IFR visibility conditions (r=-.355), indicating that visibility minimums decreased as IFR hours increased. The categorizations for weather type were nonsignificant. The comfort ratings (1-10 scale) for the weather photographs showed one significant finding for photograph 8 for IFR flight hours (r=-.394), indicating that comfort decreased as IFR hours increased.

Passenger Influence and Experience

Pilots were asked to indicate if they had interactions with passengers when they flew, and if so, with what type of passenger(s). As can be seen in table 13, significant correlations for VFR flight hours were percentage of time spent with a family member (r=-.311), and percentage of time spent with a flight instructor (r=-.404). The correlations indicate that as VFR flight hours increase, time spent with passengers who are family members or flight instructors decrease. Significant correlations with IFR flight hours are percentage of time with passengers who are friends (r=-.299), flight instructors (r=-.307), or none of the categories (r=.372). This correlation indicates that as IFR flight hours increase, percentage of time with passengers who are friends or flight instructors decreases, and time spent with "other" passengers increase.

Table 13: Correlations for Passenger Type and VFR and IFR Hours

VFR hours	r=
What percentage of time spent with passengers onboard is with a family member who is not a spouse?	-0.311
What percentage of time spent with passengers onboard is with flight instructors?	-0.404
IFR hours	
What percentage of time spent with passengers onboard is with friends?	-0.299
What percentage of time spent with passengers onboard is with flight instructors?	-0.307
What percentage of time spent with passengers onboard is with none of the previous categories?	0.372

The questionnaire asking if behavior would change due to the presence of different types of passengers found two significant differences. Less experienced pilots noted that if the passenger had been a family member this would have resulted in a decrease in their willingness to continue through the weather, as compared to more experienced pilots who would not have changed their behavior. A similar trend was found for the same type of question involving a significant other or spouse, the less experience pilots said that their presence would result in a decreased willingness to continue, as compared to the more experienced pilots who stated it would not make a difference.

Table 14: Correlations for Questionnaire: Type of Passenger and VFR and IFR Hours

VFR hours	r=
If your passenger had been a family member, would that have changed your willingness to continue through the weather? (Increase/Decrease/No change)	0.362
If your passenger had been a significant other or spouse, would that have changed your willingness to continue through the weather? (Increase/Decrease/No change)	0.406
Did the fact that this was a simulation (and not reality) affect your willingness to continue through the weather? (Increase/Decrease/No change)	-0.49
IFR hours	
If your passenger had been a significant other or spouse, would that have changed your willingness to continue through the weather? (Increase/Decrease/No change)	0.308
If your flight mission had been critical (for example, delivering a human heart for surgery), would that change your willingness to continue through the weather? (Increase/Decrease/No change)	-0.309
Did the fact that this was a simulation (and not reality) affect your willingness to continue through the weather? (Increase/Decrease/No change)	-0.438

Simulator Usage and Comfort

A negative correlation was found for previous use of X-Plane and/or other simulation technologies for both VFR (r=-.34) and IFR (r=-.328) flight hours. Pilots with less flight hours used simulation more frequently. No significant differences were found in the percentage of pilots familiar with the route or area. The self-assessment of the impact of the simulator on technology was negatively correlated to both VFR (r=-.49) and IFR (r=-.438) flight hours. This indicates that pilots with more flight experience were less impacted by the use of the technology. The explanation of not being able to get injured was agreed with more frequently by those pilots with less experience, than those pilots with higher levels of experience.

Questionnaires

Questions pertaining to previous accident/incident involvement found a significant difference for several questions for both VFR and IFR hours. All statements were associated with positive correlations, indicating an increase in VFR and/or IFR hours with an increase in the number of incidents and/or accidents (Table 15).

Table 15: Correlations for Accident and Incident Involvement for VFR and IFR Hours

VFR hours	**r=**
How many times have you run so low on fuel that you were seriously concerned about making it to an airport before you ran out?	0.439
How many times have you made a precautionary or forced landing at an airport other than your original destination?	0.684
How many times have you made a precautionary or forced landing away from an airport?	0.329
How many times have you had a mechanical failure which jeopardized the safety of your flight?	0.605
How many times have you flown into areas of instrument meteorological conditions, when you were not on an instrument flight plan?	0.314
How many times have you turned back or diverted to another airport because of bad weather while on a VFR flight?	0.569
IFR hours	
How many aircraft accidents have you been in (as a flight crew member)?	0.303
How many times have you run so low on fuel that you were seriously concerned about making it to an airport before you ran out?	0.392
How many times have you made a precautionary or forced landing at an airport other than your original destination?	0.557
How many times have you had a mechanical failure which jeopardized the safety of your flight?	0.533
How many times have you turned back or diverted to another airport because of bad weather while on a VFR flight?	0.462

Questions pertaining to the agreement with aviation statements indicate that as pilots gain VFR and IFR flight hours, experience can be found in the assessment of their ability to deal with stress, maintain proficiency, knowledge of aircraft, and of being cautious, capable, and careful (Table 16).

Table 16: Correlations for Aviation Safety Attitude Scale for VFR and IFR Hours

VFR hours	
I would duck below minimums to get home	-0.311
I am capable of instrument flight	0.753
I am a very careful pilot	0.389
I am a very capable pilot	0.626
I am very skillful on controls.	0.709
I know aviation procedures very well.	0.814
I deal with stress very well.	0.647
I have a thorough knowledge of my aircraft.	0.327
I am a very cautious pilot.	0.382
I find it easy to understand the weather information I get before flights.	0.47
I fly enough to maintain my proficiency.	0.336
I know how to get help from ATC if I get into trouble.	0.317
There are very few situations I couldn't get out of.	0.399
I often feel stressed when flying in/near weather.	-0.453
IFR hours	
I am capable of instrument flight	0.8
I am a very capable pilot	0.582
I am very skillful on controls.	0.709
I know aviation procedures very well.	0.814
I deal with stress very well.	0.647
I have a thorough knowledge of my aircraft.	0.325
I find it easy to understand the weather information I get before flights.	0.401
I fly enough to maintain my proficiency.	0.367
I know how to get help from ATC if I get into trouble.	0.307
There are very few situations I couldn't get out of.	0.475
I often feel stressed when flying in/near weather.	-0.369

Significant decision scenarios include examples of engine problems, taxiing passengers around the runway, and holding for a vector approach. The decision scenarios and ratings of options are given in Table 17. The assertiveness questionnaire was used to determine if differences in assertiveness exist between pilots of different experience levels. Only one statement was significant for either VFR or IFR flight hours. The statement, "When a friend borrows something of value to me and returns it damaged I don't say anything," was positively correlated (r=.523) with IFR flight hours.

