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# The Effect of an Unconscious Auditory Stimulus on Pilot Performance under Varying Instrument Flying Conditions

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by

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This thesis was prepared under the direction of the candidate's thesis committee chair, Dennis A. Vincenzi, Ph.D., Department of Human Factors & Systems, and has been approved by the members of the thesis committee, Dahai Liu, Ph.D., and Charlie Bass, Ph.D. It was submitted to the Department of Human Factors & Systems and has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Human Factors & Systems.

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One more journey has ended.......another will begin.....

## ABSTRACT

Human error remains a significant contributing factor with respect to accidents in civil air transportation. It is therefore crucial to establish avenues by which performance on the flightdeck can be enhanced under conditions of distress. The purpose of this study was to examine whether an unconscious auditory stimulus (UAS) could enhance pilot performance under varying instrument flight (IFR) conditions on the aircraft flightdeck. Forty IFR student pilots underwent two eight-minute simulated flights, whereupon they were presented with different IFR weather conditions. During the trial, the experimental group listened to a UAS, whereas the control group listened to white noise (WN). Performance was measured based on the deviation from the localizer (LOC), the glide slope (GS), and the air speed (AS). It was hypothesized that the UAS would assist in enhancing pilot performance under varying IFR weather conditions, and that overall good weather conditions would degrade performance less than poor weather conditions. The results of this experiment did not support the hypotheses. Possible explanations are presented in the discussion section.

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# INTRODUCTION

Human error remains a significant contributing factor with respect to accidents in civil air transportation. Research (Boeing, 2001) demonstrates that crew failure (human error) contributes to more than 66% of accidents globally. Piloting an aircraft is a highly complex task that imposes great cognitive demands on the pilots (Wilson, 2001). Several studies reveal that variables such as poor weather and IFR conditions pose an even greater demand on pilots. This results in higher states of stress and workload. For example, in a study conducted by Wilson (2001), several psychophysiological measurements were obtained in order to determine the levels of mental and psychological load the pilots experienced during different flight scenarios. The results of this study indicated that during the IFR flights the pilots scored higher in the subjective workload ratings, and their physiological measurements differed significantly from pilots engaged in visual flights (VFR). Leino, Leppaluotto, Ruokonen, and Kuronen (1999) also measured the neuroendocrine responses of student pilots in IFR flights in order to determine the stress and the psychological workload that IFR conditions impose on pilots. They concluded that during the IFR flight student pilots' neuroendocrine levels increased revealing that during the IFR conditions pilots were more stressed as a result of higher workload. Moreover, acute reactive stress appears to potentiate further error by degrading performance (Parnell, 1999). It is therefore crucial to establish avenues by which performance on the flightdeck can be enhanced during stressful events. Furthermore, unconscious stimuli have been found to have an effect on human behavior and performance (Borgeat, 1983; Borgeat & Goulet, 1983; Cuperfain & Clarke, 1985; Dreschsler, 1961; Peretti & Kim, 1996).

The purpose of this study is to examine whether a UAS can enhance pilot performance under different IFR conditions in the aircraft flightdeck.

*Stress and Performance*

The effects of stress have been investigated from many perspectives that include physiological, social, cognitive, and individual and team performance. Stress may be perceived as a state of compromised physical and psychological strain, may compromise an individual's resources, and lead to a break down in cognitive functioning (Goldenson, 1984). For the purpose of this study, stress will be operationally defined as a wide variety of environmental effects and human perceptions that have an impact on human performance and an individuals' well being.

Aviation related studies conducted by the Federal Aviation Administration (FAA) and the United States Air Force (USAF) have identified stress as an important factor in performance (Krahenbuhl & Harris, 1984). Historical evidence demonstrates that a career as a pilot has been found to be one of the most stressful professions (Bowels, Ursin, & Picano, 2000). Numerous types and degrees of stressors exist on the flightdeck. Many of these stressors lead to decreased performance and erroneous decisions or actions. Examples of stressors include atmospherical and gravitational correlates such as height, pressure changes, acceleration, motion, turbulence, glare, extreme weather, inactivity, and uncomfortable personal equipment. Psychological and physiological correlates may include excess noise and vibration, level of training, level of confidence, unfamiliar aircraft, unfamiliar route, unfamiliar airport, poor runway conditions, poor weather, low fuel, malfunctioning navigation equipment, low altitude, instrument flying and night flying, shame, lack of confidence in aircraft design, physiological deprivation (hunger, fatigue, lack of sleep, hangover), minor-illness, self-medication, complacency, lack of family support, and the presence of psychopathology. Mechanical and emergency factors may include low fuel, control and trim malfunction, engine failure, in-flight fire or explosion, mid-air collision, birdstrike, ditching, disorientation, and in-flight incapacitation (Edwards, 1990; Gohm, Baumann, & Sniezek, 2001; Haakonson, 1980; Hixson, 1987; Little, Gaffney, Rosen, & Bender, 1990; Raymond and Moser, 1995; Sloan and Cooper, 1985).

Interestingly, optimal stress levels can also be productive. For example, Yerkes and Dodson (1908) found that there is a non-linear relationship between arousal and performance. At low levels of arousal, performance has been found to be equally as poor as when arousal is too high. Conversely, when arousal reaches an optimum level, then performance is optimized.

Janis and Mann (1976) postulated that there are five coping patterns with which people react when faced with emergency warnings and fear-arousing messages. These coping mechanisms require immediate action such as unconflicted adherence, and/or change to a new course of action, defensive avoidance, hypervigilance, and vigilance.

In the case of unconflicted adherence, the decision-maker complacently decides to continue whatever he or she has been doing, and thereby ignored information about the risk of losses. In the case of unconflicted change to a new course of action, the decision-maker uncritically adopts whichever new course of action is most salient or most strongly recommended. Conversely, in defensive avoidance, the decision maker evades the conflict by procrastinating, shifting responsibility to someone else, or constructing wishful rationalizations and remaining selectively inattentive to corrective information. In the case of hypervigilance, the decision maker searches frantically for a way out of the dilemma, and impulsively seizes upon a hastily contrived solution that would appear to promise immediate relief, thereby overlooking the full range of consequences of his or her choice because of heightened emotional state, repetitive thinking, and cognitive constriction (manifested by a reduction in immediate memory span and simplistic ideas). An extreme form of hypervigilance is referred to as panic. Lastly, in the case of vigilance, the decision maker searches painstakingly for relevant information, assimilates it in an unbiased manner, and appraises alternatives carefully before making a choice (Janis & Mann,1976).

Raymond and Moser (1995) reviewed several aviation related accident cases in order to examine the effects of stress on pilots' performance. They concluded that during lower levels of stress there is evidence of drowsiness, lack of vigilance, and slow reactions, particularly in cases of emergencies. Conversely, during high levels of stress, the researchers concluded that stress interfered with the pilots' ability to concentrate, and scan all the possibilities. Additionally, during high levels of stress, the evidence has demonstrated the occurrence of disorganization, impulsivity, inability to disregard irrelevant stimuli, and in some cases even panic. In short high levels of stress, performance is degraded.