Table 17: Correlations for Aeronautical Decision Making (ADM) Questions for VFR and IFR Hours

VFR hours	**r=**
You are cruising at 4500 feet on top of a thin haze layer with the outside air temperature at 65 degrees. It has been twenty-five hours since the engine was overhauled and the run-up check was well within limits. The engine slowly loses RPM with no indications of oil or fuel problems. You suspect carburetor icing and pull on the carb heat. The engine backfires, vibrates and loses RPM fast. You decide to:	
Push in the carb heat, keep the engine at idle, declare an emergency and ask for advice. – 3	0.425
Push in the carb heat, keep the engine at idle, declare an emergency and ask for advice. - 4	-0.365
Bad weather forced you to cancel flying your boss into another city where he is to address a convention. There are openings on a flight going to the same city departing from the airline terminal on the other side of the airport in 15 minutes. It will take too long to call a taxi so he asks you to run him over to the terminal in the 172. You decide to:	
Say you're sorry but it is illegal for you to deliver passengers to the back side of the terminal and help find a ride through the FBO. - 2	-0.315
En route weather to the fuel stop. - 3	0.342
Weather at the final destination. - 1	0.362
IFR hours	
After holding for 15 minutes you elect to proceed to your alternate, which is 45 minutes away and is reporting VMC. You receive a clearance and depart that hold. ATC calls you 15 minutes after you leave the hold to tell you that Approach has an open slot and could take you now if you would like to return.	
You accept the offer and are given a vector for the approach - 2	-0.341
You accept the offer and are given a vector for the approach - 4	0.348
Keep the carb heat on and see what happens. - 1	0.306
Push in the carb heat, keep the engine at idle, declare an emergency and ask for advice. - 3	0.401
Bad weather forced you to cancel flying your boss into another city where he is to address a convention. There are openings on a flight going to the same city departing from the airline terminal on the other side of the airport in 15 minutes. It will take too long to call a taxi so he asks you to run him over to the terminal in the 172. You decide to:	
Say you're sorry but it is illegal for you to deliver passengers to the back side of the terminal and help find a ride through the FBO. - 2	-0.39

CHAPTER 7: DISCUSSION

The purpose of this study is to determine the effect of passenger influence during a VFR into IMC scenario. Previous research in social psychology, flight crew interactions, and analyses of accident statistics have suggested that passenger influence does play a role in pilot decision making. This study extended those theories and findings to an experimental setting where the impact of passenger influence on the pilot's distance into the weather was measured. Results conclude that the distance the pilot continued into the weather for positively motivated pilots (persuaded to continue) increased, and decreased for the pilots who were negatively motivated (persuaded to divert). What is key is that these findings occurred in a low-tech desktop simulator, without many of the features present during real flight, including motion, high-fidelity graphics, or the threats to safety. Due to, and particularly given the presence of these limitations, these results provide additional support for the conclusion that passenger influence does impact pilot decision making during a VFR into IMC scenario.

In order to gain additional insight into why certain individuals might be more susceptible to passenger influence than others, a series of questionnaires and surveys were used to measure a wide range of factors previously thought to influence pilots during VFR into IMC situations. Differences in pilot skill, licensure, flight time, and age were used to determine their impact on pilot behavior. Although not significant, a clear increase in instrument time and instrument ratings were found for pilots who had continued further into the weather. Additionally, the percentage of pilots with a private pilots license increased, and the number of more advanced licenses (e.g., commercial and ATP) decreased.

These findings can be summarized into two findings. First, private pilots with instrument ratings are continuing further than either the low time VFR pilots or the high time commercial and/or ATP pilots. Second, these findings are compounded by the lack of significance based on experience for the weather photographs, leading to the conclusion that lack of knowledge of weather conditions was not an issue for the pilots in the current study. These results are contrary to what had previously been found in VFR into IMC accident analyses and simulator studies, that the pilots involved in these accidents are mainly low time VFR pilots with no instrument rating, and an inadequate knowledge of weather conditions. Therefore, unlike the previously discussed studies that supported lack of expertise as the cause of these accidents (e.g., situation assessment), results from the current study show support for a motivationally based theory of passenger influence. Questionnaires intended to determine support for this conclusion were generally nonsignificant, non-predictive, and inadequate for determining differences in pilot decision making. These findings are unfortunately consistent with previous studies measuring motivation in aviators (e.g., Knecht, Harris, & Shappell, 2003).

One nonsignificant finding that was particularly revealing was the finding from a question used to determine the impact of the experimental condition on the pilot. The nonsignificant responses and a lack of data trend for the distance into the weather indicates that the pilots were unaware of the impact of the passenger on their decision to either continue or divert during the experimental scenario. The lack of awareness of the influence of the passenger pressure, the significant differences between the incentive conditions, and the experimental setting lacking the consequences of actual flight, leads to a problematic situation worthy of future investigations.

Anecdotal evidence from interactions with and observation of the pilots during the study lead to several additional conclusions. First, pilot's acceptance of weather conditions are incredibly different. The original pre-flight briefing suggesting the potential for marginal weather conditions had to be modified after several participants stated that they would not file a VFR flight plan, particularly given the mountainous conditions they would be facing en-route. Second, as participants varied widely in both skills and abilities, this wide range continued in regards to both comfort and experience with the flight simulator. This effect was magnified by the touchiness of the simulator in comparison to a real aircraft (or more realistic flight controls). Several pilots required additional time to adjust to the simulator before they were comfortable to take part in the experimental simulation. Third, the response of the pilots to the study, including both the weather briefing and the simulated flight, varied widely. Some pilots studied the briefing materials for 30 minutes or more (and had to be asked to finalize their pre-flight briefing), and other pilots only required 5-10 minutes to become familiar with the materials. This was also evident during the simulated flight, as some pilots did not take the simulated flight as seriously as others. These differences were not evident in the questionnaire data.

Several of these points are consistent with the limitations of this study, and could be points for future improvements. It is a given that for any experiment using a flight simulator certain aspects of realism are sacrificed, which ensures the safety and repeatability of the study. That being said, one of the main difficulties for the pilots in this study was being able to adjust to the touchiness of the controls. Although several re-workings of the controls were necessary for calibration, a realistic handling of the aircraft was never fully achieved. Although the pilots were given an explanation of this limitation prior to takeoff, several pilots, particularly those without previous simulator experience, had difficulties. Therefore, an improved handling through the use of more advanced controls would be helpful for future studies. An additional improvement that could be made for similar studies is the use of a more realistic weather briefing. Several of the pilots commented that they do not typically receive a weather briefing in the format it was given. Therefore, the use of an abbreviated briefing via the computer would allows the pilot to interact with the information in a format more similar to what they typically use.