The effects of stress on cognition are numerous. Schaab (1997) has suggested that individuals under stress display behaviors in which information processing is diminished, scanned in a nonsystematic manner, and there is a decrease in reaction time, increase in human error, and decrease in working memory. Furthermore, several well-established overall relationships between stress and cognitive performance have been documented, such as perceptual narrowing (cognitive fixation), and a significant decrease in the cognitive constructs of working memory (Guest, 2001). Working memory has been found to be particularly vulnerable to the effects of stress, either through limiting its capacity, or interfering with neural processing in working memory.

According to Miller (1963), stress is responsible for producing physical tension as well as anxiety, which in turn can result in fatigue. Thus, impaired performance is frequently observed. It must be emphasized that the effects of stress can significantly interfere with the pilots' ability to focus on the status of the airplane. This can result in a pilot giving undivided attention to one area (fixation), as opposed to distributing attention throughout the flightdeck displays accordingly. Moreover, the consequences of stress can also inhibit and reduce the pilots' ability to respond properly, thus resulting in fatal consequences (Raymond & Moser, 1995).

Klein and Boals (2001) conducted three studies in which they examined the relationship of daily life stressors and working memory. The results of these investigations demonstrated that stressful events are significantly analogous to secondary tasks that demand the involvement of the working memory. Thus it would appear that stressful conditions impair complex problem solving skills.

According to Kontogiannis (1996), much of the data gathered from simulation studies and analyses of actual incidents have emphasized the potential for serious human errors precipitated by emergency conditions. For example, under duress, risky and impulsive decisions may be made, skilled performance declines, and crucial information is ignored. Furthermore, individuals under stress tend to be less effective in scanning alternative solutions and problem solving (Gohm, et al., 2001).

According to Carmigniani (1989), the French Civil Aviation Administration (FCAA) conducted several studies, in which a file was created that contained data from aeronautical accidents due to human error. Utilizing a human factors perspective, these files were then classified into different types of errors, and finally reproduced in a flight simulator, in order to observe human performance and reactions. According to the national and international standards of aviation, the participants were highly skilled and qualified pilots. The results of these studies indicated that crews under stress, failed to notice all available information critical for flight safety. For example, the flight crews hesitated before making a decision, actions were taken (e.g. turns) without prior check, and erroneous actions took place leading to disorientation (Carmigniani, 1989).

Stokes (1995) examined the effects of stress on pilot performance in a flight simulation task. Novice and expert pilots were administered a battery of cognitive, personality, and flight simulation tasks under stressed and non-stressed conditions. Stressful conditions involved task instructions that were difficult to understand, dual tasks, time restraints, high noise levels, and financial risk. The results of the experiment demonstrated that both groups had significant performance deficits. Both novice and expert pilots experienced a decrement in working memory while performing a non-domain-specific information processing tasks. Conversely, in domain-specific tasks only the novices exhibited impaired performance.

Norway (2001) investigated the relationship between stress and effective communication. Airline pilots underwent several simulated flights in which operational failures took place (viz., engine failure on cruise, engine failure during take off). The crew performance conversations were recorded. The results of the study indicated that under high levels of stress and workload, communication was inefficient, and problem solving was compromised.

Alkov, Borowsky, and Gaynor (1983) examined the effects of impaired stress coping mechanisms and pilot performance. Naval aviators that had been involved in major aircraft mishaps were separated into two groups: those who were accountable for their mishaps, and those who were not. The aviators then completed several psychological questionnaires. Results of the studies indicated that those pilots who were held accountable for their mishaps, were not able to adequately cope with stress. Conversely, the pilots who were not responsible for their mishaps were found to cope better with stress.

*Limitations of the Review of the Literature*

A thorough review of the literature demonstrates that the existing research, specific to the use of a UAS and pilot performance under varying IFR conditions, is significantly limited.

*Unconscious Perception*

*The Evolution of Unconscious Perception*

Unconscious perception has an extensive history, and has created much controversy within the disciplines of psychology and science. Unconscious perception can be traced back to ancient Greece (Beare, 1906; Dixon, 1971; Hartman, & Secrist, 1993). For example, Democritus, Aristotle, and Plato (Dixon, 1971) postulated that a significant amount of perceptual processing occurs outside the realm of human consciousness, and that unconscious processing was often masked by dominating conscious processing of information.

During the mid nineteenth century, many researchers demonstrated an interest in studying unconscious perception and the effects of preferences and performance in human behavior. Sigmund Freud and Pierre Janet, for example, were two of the first scientists who attempted to establish theories specific to unconscious processes

(Bowers & Meichenbaum, 1984). Researchers presented the experimental participants with visual or auditory stimuli. The visual stimuli (e.g. words) were presented at an extreme distance, thereby making it impossible for the participants to read. Additionally, the auditory stimuli were whispered at a significantly low intensity, making it impossible for the participants to hear them. The participants were then asked to make guesses about the stimuli, and to identify whether they were numbers or letters. The results demonstrated that many participants found the correct answer, thus supporting the presence of subliminal perception. (Dixon, 1971; Kazdin, 2000).

During the 1950's, the concept of unconscious perception underwent much scrutiny. McConell, Cutler and McNeal (1958) addressed the controversy, and have provided a historical overview of the effects of unconscious stimulation on behavior. For example, in one experiment conducted in an American movie theater, the words "Eat Popcorn," and "Drink Coca-Cola," were projected in alternate periods during the presentation of a motion picture. The results of the experiment demonstrated a 50% increase in popcorn sales, and an 18% increase in Coca-Cola sales. As a result of this study, sales and marketing companies surmised that they could influence the preferences of consumers through advertisement. This resulted in a fear of commercial unconscious exploitation, and the perpetuation of academic respectability and ethics (Dixon, 1971).

From 1863 to 1864, further investigations by McConell et. al. (1958) also demonstrated the influence of unconscious messages on experimental participants. For example, Suslowa (1863) investigated the effects of electrical stimulation upon an individual's ability to determine two-point threshold discrimination. The results of this experiment demonstrated that despite the significantly low intensity of the electrical stimulation the participants maintained the ability to discriminate between a variety of levels of stimulation. Similarly, Peirce and Jastrow (1884) found that experimental participants had the ability to discriminate differences in weight among objects despite minute weight differences.

During the 1960's, the advent of signal detection theory (SDT) supported the contention and existence of unconscious perception. Further support was obtained via neurophysiological and behavioral studies, and a new awareness in the academic community regarding unconscious perception was achieved. It would appear that increased theoretical bases and existing empirical research have produced a greater compliance towards the consideration of unconscious perception as a valid area of scientific enterprise, particularly within the past twenty-five years (Dixon, 1971; Hartman, & Secrist 1993).

*Implicit Memory & Unconscious Perception*

One mode of unintentional learning is implicit, or otherwise called unconscious learning and/or priming. Implicit learning may be defined as a process whereby complex knowledge is primarily acquired independently from awareness. Cognitive psychologists for example, have demonstrated a high interest in those processes of cognition whose functions are dependent upon implicit memory and implicit or unconscious perception. Numerous systematic laboratory examinations have assessed this phenomenon (Reber, 1997; Schacter & Badgaiyan 2001).

There are various theories that address explicit-implicit learning (Dulany, 1997). For example, the "standard theory" suggests that explicit learning is intentional, comprised of rules, and is a process suited more for prominent domains. Conversely, implicit learning is perceived to be incidental learning, and involves an unconscious abstraction system, where the production of knowledge is not recognized by the stimuli that has led the individual to the acquisition of this knowledge (Dulany, 1997).

The "mentalistic theory" on the other hand, suggests that explicit learning consists of conscious processing, implements a hypothesis in the form of rules, represents evidence for the hypothesis, verifies or disproves the hypothesis, and then observes the evidence. Conversely, implicit learning consists of thought processing where people acquire knowledge by coincidence. Knowledge is then established in memory, and progressively strengthened with time (Dulany, 1997).

Further evidence of implicit memory –commonly referred to as priming- are numerous cases of individuals diagnosed with various visual disorders (Hamann, 1996; Kazdin, 2000) , including, but not limited to, dyslexia, aphasia (inability to understand or express language), and Alzheimer's disease (Yonelinas, et al., 2001). Investigations involving the dissociation between performance on direct and indirect tests on memory and perception further support the contention of the significant role memory plays in unconscious (implicit) memory. Major contributions to this theory are experiments that have involved individuals diagnosed with amnesia. When these research participants were asked to remember or recognize (direct memory) specific items, they did very poorly. In contrast, when they were initially exposed to words, and then were asked to read fragmented versions of those same words (indirect memory) previously shown, they did very well. Thus, it would appear that the effects of memory on an indirect or implicit test may reflect unconscious influences in the sense that an individual does not necessarily have to know about using memory (Gabrielli, Fleischman, Keane, Reminger, & Morrell, 1995; Jacoby & Kelley, 1992; Schacter & Badgaiyan, 2001; Schacter, Church, & Treadwell, 1994; Siegler, 2000).

Unconscious perception has been found to exist even in individuals that have suffered neurological damage. For example, patients with "blindsight" (damage to the primary visual cortex) are unable to see in the fourth visual quadrant. In an experiment conducted by Kazdin (2000), participants were presented with stimuli beyond their field of vision. Interestingly, they were able to guess the size, shape, and the orientation of the stimuli that they claimed they could not see. Additionally, individuals diagnosed with prosopagnosia (seeing a person, but having no recognition of them) were presented with information about various faces. Although their neurological deficit did not provide them with the ability to perceive any information on "whose" faces they were viewing, some individuals were able to choose which of the two names corresponded with the appropriate face (Kazdin, 2000).

Another example of perception in the absence of conscious awareness is that of individuals undergoing general anesthesia while wearing earphones and listening to the repetition of specific words. Despite an altered state of consciousness, when asked to complete a stem of words the individuals correctly completed and accurately reproduced the words they heard (Kazdin, 2000).

*Unconscious Visual Perception (UVP)*

Smith, Spence, and Klein (1959) examined the influence of verbal stimuli on impression. Experimental participants were shown a human face through a tachitoscope (a device that rapidly projects visual presentations), and were exposed to unconscious words such as "happy" or "sad". The results of the study demonstrated that the "unconscious visual stimuli" (UVS) influenced the way participants viewed the expression of a visually and consciously presented face.

Drechsler (1961) investigated whether or not emotionally evoking unconscious stimulus, in the presence of a second consciously emotionally evoking stimulus could induce exaggerated affective responses to the consciously perceived stimulus. Using the color red as the emotionally toned stimulus, and the color gray as the neutral stimulus, Drechsler found that the participants' reaction was reinforced by the color red, while those who were exposed to the color gray did not demonstrate an affective response.

Cuperfain and Clarke (1985) postulated that it was possible to influence an individual's stated preferences without them being consciously aware. In their study, participants were presented with an advertisement demonstrating how to wash wool. The commercial illustrated a woman washing wool with a detergent that was contained in a white package. The group who was presented with the film also received an UVS, utilizing the Zero detergent, through a tachitoscope. Another group was presented with the same film, and also received an UVS through a tachitoscope, however using the Woolite detergent. The control group did not receive any treatment. All conditions were held constant with the exception of the UVS. The groups were then asked to rank in order the soaps that they thought were more appropriate for washing delicate fabrics, as depicted by the film. The results of this experiment demonstrated that the UVS had influenced the participants' preference. As a result of the conditions that it was presented unconsciously to the participants, the Zero detergent was higher in ranking. Conversely, none of the measures for the Woolite detergent were significant, most likely because the Woolite was a new and fairly unknown detergent.

McCleary and Lazarous (1949) found that nonsense syllables (non provoking emotional responses), that had previously been associated with shock, produced a higher psychogalvanic (variations in electrical resistance of skin in response to emotional stimuli) reflex when they were presented as an UVS via a tachitoscope.

Gustafson and Kallmen (1990) examined the effects of unconscious messages on cognitive and motor performance. The theory behind their study was based on the premise that people have a need for symbiotic oneness –a close relationship with a mother figure. The researchers found that when individuals were presented with the unconscious message, "Mommy and I Are One," their stress levels were inclined to decrease, thus positively influencing performance. Gustafson's and Kallmen's study was based on previous studies by Silverman, et al. (1982), which have empirically demonstrated that it is possible to temporarily manipulate the intensity of a symbiotic conflict by exposing participants to unconscious messages through a tachitoscope.

In their experiment, Gustafson and Kallmen (1990) used the message "Mommy and I Are One" for the experimental group, and "People are Walking" in the control group. Their results demonstrated that in the experimental group both cognitive and motor performance were improved. Conversely, the control group exposed to the neutral message did not show any significant improvement. It would appear that cognition was thus enhanced, as evidenced by the participants' ability to interpret incomplete fragmented pictures, and motor performance.

Ariam and Siller (1982) also examined the effects of the unconscious symbiotic oneness message. For example, in an attempt to improve academic performance, the UVS "Mommy and I are One," "Teacher and I are One," and "People are Walking", were presented to a group of Israeli high-school students tachitoscopically. The results demonstrated that both the group exposed to the message, "Mommy and I are One," and the group exposed to the message: "Teacher and I are One," scored significantly higher than the group that was exposed to the message, "People are Walking." These results support the notion that symbiotic unconscious messages are a real phenomenon.

Dixon (1981) reported that experimental participants who received an unconscious exposure to the word "pencil," identified the word, and reported it in writing more rapidly than the control group. Additionally, Marcel (1983) found that experimental participants, who were unconsciously exposed to the name of a color, within a minimal and recent time frame, were able to identify that color on a computer screen more rapidly than the control group. According to Zajonc (1968) the phenomenon of even a mere exposure to an UVS seemingly influences people's preferences. Zajonc (1968) has suggested that the more individuals are exposed to a stimulus, the more they find it appealing.