CHAPTER 8: CONCLUSION

It is impressive that even in a simulated setting (albeit low-fidelity), a clear and distinctive trend could be found for the impact of passenger influence on pilot behavior during an adverse weather scenario. The additional information gathered from pilots tentatively suggests that the less experienced pilots may be more cautious, and the more experienced pilots more able to handle a variety of flight conditions. This leaves the pilots with a moderate level of experience (500-1000 VFR hours) as the ones most vulnerable. This conclusion is supported by other authors (eg, Craig, 2001), who suggest that there is a period of increased vulnerability when a pilot is no longer under the supervision of a flight instructor, but has enough experience to believe that they are capable to handle any situation, without the additional experience to know otherwise. Findings from other questionnaires were not as helpful as would be expected in understanding the thought processes behind pilot behavior.

Even though no significant differences were found between the distance prior to diverting for the two individuals tasked with the role of the passenger, it would be interesting to determine what characteristics of these individuals contributed to the pilot's decision to continue further into the weather. Is this inability to resist persuasion a trait consistent among a variety of flight conditions and operations? Due to the lack of significant findings for the questionnaires in the current study, the creation of a tool to determine which pilots are most at risk for passenger influence would be particularly useful for future research in this field. The second part of the process, the ability to decrease potentially harmful and dangerous motivational behavior, is quite complex and may be very difficult to answer.

Although additional knowledge would be useful to helping solve this portion of the problem, from what we now know, one of several potential solutions can be explored for effectiveness.

One potential solution is the new driver regulations that restrict driving with peers for newly licensed teen drivers. Although this solution has found success for young drivers, both the population (teen versus adult), and the results from this study showing nonsignificant findings for both age and VFR hours, indicates that this solution would not be a feasible option. An additional potential solution might be the use of training to make pilots more aware of this potentially dangerous situation, which has been used successfully for ADM/judgment training for GA pilots, and during CRM and assertiveness training for commercial pilots. This solution may be particularly effective due to the results indicating that pilots were not aware that the passenger was influencing them during the simulation, contrary to the significant findings. A third potential solution would be the use of pre-flight briefings for passengers. The pilot would be able to explain to the passenger the limitations of both the aircraft and their personal minimums regarding weather in order to educate the pilot on aviation safety. Conversely, the pilot could inform the passenger to alert them if they feel uncomfortable with any flight conditions. A final potential solution would be the use of weather technology, such as GPS, NextGen, or any other technology to measure current weather information. This, or similar technology, could provide an updating recommendation for the pilot in-flight based on the minimums he or she has previously chosen. Therefore, the pilot would be alerted when a change in plans is necessary, and no subjective judgment would be included in the decision process.

This research should be considered a first step in a multi-step effort to understand, mitigate, and prevent VFR into IMC accidents. It is hoped that the knowledge gained through this research contribute to a body of work that can impact aviation safety for VFR into IMC accidents and incidents.

APPENDICES

APPENDIX A: Pre-Experimental Questionnaires for Pilots

Pilot Pre-Experiment Questionnaire: Part 1: Demographic and Flight Information

1. **Your Age:** ______

2. **Sex**: Male ______ Female ______

3. **Place you learned to fly**: City, State: ________________________

4. **Years since received license** ___________

5. **Current license held:**

Private Pilots License ____	Commercial Pilots License _____
Instrument Rating ____	Air Transport Private License ____
Flight Instructor ____	

6. **Please list your total flight hours:**

VFR _________

IFR: actual _________

IFR: simulated _________

IFR: total _________

Cross country (>50nm) _________

Pilot in command _________

7. **Please list your recent flight hours:**

Past 30 days VFR: __________ Past 30 days IFR: __________

Past 60 days VFR: __________ Past 60 days IFR: __________

Past 90 days VFR: __________ Past 90 days IFR: __________

8. **Hours as Pilot in Command: _________**

9. **What percentage of your time do you spend with passengers? _________**

10. **What percentage of the time you spend with passengers is spent with the following type of passengers (responses should sum to 100%):**

Friend _________ Family member _________
Spouse/significant other _________ Flight instructor _________
Other _________

11. **Date of Last Medical certificate ____________** Class of Medical Certificate _____________

Waivers? _______________

12. **Date of last instructor training _______________**

13. **Aircraft type usually flown:**

Primary Make/ Model: __________________________ Percentage of time in aircraft: _______

Secondary Make/ Model: ________________________ Percentage of time in aircraft:_______

14. **Do you have any experience with flying a Cessna 172?** Please list an approximate amount of time spent flying, and indicate if it was recent.____

15. **Check one of the following categories which best described your current flying activities:**

Training ______ Self-Transport _____ Agriculture/Aerial work ______

Recreational ______ Commercial Transport ______ Flights for hire ______

Other (please specify) ___________________________

16. Do you participate in the WINGS program (or any similar program? If so, how often?:

____

17. **What weather providers do you usually use?**

Flight Service _____ Direct User Access Terminal (DUATS) _____ Weather Channel _____

National Oceanic & Atmospheric Administration (NWS) ______

Transcribed Weather Broadcast (TWB) ______

Hazardous Inflight Weather Advisory Service (HIWAS) ______

Enroute Flight Advisory Service (EFAS) ______

Pilots Automated Telephone Weather Answering Service (PATWAS) ______ Other pilots______

Commercial vendors ______ if so, please specify: __________________

Other ______

APPENDIX B: Post-Experimental Questionnaires for Pilots

For the 10 photographs:

1. Please indicate if you would classify the weather condition by choosing Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR).

2. Please indicate your comfort rating in continuing through the weather conditions on a scale from 1-10 (1= the least comfortable, 10= most comfortable)

Photograph 1:

Photograph 1: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 1: Please estimate the following:
Comfort rating (1= most, 10= least): _____

Photograph 2:

Photograph 2: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 2: Please estimate the following:

Comfort rating (1= most, 10= least): _____

Photograph 3:

Photograph 3: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 3: Please estimate the following:

Comfort rating (1= most, 10= least): _____

Photograph 4:

Photograph 4: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 4: Please estimate the following:

Comfort rating (1= most, 10= least): _____

Photograph 5:

Photograph 5: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 5: Please estimate the following:

Comfort rating (1= most, 10= least): _____

Photograph 6:

Photograph 6: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 6: Please estimate the following:

Comfort rating (1= most, 10= least): _____

Photograph 7:

Photograph 7: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 7: Please estimate the following:

Comfort rating (1= most, 10= least): ____

Photograph 8:

Photograph 8: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 8: Please estimate the following:

Comfort rating (1= most, 10= least): _____

Photograph 9:

Photograph 9: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 9: Please estimate the following:

Comfort rating (1= most, 10= least): _____

Photograph 10:

Photograph 10: Please indicate if you would classify the weather condition as Visual Flight Rules (VFR), Marginal VFR (MVFR), or Instrument Flight Rules (IFR): **VFR** **MVFR** **IFR**

Photograph 10: Please estimate the following:

Comfort rating (1= most, 10= least): _____

The definition of an **accident** is as follows: an event involving fatal or serious injury (requiring more than 48 hours hospitalization or involving fractures, burns, or internal injury) to any person in an aircraft or around an aircraft, or damage or structural failure to an aircraft requiring major repair or replacement of a component or complete hull loss.