Peretti and Kim (1996) postulated that physiological responses to unconscious stimuli may help to support the existence and effects of this seemingly controversial phenomenon. However, Peretti reported that investigations by Silverman (1983) failed to support this theory. Silverman presented elderly individuals with a peaceful film in which taboo and swear words were unconsciously embedded. The reactions of the participants were monitored by electromyogram (EMG) and electrocardiogram (EKG) activity, and they failed to demonstrate any response to the unconscious stimuli.

In further studies, Peretti and Kim (1996) examined the effects of unconscious number stimuli on verbal responses. Both the control and the experimental group were presented with a series of numbers from 30 to 50. However, the experimental group received an unconscious projection of the number 39. When both groups were then asked to record the numbers that they remembered having seen on the film, the experimental group reported the number 39 significantly more times than the control group.

*Unconscious Auditory Perception (UAP)*

Mykel and Daves (1979) replicated two experiments previously investigated by Henley and Dixon (1974). In the first study, the experimental group received unconscious words to the right ear and music to the left ear, and vice versa. Results revealed reports of imagery as well as auditory processing performance. On a checklist containing critical, associated, or non-related words, participants reported stronger auditory processing in the right ear. No differences were found between the two groups with words in the right and left ear. In the second experiment, the music was eliminated, and the participants received unconscious words in the right ear as opposed to the total absence of words. In conclusion, there was a significant difference between the two groups, based on the imagery reported and the performance on the checklist, thus validating the contention of unconscious auditory perception (UAP).

Borgeat and Goulet (1983) measured the psychophysiological changes resulting from an UAS activation and deactivation in a state of relaxation, and in combination with a stressful task (e.g. mathematical problem solving), and during recuperation. Physiological changes were measured by EMG, heart rate, and galvanic skin response (GSR). The researchers concluded that the UAS demonstrated an effect during and following the stressful task.

Borgeat (1983) investigated the physiological effects of progressive relaxation (i.e., individuals receive a series of verbal instructions leading to relaxation), and unconscious relaxation. The participants listened to soft music involving unconscious suggestions of relaxation. The results of the study demonstrated no significant difference between the progressive relaxation and unconscious techniques. Interestingly, they both induced the same levels of relaxation. However, a difference was observed in the EMG readings of very anxious participants during progressive relaxation. Anxiety levels were significantly reduced. These results support the contention that progressive relaxation is more effective with highly anxious people, and unconscious relaxation is more effective with less anxious people.

Bouchard (1984) examined the effects of self-administered unconscious relaxation treatment on anxiety. One group of experimental participants underwent unconscious relaxation treatment. A second group received unconscious symbiotic activation treatment. A third group received relaxation training treatment, and a fourth group received neutral music. The results of Bouchard's study failed to show any significant difference between the groups. However, all four groups demonstrated a significant reduction of anxiety during the experimental procedure.

Kaser (1986) examined the effects of unconscious messages in the production of images and dreams. The theoretical basis for his study was previously investigated by Becker (1979); Borgeat, Chabot, & Chaloult (1981); Dixon (1956); Fisher (1976); Mykel, & Daves (1979); Poetzl (1960). These studies examined the influence of an UAS on experimental participants. The only variations among these studies were the way in which the UAS was presented. However, it is important to note that the experiments were based upon the subliminal activation theory (SAT). The SAT claims that the unconscious/preconscious mind appears to maintain perception at a level below the normal threshold of hearing and seeing.

Kaser (1986) investigated the use of a UAS in imagery and dreams. The experimental group received an UAS embedded with music. Conversely, the control group was administered only music. Both groups were asked to draw a picture prior to receiving the auditory stimuli. Immediately after listening to the cassette tapes, participants were asked to draw an imagery drawing, and a drawing of any dreams that they had the night following the experiment. The results of Kaser's experiment support the contention that an UAS is influential in imagery and dreams. Furthermore, it would appear that the unconscious mind is able to perceive recorded verbal messages that cannot be consciously understood.

Zenhausern, Ciaiola, and Pompo (1973) examined the effects of unconscious and conscious stimuli on perceptual illusions. The results of their experiment demonstrated that there was an influence on perception when the unconscious stimulus was below a -30decibels (db) threshold.

Kotze and Moller (1990) examined the effects of UAS on GSR. They based their hypothesis on previous studies (e.g., Borgeat & Goulet (1983); Corteen & Dunn (1974); Dixon (1958), Foster & Govier (1978); Martin, Hawryluk & Guse (1974), and the fact that other researchers (e.g., Erikson, Azuma & Hicks (1959) had reported negative results. In Kotze and Moller's (1990) experiment, one group of participants was presented with two sets of UAS. One set consisted of nine emotional words and nine neutral words. This set was used to establish a baseline with the GSR. The second set of UAS contained nine emotional words. Participant responses were measured with GSR. The results of the experiment confirmed the hypothesis that exposure to UAS increases levels in GSR.

In another study, Kotze and Moller (1991) attempted to examine the relationship between personality traits and the effects of UAS on preference behavior. Their study, however, failed to support their hypothesis that participants with low anxiety, less neuroticism, and external locus of control (a trait of extraversion) would be more susceptible to unconscious stimulation. The reasons their hypothesis was not supported may be due to the fact that neutral messages were used, (i.e., "I prefer symbols," "Choose symbols," "Ignore numbers"), and therefore failed to personally motivate the participants or to meet their needs.

Arndt, Greenberg, Pyszczynski, and Solomon (1997) examined the effects of unconscious death-related stimuli on faithfulness and cultural worldview. Three experiments were conducted. The first experiment investigated an individual's exposure to death-related messages, standard mortality-salience treatment, and a neutral UAS. The results of this experiment indicated that both death-related unconscious messages, and a standard message, led to more favorable evaluations of people who admired their cultural worldview versus those who did not. The second experiment replicated the first one by comparing the effects of unconscious death-related stimuli, and unconscious pain stimuli. In a third study, the researchers compared unconscious death stimuli, conscious death stimuli and unconscious pain stimuli. The results demonstrated that only unconscious death stimuli produced the effects found in experiments one and two.

Merikle (1988) conducted a study in which audio cassette tapes were tested to insure that they contained an unconscious message. Results of this study demonstrated that audio cassettes that are marketed, and claim they can help alter specific behaviors (e.g. academic achievement, self-esteem, weight-loss), did not contain any form of unconscious messaging. Thierfelder (1990) also examined the effects of commercially available unconscious self-help audio cassette tapes in relation to reaction time, heart rate, electrodermal response, and word recognition speed. Two experiments were conducted with three conditions each. The first experiment addressed participant body arousal. The second experiment included a word recognition task. The results of the first experiment revealed that the UAS greatly influenced reaction time. The results of the second experiment demonstrated that the UAS greatly influenced word recognition, thus supporting the notion that UAS can affect performance.

Greenwald, Spangenberg, Pratkanis, and Eskenazi (1991) examined the effects of commercially available self-help audio cassettes that claimed to improve memory and increase self-esteem. Two experimental groups participated in the study. One group was exposed to self-esteem cassette tapes while the other group was exposed to memory cassette tapes. Both groups used the exact opposite of the self-help cassette tape than they thought they would receive. The results of the experiment indicated that neither the memory nor the self-esteem cassette tapes produced their claimed effects. However, a general improvement for all the participants in both memory and self-esteem was observed. The participants also reported feeling more confident relevant to the domain in which their tape identification label claimed to make improvements on. The researchers believed that the results were due to the placebo effect.

Russell, Rowe, and Smouse (1991) examined the effects of a commercially prepared unconscious messaging audio cassette tape on academic achievement. One group of participants listened to audio cassette tapes with messages masked by ocean waves. A placebo group listened to audio tapes with ocean waves, and the control group received no treatment. The dependent variables were final examination scores and current semester grades. The results of this experiment demonstrated no treatment difference between groups.

Lenz (1990) examined the effects of UAS on academic learning and motor skill performance among police recruits. One group of participants received treatment with

UAS embedded to music, and one group did not receive any treatment. Results of Lens's study demonstrated that there were no differences in either academic learning or motor performance between groups.

Tricou (1987) investigated the effects of UAS on sixth grade public school children and their attitudes towards mathematics. Another scope of the study was to determine if there were gender differences associated with an UAS. The experimental group was subjected to UAS. Conversely, the control group was presented with music. The results failed to demonstrate any differences between the control and the experimental group.

Chimera (1987) examined the effects of an UAS on abnormal thought processing. One group of individuals diagnosed with schizophrenia received an UAS that was intended to decrease the state of their psychopathology, and an UAS with a neutral meaning serving as the control stimulus. The results of this experiment failed to support the hypothesis that the UAS would have a positive effect by decreasing their psychopathology.

Sedgwick (1991) examined the effects of UAS on weight, preconscious processing, and self-esteem. The experimental group listened to audio cassette tapes that included unconscious messages. The control group listened to audio cassette tapes without unconscious messages. Interestingly, the results of this study demonstrated no significant differences between the experimental and the control group. However, after a period of time the experimental group exhibited a loss in weight, while the control group exhibited weight gain.

Several explanations may exist for the experiments that failed to find results that would support the existence and the effect of unconscious stimuli. For example, as previously illustrated, Merikle (1988) found that commercially available self-help audio cassette tapes did not contain any unconscious stimuli, thus had no effect on the individuals that used them. In their experiments Russel, et al., (1991) and Greenwald, et al., (1991) used commercially available self-help audio cassette tapes. It would appear that an explanation for the results of their studies is that the cassette tape did not contain any UAS, hence there would be no improvement. Furthermore, studies conducted by Lenz (1990), Tricou (1987) and Chimera (1987) may fall under in this category. However, Chimera's results may not have supported the initial hypothesis due to the diagnosed psychopathology of the participants.

Despite the controversy that exists, it is important to realize that a review of the literature strongly suggests that unconscious perception is a valid phenomenon, and studies under the correct circumstances have demonstrated its effect on individual behavior and performance.

*Purpose of the Study*

A review of the literature reveals that under stress, pilot performance deteriorates. For example, working memory declines, attention is fixated to limited sources, poor judgment arises, rushed decisions are made, communication deteriorates, and panic frequently occurs leading to errors and often fatal results. It is therefore crucial to establish avenues by which flightdeck performance can be enhanced under stressful conditions. A resolution to this severe danger could save many lives and much money.

Numerous studies have demonstrated that unconscious perception is a valid phenomenon. Both unconscious visual and auditory stimuli have been found to affect behavior and improve performance. Therefore, it appears appropriate to examine the effects that an UAS could have on performance under stressful conditions in an aircraft flightdeck. The reason for choosing an auditory message versus a visual one is that the visual stimuli are often excessive in relation to auditory stimuli. Therefore, it appeared more logical to introduce an auditory stimulus.

*Statement of Hypotheses*

Hypothesis 1:

It was hypothesized that the introduction of a UAS would affect pilot performance. Speciffically, performance under the UAS condition would be better than performance under the WN condition.

Hypothesis 2:

It was hypothesized that varying IFR conditions would affect pilot performance. Specifically, pilot performance under good weather IFR conditions would be better than performance under poor weather IFR conditions.

Hypothesis 3:

It was hypothesized that an interaction between the type of stimulus and varying IFR conditions would exist.

Prediction 1: Under the good weather conditions, pilot performance would not differ significantly when exposed to either the UAS or WN stimulus.

Prediction 2: Under poor weather conditions, performance would differ significantly. Specifically, performance under poor weather conditions where participants are exposed to a UAS would be better.

# METHOD

*Participants*

Forty volunteer student pilots (ages 18-28) IFR rated were randomly selected from Embry-Riddle Aeronautical University (ERAU) to participate in the experiment. Participants had a Class II medical certificate. The Class II medical certificate includes the assessment of visual acuity 20/20, auditory proficiency and the absence of any pre-existing medical history (Department of Transportation, 2002). The total flight hours of participants ranged between 100 to 500 hours.

*Apparatus*

Upon arrival for the experiment, the participants were briefed and signed an informed consent form. The Microsoft Simulator (MS) 2002 Professional Edition of the Human Factors & Systems (HFS) department of ERAU was used for the simulated flights. The simulator was configured to fly as a Cessna 172 single engine aircraft. Deviation from the LOC, GS, as well as AS determined pilots' performance. Pilot performance was quantified as root mean square error (RMSE). RMSE is widely used to measure tracking performance (Rantanen, et. al., 2001; Scallen, Hancock, & Duley, 1995; Wickens, & Holland, 2000). The RMSE is calculated by squaring the error, in this case the degrees of needle deflection from the GS, LOC, and AS, then adding them together, dividing the sum by their total number, and then taking the square root of this measure. A low number reflects good performance.

The levels of stress experienced by the pilots during the flights were determined with the Beck Anxiety Inventory (BAI) (Beck & Steer, 1993). The BAI is a 21-item scale that measures the levels of anxiety in adults and adolescents. The higher is the score, the higher the anxiety experienced by the individual. The BAI has an internal consistency reliability of coefficient alpha = .94. Additionally, BAI's content validity based on Cronbach's coefficient alpha varies from .93 to .85. The construct validity for the same test varies from .05 to .001 (Beck & Steer, 1993).

The NASA Task Load Index (TLX) determined the levels of workload experienced by the participants during the flights. The NASA TLX is a widely used multidimensional measure of workload, based on weighted averages of six subscales (Hitt, et al., 1999). The higher the score obtained on the NASA TLX, the higher the workload experienced.

The UAS used in the experiment was recorded in the Base Line Rehearsal & Recording Studios. The message recorded was "Relax, You Are In Control". The experimenter's voice was used to record the message. It was recorded on a Taiyo Yuden 700MB CD-R on a high-speed. The initial resolution of the message was 44.1 KHZ, 16 BIT. It was then recorded 286% times faster than the original one. The message was then embedded with WN, and its loudness was reduced –29 db from the white noise. The message was then recorded repeatedly in order to cover 1h and 14 minutes on the Compact Disc (CD). The phrases have a distance of 6 milliseconds. The microphone was a NEUMAN (TUBE 49) with a preamp MIC Tube dbx 586. The microphones filter was a pop filter – SHURE. The mixer was a EYRODESK 8000, and the processor a L2 WAVES Ultramaximizer. The Personal Computer (PC) configured Windows 98B. A simple CD player with headphones was used to administer the UAS.