How many aircraft accidents have you been in (as a flight crew member)?	0 1 2 3 4 5 6+
How many times have you run so low on fuel that you were seriously concerned about making it to an airport before you ran out?	0 1 2 3 4 5 6+
How many times have you made a precautionary or forced landing at an airport other than your original destination?	0 1 2 3 4 5 6+
How many times have you made a precautionary or forced landing away from an airport?	0 1 2 3 4 5 6+
How many times have you inadvertently stalled an aircraft?	0 1 2 3 4 5 6+
How many times have you become so disoriented that you had to land or call ATC for assistance in determining your location?	0 1 2 3 4 5 6+
How many times have you had a mechanical failure which jeopardized the safety of your flight?	0 1 2 3 4 5 6+
How many times have you had an engine quit because of fuel starvation, either because you ran out of fuel or because of an improper pump or fuel tank selection?	0 1 2 3 4 5 6+
How many times have you flown into areas of instrument meteorological conditions, when you were not on an instrument flight plan?	0 1 2 3 4 5 6+
How many times have you turned back or diverted to another airport because of bad weather while on a VFR flight?	0 1 2 3 4 5 6+

Rate the following statements from on a 5 (strongly agree) to 1 (strongly disagree) scale.

I would duck below minimums to get home. ______

I am capable of instrument flight. ______

I am a very careful pilot. ______

I never feel stressed when flying. ______

The rules controlling flying are much too strict. ______

I am a very capable pilot. ______

I am so careful that I will never have an accident. ______

I am very skillful on controls. ______

I know aviation procedures very well. ______

I deal with stress very well. ______

It is riskier to fly at night than during the day. ______

Most of the time accidents are caused by things beyond the pilot’s control. ______

I have a thorough knowledge of my aircraft. ______

Aviation weather forecasts are usually accurate. ______

I am a very cautious pilot. ______

The pilot should have more control over how he/she flies. ______

Usually your first response is the best response. ______

I find it easy to understand the weather information I get before flights. ______

You should decide quickly and then make adjustments later. ______

It is very unlikely that a pilot of my ability would have an accident. ______

I fly enough to maintain my proficiency. ______

I know how to get help from ATC if I get into trouble. ______

There are very few situations I couldn’t get out of. ______

If you don’t push yourself and the aircraft a little, you’ll never know what you could do. ______

I often feel stressed when flying in/near weather. ______

Sometimes you just have to depend on luck to get you through. ______

Speed is more important than accuracy during an emergency. ______

First, carefully read the scenario and the four listed Alternative responses. Assume you have leased a Cessna 172 in good condition. Based on your experience, decide which of the alternatives you would most likely select as your course of action, what would be your first, second, third and fourth choices, as if you were in the pilot scenario.

1. After holding for 15 minutes you elect to proceed to your alternate, which is 45 minutes away and is reporting VMC. You receive a clearance and depart that hold. ATC calls you 15 minutes after you leave the hold to tell you that Approach has an open slot and could take you now if you would like to return.

1 2 3 4 a. You accept the offer and are given a vector for the approach

1 2 3 4 b. You are cutting it too close and elect to proceed to your alternate

1 2 3 4 c. You ask for vectors to a closer airport

1 2 3 4 d. You ask ATC to stand-by while you review the situation and your status before making a final decision.

2. Three of your closest friends have bought you a choice ticket and are paying for you to rent this airplane and fly the four of you the 180 miles up to the university in the morning for the "BIG" early afternoon football game, then back in the early evening. Another friend will meet you at the college Airport and drive all of you to the game and back. Departure weather was overcast 3000 ft ceiling with 5 miles and light haze with temperatures in the 60s. Pilots flying the same route reported en-route weather as occasional 1500 ft ceilings with 3 miles visibility and scattered showers. The College Airport is clear with bright sunshine. Forty- five miles from the College Airport you have descended to 1000 feet staying just below the ceilings and encounter rain dropping visibility to under 3 miles. The terrain is flat farmland with no published obstacles above 250 ft tall. You decide to:

College Airport: Runway 5000x100 and 4099x100, tower 24 hrs, ARSA none, lighted runway, telephone, and 24 hr maintenance

Madison County Airport: Runway 3800x75, no tower, no ARSA, lighted runway, telephone available, no maintenance.

1 2 3 4 a. Remain under the clouds, keep visual contact with the ground and scoot through.

1 2 3 4 b. Do a 180 and return home.

1 2 3 4 c. Divert to the Madison County Airport located at 7 o'clock 50 NM and wait for the worst weather to pass.

1 2 3 4 d. Put it to a vote.

3. You are cruising at 4500 feet on top of a thin haze layer with the outside air temperature at 65 degrees. It has been twenty-five hours since the engine was overhauled and the run-up cheek was well within limits. The engine slowly loses RPM with no indications of oil or fuel problems. You suspect carburetor icing and pull on the carb heat. The engine backfires, vibrates and loses RPM fast. You decide to:

1 2 3 4 a. Pull out the mixture, stop the engine and check the fuel selector valve, mag switch settings and declare an emergency.

1 2 3 4 b. Push in the carb heat, keep the engine running and divert to the closest airfield.

1 2 3 4 c. Keep the carb heat on and see what happens.

1 2 3 4 d. Push in the carb heat, keep the engine at idle, declare an emergency and ask for advice.

4. Bad weather forced you to cancel flying your boss into another city where he is to address a convention. There are openings on a flight going to the same city departing from the airline terminal on the other side of the airport in 15 minutes. It will take too long to call a taxi so he asks you to run him over to the terminal in the 172. You decide to:

1 2 3 4 a. Start the engine and ask ground control for permission to taxi to the back of the terminal, drop off a passenger and taxi back to the FBO ramp.

1 2 3 4 b. Start and ask ground control for permission to taxi around the airport for a maintenance check and conveniently drop the boss off near the terminal.

1 2 3 4 c. Say you're sorry but it is illegal for you to deliver passengers to the back side of the terminal and help find a ride through the FBO.

1 2 3 4 d. Ask ground control if there is any way a representative from the airline could meet you at a door to the ramp and escort the boss into the terminal.

5. You have paid for and been planning this flight to the Lodge Resort at the Lake for six months. The weather is forecast good VFR with a summer haze under 3000 feet and broken scattered clouds along the route of flight. The only problem is you know you have a minor summer cold. You can clear your ears and only feel a little achy with no headache. You decide to:

1 2 3 4 a. Take the minimal dosage of cold tablets and go.

1 2 3 4 b. Cancel the flight.

1 2 3 4 c. Call your doctor and ask for a prescription for medication.

1 2 3 4 d Stick a menthol inhaler in your pocket, take no other medication and go.

6. You are looking for 172s to rent. You have decided the most important thing to look for in a rental plane is:

1 2 3 4 a The overall appearance, is it neat and does it look cared for

1 2 3 4 b. A clean engine with clean oil.

1 2 3 4 c. New COM/NAV radios.

1 2 3 4 d. Smooth skin, no dents or dings.

7. When you get your weather briefing for a cross country flight requiring at least one fuel stop, which part of the forecast do you consider the most critical:

1 2 3 4 a. The weather at the departure point.

1 2 3 4 b. En route weather to the fuel stop.

1 2 3 4 c. The weather at the fuel stop.

1 2 3 4 d Weather at the final destination.

8. It had rained all day, but the font pushed south of you and cleared the skies. You are out with two friends on a sight seeing trip to the hills 40 miles away and plan to be back before dark. With sunset still an hour away you notice ground fog beginning to form. You decide to:

1 2 3 4 a. Apply full power and race back to the home Airport.

1 2 3 4 b. Call Flight Watch and cruise back home.

1 2 3 4 c. Call on your home airfield's CATF to see if anyone is there and can tell you what the weather is doing.

1 2 3 4 d. Go directly to an Airport you know is closer than your home Airport, land and find out what the weather is doing.

Please indicate how characteristics or descriptive of you each of the following statements is by using a rating scale from 1-6:

1: very uncharacteristic of me, extremely nondescriptive
2: rather uncharacteristic of me, quite nondescriptive
3: somewhat uncharacteristic of me, slightly nondescriptive
4: somewhat characteristic of me, slightly descriptive
5: rather characteristic of me, quite descriptive
6: very characteristic of me, extremely descriptive

1. I have no particular desire to be the leader of a group. ________
2. It is difficult for me to start a conversation with a stranger. ________
3. When someone repeatedly kicks the back of my chair in a movie or on an airplane I don't say anything. ________
4. In discussions I go along with the will of the group. ________
5. I shy away from situations where I might be asked to take charge. ________
6. When I meet new people I usually have little to say. ________
7. It is uncomfortable for me to exchange a purchase I've found to be defective. ________
8. I try to dress like the other people I work or go to school with. ________
9. I let others take the lead when I'm on a committee. ________
10. I feel uncomfortable around people I don't know. ________
11. When a friend borrows something of value to me and returns it damaged I don't say anything. ________
12. I'll take a drink (or smoke tobacco or pot) when out with a group even though I really don't want to. ________
13. I would avoid a job which required me to supervise other people. ________
14. I find it difficult to make new friends. ________
15. When someone interrupts me in a serious conversation, I find it hard to ask him/her to wait a minute. ________
16. When there is disagreement I accept the decision of the majority. ________
17. I work best in a group when I'm the person in charge. ________
18. At a party I find it easy to introduce myself and join a group conversation. ________
19. If I have been "short-changed" I go back and complain. ________
20. My opinions are not easily changed by those around me. ________
21. I seek positions where I can influence others. ________
22. It's easy for me to make "small talk" with people I've just met. ________
23. If the food I am served in a restaurant is unsatisfactory I complain to the waiter. ________
24. I defend my point of view even though someone in authority disagrees with me. ________
25. I am usually the one who initiates activities in my group. ________

26. I find it easy to talk with all kinds of people. ________

27. If a friend betrays a confidence I express my annoyance to him/her. ________

28. I nearly always argue for my viewpoint if I think I'm right. ________

29. In an emergency I get people organized and take charge. ________

30. When I am attracted to a person I've not met I actively try to get acquainted. ________

31. When an acquaintance takes advantage of me I confront him/her. ________

32. I follow my own ideas even when pressured by a group to change them. ________

APPENDIX C: Pilot Debriefing

How long had the flight been going on before it ended (approximate in minutes)? _________

How far do you estimate you were from the destination when the program ended (approximate in sm)? _____

What do you think the weather conditions were when the program ended? Estimate the following:

Weather condition: **VFR** **MVFR** **IFR** **LIFR**

Comfort rating (1= least, 10= most): _______

What is your own normal personal minimum for VFR visibility? ________

What is your normal personal minimum for VFR cloud ceiling? ________

Are these minimums rock-solid, or do you adjust them a little, depending on the circumstances?________

Have you ever flown this particular route before (or in this area)? ________

Have you used Microsoft Flight simulator X or an earlier version previously? Y N

If you have used another flight simulator list here and answer the questions below:_______________

If yes, for what purpose did you use Microsoft Flight Simulator? Recreation Training

If for another reason, please explain: _________________________

If yes, how much experience do you have using Microsoft Flight Simulator? Estimated hours used: _______

If yes, did you use flight controls with Microsoft Flight Simulator? ___________________________________

Do you have video game experience? If so, what types of games do you play, and how much experience for each? *Types of games: action, adventure, role playing, strategy, vehicle simulators, etc.; list hour/ how often you play each*

____

____

How often do you fly with passengers? Usually ______ Sometimes _____ Rarely ______ Never ______

Who is your typical passenger? What is their relationship to you? ___________________________________

Did the addition of passengers affect your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

Did the promptings from passengers affect your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

If you had more flight hours, would that have changed your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

If your passenger had been a family member, would that have changed your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

If your passenger had been a significant other or spouse, would that have changed your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

If your passenger had been a friend, would that have changed your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

If your passenger had been an attractive member of the opposite sex, would that have changed your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

If your flight mission had been critical (for example, delivering a human heart for surgery), would that change your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

If your flight had been a for-hire paid flight, would that change your willingness to continue through the weather? (increase it ____, no change____, decrease it ____)

Did the fact that this was a simulation (and not reality) affect your willingness to continue through the weather?