*Design*

The UAS and the different IFR weather conditions represented the IV in the present study at two levels: UAS versus WN, and good weather versus poor IFR weather conditions. The DV represented pilot performance, as well as the stress and workload.

The experimental design was a 2x2 balanced mixed factorial design. The reason for using the mixed design was to avoid the confound of the carry over effect (viz., learning effect) which can be generated if the participants run all four possible scenarios. Therefore, the first group was given an UAS for eight minutes during a good weather IFR flight, and then during a poor weather IFR flight. The second group was given WN for eight minutes during a good weather IFR flight, and then during a poor weather IFR flight. The data were analyzed using an independent t-test, a paired t-test, and analysis of variance (ANOVA).

*Procedure*

Prior to selection, participant criteria included ERAU IFR student pilots, with total flight hours between 100 and 500, and a second-class medical certificate. Forty participants were randomly assigned to the groups. This was done to account for individual characteristics. Additionally, the pilots were randomly assigned the weather condition of their first flight in an effort to control for the order of administration, and learning effects.

Upon their arrival for the experiment, the participants were briefed about the nature of the experiment (Appendix A). They were told that the purpose of this study was to measure performance under stress. They were informed that they were to fly two VFR flights for duration of two minutes each, to familiarize themselves with the simulator. The VFR flights started on cruise and the participants were free to fly the simulator anyway they wanted, with no specific instructions. Before the familiarization with the simulator, the participants were given a preflight BAI. Following the familiarization with the simulator, the participants had to strive for two IFR approaches. After each recorded IFR approach, the pilots were administered a BAI and a NASA TLX respectively. These tests measured participant stress and workload respectively. Additionally, participants were informed that they had the right to withdraw from the study at any time and without any penalty.

Finally, the participants were asked to sign the informed consent form (Appendix B). The pilots were seated in front of the MS 2002 Professional simulator. All seat adjustments were made accordingly. The familiarization flights were not recorded. Participants were then given specific flight instructions. Their flights would begin on cruise, on final vector to the ILS 7L at Daytona Beach. They were located North of the course. Their goal was to intercept the Glide Slope, maintain 90 knots, while keeping the Localizer, and the Glide Slope Needle straight. At a decision height of 232 ft., they had to execute a missed approach. They were to fly a heading of 100, and maintain 1600 until established. The goal was for the participants to fly the aircraft to the best of their ability. Additionally, participants had to report the outer marker, report a thousand feet, and finally report the decision height (DH) (Appendix C & D). Participants were then asked to place a pair of headphones on their head. Following the placement of the headphones, the flight simulation began.

Each participant underwent testing for thirty-minutes. Each IFR approach lasted approximately eight minutes. One IFR approach was under good weather conditions, and one was under poor weather conditions. The good weather approach was programmed to have overcast clouds, and ½ mile visibility. The poor weather approach was programmed to have overcast clouds, ½ mile visibility, a wind speed of 20 knots of crosswind, and heavy precipitation. One group was administered a UAS for eight minutes per flight, and one group was administered WN for eight minutes per flight. Except for the UAS versus WN and the weather conditions, everything else was held constant. Throughout the whole procedure, the PC recorded pilot performance. At the end of the experiment participants were thanked for their participation in the study.

# RESULTS

The purpose of this study was to examine the effect of a UAS on pilot performance under varying IFR conditions. Pilot performance was measured by deviation from the LOC, the GS, and the AS. Three hypotheses were formed. The first hypothesis stated that under the UAS condition, performance would be better than performance under the WN condition. Table 1 summarizes the means (*M*), standard deviation (*SD*), and sample size (*n*) for each variable, followed by t-test results.

Table 1

*Group Means and Standard Deviations*

| Auditory Stimulus | RMSE | *M* | *SD* | *n* |
|---|---|---|---|---|
| UAS | LOC | 18.1 | 10.1 | 20 |
| | GS | 35.6 | 15.6 | 20 |
| | AS | 3.5 | 2.5 | 20 |
| WN | LOC | 21.9 | 14.7 | 20 |
| | GS | 38 | 24 | 20 |
| | AS | 3.7 | 2.6 | 20 |

An independent t-test was used to analyze the data collected. An alpha level of .05 was used for all significance testing. The results of the independent t-test revealed no significant differences for both auditory stimuli. For the LOC, $t(38) = -.951$, $p = .348$. For the GS, $t\,(38) = -.323$, $p = .748$, and for the AS, $t\,(38) = -2.91$, $p = .773$.

The second hypothesis stated that different IFR weather conditions would affect performance. Specifically, under good IFR weather conditions performance would be significantly better than under poor weather conditions regardless of the stimulus. Table 2 summarizes the *M*, *SD*, sample size for each variable, and t-test results.

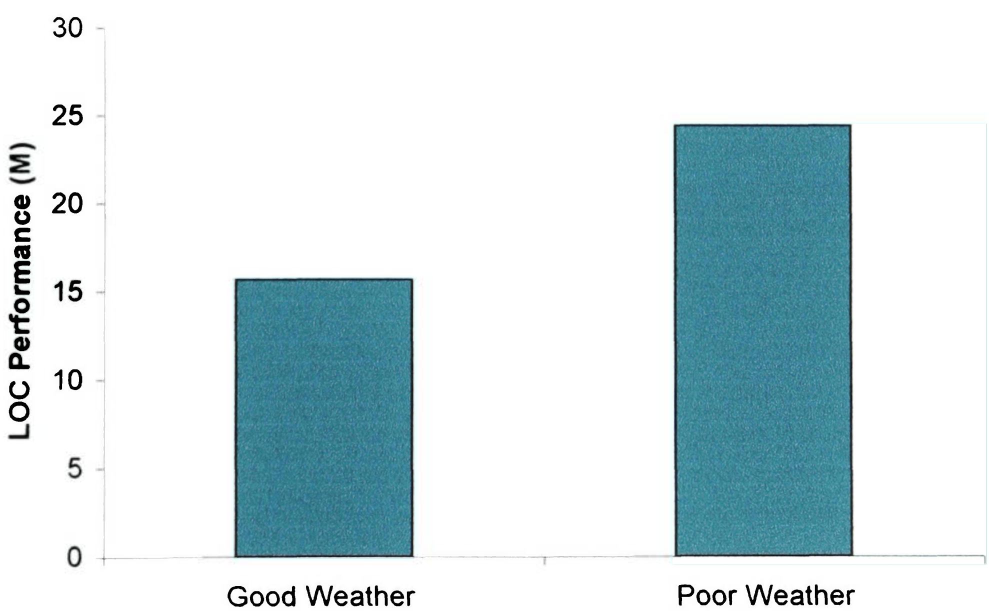
Table 2

*Group Means and Standard Deviations*

| Weather Conditions | RMSE | *M* | *SD* | *n* |
|---|---|---|---|---|
| Good Weather | LOC | 15.6 | 10.9 | 40 |
| | GS | 36.7 | 22.4 | 40 |
| | AS | 3.6 | 3.1 | 40 |
| Poor Weather | LOC | 24.4 | 19.2 | 40 |
| | GS | 37.3 | 21.7 | 40 |
| | AS | 3.7 | 3 | 40 |

For the analysis of this prediction a paired t-test was used. An alpha level of .05 was used for all significance testing. The results of the paired t-test revealed no significant differences for the GS, $t\,(39) = -.208$, $p = .837$, and the AS, $t\,(39) = -.015$, $p = .988$. However, the results for the LOC revealed significant results, $t\,(39) = -2.98$, $p = .005$. Figure 1 illustrates the difference.

Figure 1



The third hypothesis assumed an interaction between the type of stimulus and varying IFR conditions. Two predictions were made. The first prediction assumed that under good weather conditions, performance would not differ significantly for either stimulus. The second prediction stated that under poor IFR weather conditions performance under the UAS would be significantly better than performance under the WN condition.

Table 3 summarizes the *M*, and *SD* for the LOC for good and poor weather conditions under both stimuli.

Table 3

*Group Means and Standard Deviations*

| LOC | Auditory Stimulus | *M* | *SD* | *n* |
|---|---|---|---|---|
| Good Weather | UAS | 15.5 | 10.6 | 20 |
| | WN | 15.8 | 11.4 | 20 |
| Poor Weather | UAS | 20.8 | 13.9 | 20 |
| | WN | 28 | 23.2 | 20 |

The results indicate no differences for the LOC between performances in good or poor weather conditions under either stimulus.

Table 4 summarizes the *M*, and *SD* for the GS under good and poor weather conditions.

Table 4

*Group Means and Standard Deviations*

| GS | Auditory Stimulus | *M* | *SD* | *n* |
|---|---|---|---|---|
| Good Weather | UAS | 34.8 | 18.7 | 20 |
| | WN | 38.6 | 25.8 | 20 |
| Poor Weather | UAS | 37.2 | 18.9 | 20 |
| | WN | 37.5 | 24.8 | 20 |

The results indicate no differences for the GS between performances for good or poor weather conditions under either stimulus.

Lastly, Table 5 summarizes the *M*, and *SD* for the AS in good and poor weather conditions under both stimuli.

Table 5

*Group Means and Standard Deviations*

| AS | Auditory Stimulus | *M* | *SD* | *n* |
|---|---|---|---|---|
| Good Weather | UAS | 3.4 | 2.3 | 20 |
| | WN | 3.9 | 3.7 | 20 |
| Poor Weather | UAS | 3.7 | 3.6 | 20 |
| | WN | 3.6 | 2.3 | 20 |

The results indicate no differences for the GS between performances in good or poor weather conditions under either stimulus.

The data of the interaction were analyzed with repeated measures ANOVA. Stimulus and weather reflect factors. An alpha level of .05 was used for all significant testing. The results of the ANOVA indicated a non-significant main effect for both stimuli and weather conditions. For the LOC, $F\,(1,38) = 1.36, p = .25$, for the

GS, $F(1,38) = .338$, $p = .56$, and for AS, $F(1,38) = .26$, $p = .61$. Table 6 presents additional information regarding the ANOVA results.

Table 6

*ANOVA Source Table*

| Source | | *df* | *SS* | *MS* | *F* | *p* | Partial $n^2$ | Power |
|---|---|---|---|---|---|---|---|---|
| Weather*Stimulus | LOC | 1 | 231.1 | 231.1 | 1.36 | .25 | .035 | .206 |
| | GS | 1 | 59.5 | 59.5 | .338 | .56 | .009 | .088 |
| | AS | 1 | 1.5 | 1.5 | .26 | .61 | .007 | .079 |
| Error | | 38 | 6459.1 | 169.9 | | | | |

It was also expected that weather manipulation would have produced more stress and workload between the two flights. The results of the BAI and the TLX yield no significance difference on anxiety and workload levels between the two flights. Table 7 summarizes the *M*, and *SD* for the BAI and the TLX under good and poor weather conditions.

Table 7

*Group Means and Standard Deviation*

| Weather | Tests | *M* | *SD* | *n* |
|---|---|---|---|---|
| Good | BAI | 3.8 | 3.8 | 40 |
| | TLX | 53.6 | 14.5 | 40 |
| Poor | BAI | 4.1 | 3.3 | 40 |
| | TLX | 56.6 | 14.5 | 40 |

For the analysis of this prediction a paired t-test was used. An alpha level of .05 was used for all significance testing. The results of the paired t-test revealed no significant differences for the BAI, $t(39) = -.521$, $p = .605$. The results for the TLX did not reveal significant difference, however it was significantly close, $t(39) = -1.86$, $p = .07$.

# DISCUSSION

The purpose of this study was to examine the effect of a UAS on pilot performance under varying IFR weather conditions. In that piloting an aircraft is an extremely complex task, which places high cognitive and psychological demands on the operators, it would seem necessary to reduce factors such as stress in order to enhance accuracy and safety.

The present study assessed the effect of a UAS versus WN, in good weather IFR conditions and in poor weather IFR conditions. Forty student IFR pilots (37 male, 3 female), with an age average of 21.17, and an average total flight time of 255.87 participated in the experiment. Results demonstrated no significant difference between the effect of UAS versus WN.

The most reasonable explanation for these results would appear to be the fact that in all the previous studies conducted with an unconscious stimulus, participants were either passively exposed to the UAS and then were later asked to perform a certain task, or they were exposed while performing one task. For example, in their study, Bogeat and Goulet (1983) had their participants exposed to a UAS, and then asked them participants to solve a mathematical problem and then exposed them to a UAS while they were solving the problem. In another study Kaser (1986) exposed his participants to a UAS while being passive, and then asked them to draw an imagery drawing. Finally, Kotze and Moller (1991) exposed their participants to UAS while being passive, and measured their physiological reactions.

Contrary to previous studies, this study had participants actively involved in an ILS simulated approach. An ILS approach is considered as one of the most difficult tasks involved in flying an aircraft (Hasbrook, & Rasmussen, 1970). Under IFR and poor weather conditions the levels of workload seem to increase even more. Several studies measuring psychophysiological changes resulting from mental and psychological load during simulated flights, reveal that the pilots who were engaged in IFR flights did experience higher levels of workload, and their physiological measurements did differ significantly from those that conducted flights under VFR conditions (Leino, Leppaluotto, Ruokonen, and Kuronen, 1999; Wilson, 2001). Thus, flying an aircraft is considered to be an extremely complex task, placing great cognitive demands on the pilots (Wilson, 2001).