- It **increased** willingness because:

  (a) I wanted to fly the sim___ and/or ____,
  (b) I knew I couldn't really get injured in it___,
- No, it had no effect because:
  (a) it didn't matter to me one way or the other___
  (b) there were positives and negatives but they cancelled each other out___
- It **decreased** willingness because:
  (a) I was unfamiliar with this particular simulator___
  (b) I didn't want to make any mistakes in front of the experimenter___

How economically significant was the incentive money to you?
1__not at all 2__a little 3__fairly significant 4__significant 5__very significant

If you were to crash in the simulator, how embarrassed would you be?
1__not at all 2__a little 3__fairly 4__significantly 5__extremely

Have you ever had a bad flight experience related to weather? If so, please describe briefly.

Have you been in a situation where you received pressure from a passenger or co-pilot? If so, please describe briefly.

Do your actions in this situation differ from what you thought you would do in a similar situation? If so, please describe briefly.

APPENDIX D: Pre-Experimental Questionnaires for Passengers

Please indicate how characteristics or descriptive of you each of the following statements is by using a rating scale from 1-6:

1: very uncharacteristic of me, extremely nondescriptive
2: rather uncharacteristic of me, quite nondescriptive
3: somewhat uncharacteristic of me, slightly nondescriptive
4: somewhat characteristic of me, slightly descriptive
5: rather characteristic of me, quite descriptive
6: very characteristic of me, extremely descriptive

1. I have no particular desire to be the leader of a group. ________
2. It is difficult for me to start a conversation with a stranger. ________
3. When someone repeatedly kicks the back of my chair in a movie or on an airplane I don't say anything. ________
4. In discussions I go along with the will of the group. ________
5. I shy away from situations where I might be asked to take charge. ________
6. When I meet new people I usually have little to say. ________
7. It is uncomfortable for me to exchange a purchase I've found to be defective. ________
8. I try to dress like the other people I work or go to school with. ________
9. I let others take the lead when I'm on a committee. ________
10. I feel uncomfortable around people I don't know. ________
11. When a friend borrows something of value to me and returns it damaged I don't say anything. ________
12. I'll take a drink (or smoke tobacco or pot) when out with a group even though I really don't want to. ________
13. I would avoid a job which required me to supervise other people. ________
14. I find it difficult to make new friends. ________
15. When someone interrupts me in a serious conversation, I find it hard to ask him/her to wait a minute. ________
16. When there is disagreement I accept the decision of the majority. ________
17. I work best in a group when I'm the person in charge. ________
18. At a party I find it easy to introduce myself and join a group conversation. ________
19. If I have been "short-changed" I go back and complain. ________
20. My opinions are not easily changed by those around me. ________
21. I seek positions where I can influence others. ________
22. It's easy for me to make "small talk" with people I've just met. ________

23. If the food I am served in a restaurant is unsatisfactory I complain to the waiter. ________
24. I defend my point of view even though someone in authority disagrees with me. ________
25. I am usually the one who initiates activities in my group. ________
26. I find it easy to talk with all kinds of people. ________
27. If a friend betrays a confidence I express my annoyance to him/her. ________
28. I nearly always argue for my viewpoint if I think I'm right. ________
29. In an emergency I get people organized and take charge. ________
30. When I am attracted to a person I've not met I actively try to get acquainted. ________
31. When an acquaintance takes advantage of me I confront him/her. ________
32. I follow my own ideas even when pressured by a group to change them. ________

APPENDIX E: Passenger Debriefing

What incentive condition did you participate in?

- ☐ Baseline
- ☐ Risky (Continue through weather to destination)
- ☐ Safe (Land safely at any airport)

How many times have you participated in this incentive condition? _________

How many times have you participated in this experiment (all incentive conditions)? _________

How familiar are you with how the experiment runs? *1 (not familiar at all) – 5 (very familiar)* _______

How confident do you feel with the role playing exercise? *1 (not familiar at all) – 5 (very familiar)* _______

How **effective** do you think you were in convincing the pilot to continue/divert from the weather?

Rate on a 1-5 scale: 5 (definite change) to 1 (no change). _______

How does **your performance** compare to previous experimental runs? *Rate on a 1-5 scale:*

1 (Excellent improvement) - 2 (Somewhat better) - 3 (same as previous) - 4 (Somewhat worse) - 5 (Huge deterioration)

How does **the outcome** compare to previous experimental runs? *Rate on a 1-5 scale:*

1 (Excellent improvement) - 2 (Somewhat better) - 3 (same as previous) - 4 (Somewhat worse) - 5 (Huge deterioration)

How would you rate the pilot's ability to resist your persuasion?

1 (not at all able) – 5 (completely able) _______

How did the pilot respond to persuasion? Give a brief description below:

How do you think your presence influenced the pilot?

Please provide any comments about the pilot, the flight, or anything that you think might be useful, random thoughts, etc:

APPENDIX F: Informed Consent for Pilots (Modified)

Information Concerning Participation in a Research Study

Clemson University

Utilization of weather information and pilot experience on pilot performance

Description of the research and your participation

You are invited to participate in a research study conducted by Dr. Scott Shappell, and Jaclyn Baron, MS. The purpose of the study is to understand how pilots with different levels of experience utilize weather information during a simulated flight scenario. A secondary goal of the study is to determine how much information an untrained passenger can learn about flying through their presence in a simulated general aviation flight scenario. Your participation will involve a simulated flight scenario, followed by questionnaires.

The amount of time required for your participation will be approximately 2 to 2 ½ for which you will receive $50.00 compensation.

Voice Recording

This research project includes voice recording during the study. This tape will only be heard by the researchers listed above. The tapes will be kept locked up, and you will only be identified on the tape using an assigned identification number. The tapes will be kept for a minimum of three years, according to federal guidelines, and then destroyed.

Risks and discomforts

Any risks or discomforts will be minor, resulting from the repetitive use of the flight simulator.

Potential benefits

Your participation in this study will result in an increased knowledge of this topic that can be incorporated into design of weather systems. In addition, the participant will receive financial compensation for their participation.

Protection of confidentiality

All information from each participant will be coded with an identification number that will be used for future identification and analyses.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study.

As a requirement of participation in this study, you must agree that you will not discuss the methods or conditions you experience with other pilots who might themselves become participants as this could influence their performance.

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Dr. Scott Shappell at Clemson University at 864.656.4662. If you have any questions or concerns about your rights as a research participant, please contact the Clemson University Office of Research Compliance at 864.656.6460.

APPENDIX G: Informed Consent for Pilots (Accurate)

Information Concerning Participation in a Research Study

Clemson University

Pilot weather decision making and the influence of passenger pressure

Description of the research and your participation

You are invited to participate in a research study conducted by Dr. Scott Shappell, and Jaclyn Baron, MS. The purpose of the study is to understand how pilots respond to passenger influence during a simulated flight scenario. Your participation will involve a simulated flight scenario, followed by questionnaires.

The amount of time required for your participation will be approximately 2 to 2 ½ for which you will receive $50.00 compensation.