In the present study, the ILS approach simulation demanded a great deal of attention; thus imposing a high cognitive load on the pilots. Participants' attention was divided among the following tasks: flying under IFR conditions, tracking all instruments, keeping the LOC needle straight, keeping the GS needle straight, maintaining an AS of 90 knots, reporting the outer marker, reporting 1,000 feet, and finally reporting DH, and conducting a miss approach. Additionally, participants were also exposed to aircraft noise. All these tasks demand multiple resources and require the pilot to divide available resources among the tasks to be performed.

It has been established, that two different resources compose processing: the perceptual cognitive activity (e.g., display reading, information monitoring, voice comprehension, mental rotation, situation assessment, diagnosis, or calculation), and the response processes (e.g., control manipulation switch activation, or voice output). Additionally, the auditory and visual inputs seem to use the same energetic systems (Wickens, 1991). When the tasks require use of the same resources, then they are found to be interfering with each other, produce more load, and reduce the ability of detection

(Childs, 1976; Craig, 1991; Shallice, et al., 1985). Under these circumstances, it would appear that the UAS did not have an effect on the pilots. This may be attributed to the fact that the cognitive load produced by the tasks may have inhibited any further processing of the stimulus (Adams, Tenney & Pew, 1991).

Interestingly, with the exception of the LOC, no significant differences were found between performances under good or poor weather conditions. One reason for this finding may be the fact that the GS is typically more sensitive than the LOC. For example, the typical degrees of deflection for the GS are .7 above and below, 1.4 in total; whereas for the LOC the typical degrees are 2.5 in each side, 5 degrees total (Thom, 1990). Furthermore, student pilots appear to be more familiar with lateral tracking (viz., LOC) than with vertical tracking (viz., GS), in that they are trained with global positioning system (GPS), very high frequency omni-directional radio range (VOR) tracking, and non-directional beacon (NDB). It would seem that experience in lateral tracking would be the rationale behind the better performance observed for the LOC under the good weather conditions. The decrements in performance for the LOC under the poor weather conditions on the other hand, may be due to the crosswind, which carried the aircraft off its course.

By manipulating weather conditions, the researcher attempted to produce further anxiety and workload on the participants. Nevertheless, the results illustrate no differences. This would indicate that the manipulation was either not enough, in and within itself, or that the manipulation was insufficient within the environment provided. The Microsoft 2002 Professional Simulator used in the present study does not meet the criteria of a simulator with any current accepted definition of fidelity as defined by current industry standards. The regulatory authorities have identified several levels of simulators: aircraft-specific devices with 6 degrees of freedom motion platforms, and high fidelity visual systems to fixed based flight training devices (FTDs) (Dennis, & Harris, 1998). Level A – level B flight simulators have 3 degrees of freedom motion, while level C- level D have 6 degrees of freedom motion (Rehmann, 1995). The PC software packages that allege to be flight simulators (PCS), although they have become pretty sophisticated over the last few years, they are not considered to have fidelity (Dennis, & Harris, 1998).

In contrast to a low fidelity simulator, a high fidelity simulator has more immersive qualities due to the more realistic nature of the setting, and should maximize transfer making the operator feel part of an environment that he or she in reality isn't part of (Rinalducci, 1996).

A high fidelity simulator involves equipment fidelity, environmental fidelity and psychological fidelity. The environmental fidelity is concerned with the level to which the simulator imitates the system. The environmental fidelity is concerned with the level to which the simulator imitates the sensory part of the task, and the psychological fidelity is concerned with the level to which the simulator is perceived by the operator to reproduce the system and the tasks (Rinalducci, 1996). One possible explanation for not finding any differences between anxiety and workload under good weather and poor weather conditions may be the use of a PCS such as the Microsoft 2002 Professional.

It is suggested that further examination of the effect of an UAS in pilots should be completed under different conditions. Due to the low power observed in the experiment, the use of a higher sample size would be preferred in order to possibly better establish if the insignificance was due to the treatment itself or to the lack of power that is highly correlated with the sample size (Keppel, 1991). Finally, for a better examination of the stress and workload experienced by the pilots during a simulated flight, a more sophisticated and versatile simulator would be highly recommended. A realistic environment would give the participants the impression of flying, thus inducing realistic psychological reactions.

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# APPENDIX A

## STANDARD INSTRUCTIONS PRIOR TO CONSENT FORM

The experiment you are about to participate in examines the effects of stress on pilot performance. It will last approximately 30 minutes. Your performance as well as your personal information will remain confidential. You will be given specific instructions, and a consent form to sign. At any time you can terminate your participation without any penalties.

Prior to flying you will be asked to complete a test measuring stress. Additionally, after the first and second flight you will be asked to complete two separate tests respectively, measuring stress and workload. In total you will complete five tests. The simulator is configured to fly as a Cessna 172. First you will do 2 practice VFR flights of two minutes each, just to get the feeling of the simulator. After that, you will be asked to wear these headphones and shoot for two IFR approaches. These flights will be recorded by the computer.

Do you have any questions?

# APPENDIX B

## CONSENT FORM

**Department of Human Factors and Systems**

**Embry-Riddle Aeronautical University**

The study in which you are about to participate examines pilot performance under stress. You will be requested to conduct two IFR flights. Additionally, you will be asked to complete five tests. The experiment will last approximately 30 minutes. Your information will remain confidential, since only the last four digits of your ERAU ID will be requested. At any time during the experiment you have the right to leave without penalty. After the study is completed, more information will be available upon request.

I consent to participate in the research project examining pilot performance under stress. The principle investigator of this study is Christina Christakou.
The individual above, or their research assistants, have explained the purpose of the study, the procedures to be followed, and the expected duration of my participation. I acknowledge that I have the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that I am free to withdraw consent at any time and to discontinue participation in the study without prejudice to me.

Finally I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily.

**Date:** ---------------------

**Name (ERAU ID):** --------------------------------

**Signature (Participant):** --------------------------------------

**Signed (Researcher/Assistant):** ------------------------------------------------

# APPENDIX C

## GOOD WEATHER SCENARIO

Scenario:

Ask me to repeat anything you don't understand.

Your flight is going to start in cruise, on final vector to the ILS 7L at Daytona Beach.

You are located North of the course.

Your goal is to intercept the Glide Slope, maintain 90 knots, while keeping the Localizer, and the Glide Slope Needle straight. At a decision height of 232 ft., execute a missed approach.

Additionally, report the Outer Marker, 1000 feet, and Decision Height, which is 232ft.

Fly heading 100. Maintain 1600 until established. You are cleared ILS 7L.

Any questions?

Please place these headphones.

The simulator is un-paused.

## APPENDIX D

## POOR WEATHER SCENARIO

Scenario:

Ask me to repeat anything you don't understand.

Your flight is going to start in cruise, on final vector to the ILS 7L at Daytona Beach.

You are located North of the course. Your winds are from the South.

Your goal is to intercept the Glide Slope, maintain 90 knots, while keeping the Localizer, and the Glide Slope Needle straight. At a decision height of 232 ft., execute a missed approach.

Additionally, report the Outer Marker, 1000 feet, and Decision Height, which is 232 ft.

Fly heading 100, and maintain 1600 until established. You are cleared ILS 7L.

Any questions?

Please place these headphones.

The simulator is un-paused.