Voice Recording

This research project includes voice recording during the study. This tape will only be heard by the researchers listed above. The tapes will be kept locked up, and you will only be identified on the tape using an assigned identification number. The tapes will be kept for a minimum of three years, according to federal guidelines, and then destroyed.

Risks and discomforts

There are no known risks associated with this research.

Potential benefits

Your participation in this study will result in an increased knowledge of this topic that can be incorporated into design of weather systems. In addition, the participant will receive financial compensation for their participation.

Protection of confidentiality

All information from each participant will be coded with an identification number that will be used for future identification and analyses.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study.

As a requirement of participation in this study, you must agree that <u>you will not discuss the methods or conditions</u> you experience with other pilots or participants who might themselves become participants as this could influence their performance.

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Dr. Scott Shappell at Clemson University at 864.656.4662. If you have any questions or concerns about your rights as a research participant, please contact the Clemson University Office of Research Compliance at 864.656.6460.

APPENDIX H: Weather Scenario

Airport ID	Airport Name	Altitude MSL	Nearest high pt.	Wind Speed	Dewpoint	Temp	Cloud Ceiling AGL	Cloud Type	Cloud Coverage	Visibility
KCKB	North Central West Virginia	1217 ft.	2600 ft.	10	-10	5	10000	Cumulus	Broken	12.0
KSHD	Shenandoah Valley Regional	1201 ft.	4000 ft.	20	-1	-1	2500	Cumulus	Broken	4.0
KCHO	Charlottesville-Albemarle	639 ft.	4200 ft.	15	-2	-2	800	Stratus	Overcast	2.0
KLKU	Louisa County/Freeman Field	493 ft.	1700 ft.	15	-3	-3	400	Stratus	Overcast	0.5
KOFP	Hanover County Municipal	207 ft.	1700 ft.	15	-4	-4	400	Stratus	Overcast	0.5

* Maximum elevation is indicated on the sectional charts as 5200 ft. between KSKB and KSHD, with second highest point between

APPENDIX I: Pre-Flight Weather Briefing

Flight Weather Briefing

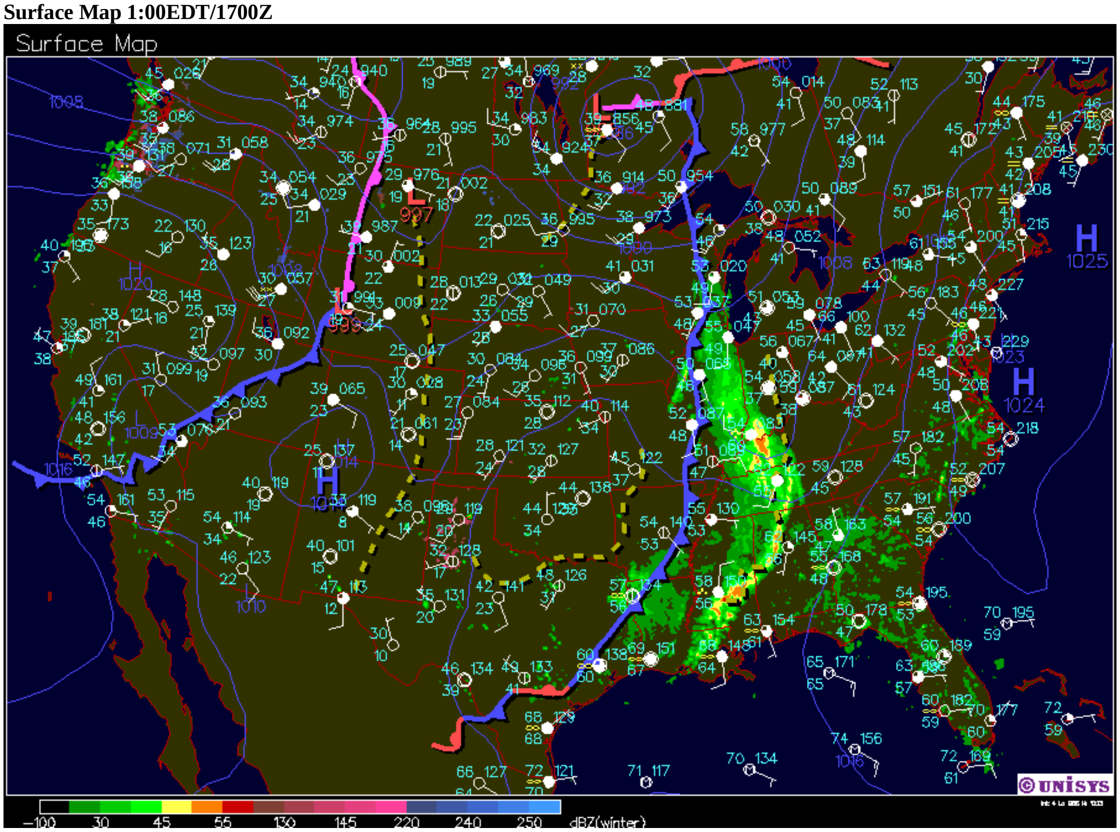
Flight Path: KCKB- KOFP
ETD: 1:00EDT/ 1700Z
ETA: 3:00EDT/ 1900Z

Adverse Conditions:

No current SIGMET/AIRMETs, PIREPs

Synopsis:

Surface Map 1:00EDT/1700Z



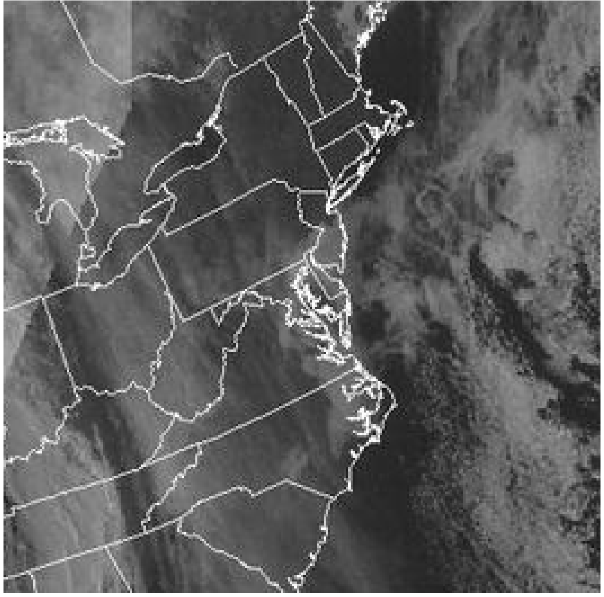
Current Conditions:

```
KCKB 081653Z 18010KT 10SM BKN100 05/M10 A2991 RMK AO2
SLP120 T00540101
```

Area Forecast (FA)

```
000
FAUS41 KKCI 081653
FA1W
BOSC FA 081653
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 091200
CLDS/WX VALID UNTIL 090600...OTLK VALID 090600-091200
.
SYNOPSIS...LOW PRES SYSTEM CNTRD OVR CNTRL CANADA COLD FRNT MVG TWD OH
VLY.  HIGH PRES SYSTEM DOMNATG ESTRN SBRD. COLD FRNT FRCST ARV 09/12Z.
.
MD DE DC WV VA
APLCNS WWD...
  NRN HLF.. SCT050-070. WND S 10KT. 02Z BKN040. TOPS 120. WND S
10G15KT. OTLK...VFR.
  SRN.. BKN090. TOPS 100. WND S 10G15KT. 02Z SCT-BKN090. TOPS 150.
    OTLK...VFR.
E OF APLCNS...
  CSTL PLAINS..
    NRN HLF..SKC. WND S 7KT. OTLK...VFR.
    SRN HLF..SCT-BKN090. TOPS 100. SCT -RA. WND S 10G20KT. OTLK...VFR.
```

Visible Satellite Image: **12:30EDT/1630Z**

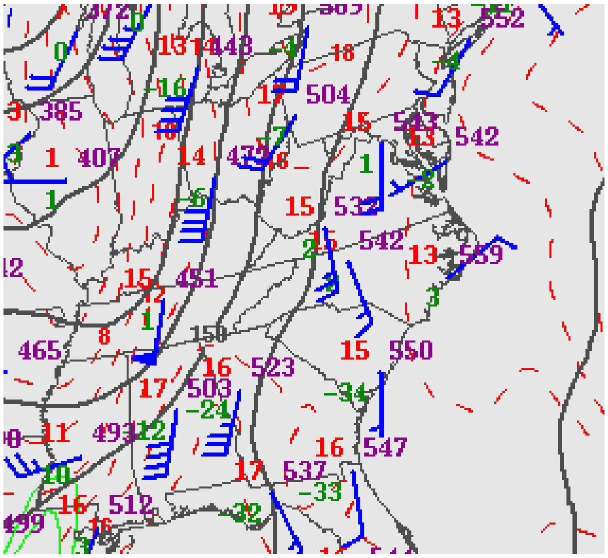


Destination Forecast:

```
KOFP 081653Z 0816/0912 18020KT P6SM BKN031
       TEMPO 0818/0820 6SM -RA OVC031
       FM091100 22025G20KT 6SM BKN035
```

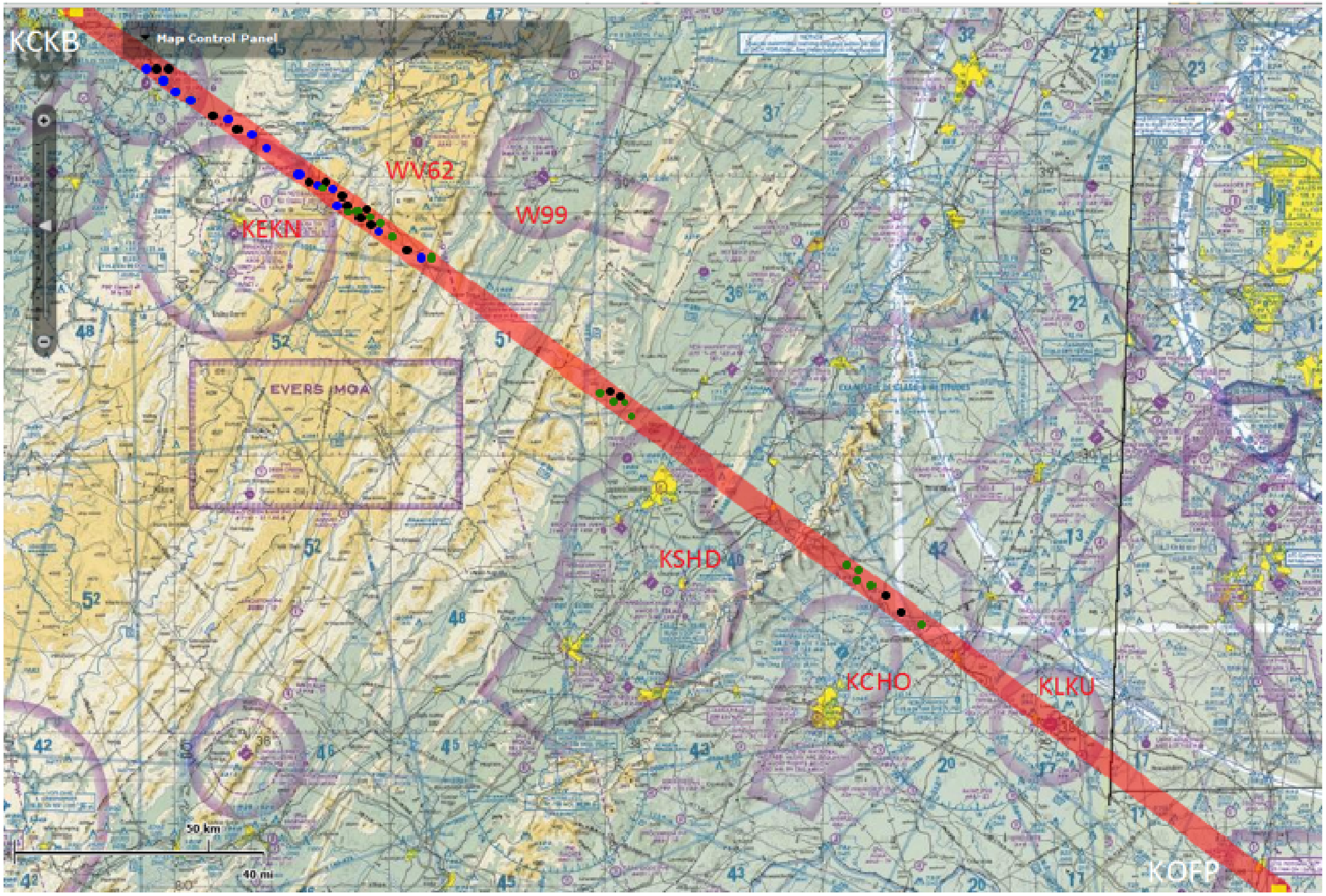
Winds Aloft:

850 mb Chart:



No current NOTAMS/TFRs

APPENDIX J: Sectional Chart with Incentive Condition Results



* Negative Incentive: Blue dots *Non incentive/Baseline: Black dots *Positive Incentive: Green dots

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