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A Simulation Study of Pilots' Ability to Perceive Angular Motion under the Influence of Alcohol

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A SIMULATION STUDY OF PILOTS' ABILITY TO PERCEIVE ANGULAR MOTION UNDER THE INFLUENCE OF ALCOHOL

by

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ABSTRACT

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The study consisted of experimental research to determine the effect of alcohol on the pilots' ability to perceive angular motion. It was hypothesized that in the absence of visual cues, pilots' thresholds of perceiving a change in angular motion is adversely affected by alcohol in the blood, thereby increasing the potential to enter a state of spatial disorientation. The experiments were designed to simulate a real time in-flight scenario, in a rotating flight simulator, where angular accelerations could be controlled and pilots' thresholds of perceiving a change in angular motion could be measured. The study revealed that the subjects registered a significant deterioration of their ability to perceive a change in angular motion at low Blood Alcohol Contents (BAC<0.04). Interestingly, the ability to detect angular motion only marginally improved when thresholds were recorded just after the BAC dropped to zero. A parallel research was also conducted to study the policies on 'BAC and flying' followed by Corporations, FBOs, Flight Schools, and Airlines. Analysis and pertinent conclusions of the empirical results indicate a need to re-look at the policies/regulations and their ramifications on aviation businesses.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter One

INTRODUCTION

While flying in inclement weather conditions, pilots have occasionally experienced 'spatial disorientation'. In the absence of visual cues, lack of adequate attention to the primary flight instruments has been a prime cause for uncontrolled and undesirable departures from a normal flight attitude. Under such conditions, prompt detection of a change in angular motion plays a critical role in retaining spatial orientation. The purpose of this study is to explore the effect of alcohol content in the human body on the ability of a pilot to perceive a change in angular motion. Federal Aviation Regulation permits flying with Blood Alcohol Content (BAC) less than 0.04% provided eight hours have lapsed after the last drink.[1] If consumption of alcohol within the permissible legal limits has a residual effect which impairs the ability of a pilot to detect angular motion, then there may be many disorientation cases that could possibly be attributed to this alcohol induced physiological deficiency.

There is evidence that the vestibular system remains affected by alcohol many hours after the Blood Alcohol Content drops to zero.[2] The duration of positional alcohol nystagmus (PAN)[3] and associated phenomena that impairs performance in visual tracking

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[1] Federal Aviation Regulations (FAR) Part 91.17.

[2] Money, K.E. et al. Role of semicircular canals in positional alcohol nystagmus. Defense Research Laboratories Research Paper No. 573. 1965.

tasks and reaction times have been studied by various researchers, and it has been repeatedly demonstrated that alcohol adversely effects the performance with respect to the researched areas. However, there is no known documented research that highlights the specific effect of alcohol in the deterioration of perception of a turning movement. While nystagmus, reaction times and visual tracking ability are contributory factors that may lead to poor in-flight performance, a decrement in the sensitivity to perceive a change in direction is more related to the disorientation potential of a pilot. In the absence of visual cues, the vestibular system is the primary sensor that indicates a change in spatial orientation. It is a well known fact that spatial disorientation generally occurs when the pilot is not paying attention to the primary flight instruments when flying under instrument meteorological conditions (IMC). If the pilot is not attending to his/her primary flight instruments, it is possible that the aircraft experiences a departure from its intended flight path. Onset of a slow turn or a change in attitude could be the result of a malfunctioning auto-pilot, a trim discrepancy, a change in the wind vector, or merely an asymmetric fuel feeding anomaly. In high performance aircraft, in particular, a few seconds of undetected pitch, roll, yaw, or a combination thereof, could mean a drastic change in flight attitude, altitude and speed in a short span of time. Therefore, any reduction in the ability to perceive a change in attitude under such like conditions could further delay detection of the ensuing change in the aircraft direction/attitude, and this small but critical impairment in the ability to detect a shift in angular velocity can have disastrous consequences. If alcohol decreases the ability to perceive changes in direction (without adequate visual

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[3] "PAN" is the rhythmic involuntary movement of eyes due to alcohol ingestion.

cues), then disorientation potential of the pilot would be increased. This simulation study is based on this very conjecture. The current study replicates an original study by Ross and Mughni (May 1994, in press), with an additional inquiry into the effect of increased work load with alcohol on the pilots' ability to detect angular motion.

Problem Statement

Federal Aviation Regulations prohibit flying with Blood Alcohol Concentration (BAC) at or above 0.04%.[4] The research thesis is focused to determine the deterioration of turn perception threshold[5] of pilots at just below 0.04% BAC, in comparison to their normal (no alcohol) threshold of turn perception. The study also examines the residual effect of alcohol on thresholds, after the BAC of alcohol administered subjects dropped to zero. Concurrently, the research probes into the interaction of increased work load on thresholds under similar conditions and BAC levels. The research includes a survey of a random sample of various aviation companies on their current corporate policies regarding "alcohol and flying". The results/inferences obtained through empirical study and the survey, are related to their possible ramifications on aviation safety. Finally, the study aims to draw pertinent conclusions and suitable recommendations for aviation businesses.

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[4] Federal Aviation Regulation (FAR) Part 91.17(a)(4).

[5] ***Threshold,*** for the purpose of this study, is defined as the minimum angular acceleration value at which the subject correctly perceives motion in the specified direction.

Review of the Literature

A number of experiments have been carried out on the effect of alcohol on nystagmus and tracking performance,[6] crew coordination and procedural errors,[7] [8] and hypoxia.[9] These, and other related studies have greatly helped the author in understanding the inherent complexity of human factors in formulating the design of the proposed experiment. A recent study on 'the effect of alcohol on the threshold for detecting angular motion', (Ross and Mughni, in press) provides a foundation for the current study.

Vestibular system and perception of angular motion. The human vestibular system comprises the nonacoustic portion of the inner ear and consists of three semicircular canals. These canals constitute angular accelerometers capable of sensing angular accelerations in any direction as the head is rotated.[10] Angular accelerations of the head in the plane of the canal cause the endolymph (fluid contained in the semicircular canals) to flow in the canal due to its inertia, which in turn deflects a cupula that gives rise to a sense of turn. The semicircular canal/endolymph/cupula system acts as a heavily dampened angular accelerometer, responding to angular accelerations in its own plane and

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[6] Schroeder, David J., et al. "Effect of Alcohol on Nystagmus and Tracking Performance During Laboratory Angular Accelerations About the Y and Z Axis". Aerospace Medicine. May, 1973. Vol. 4. pp. 5-12.

[7] Billings, C.E., et al. Effect of Alcohol on Pilot Performance in Simulated Flight. Aviation, Space, and Environmental Medicine. March, 1991. pp. 223-235.

[8] Ross, L.E., et al. "Pilot Performance with Blood Alcohol Concentrations Below 0.04%". Aviation, Space and Environmental Medicine. November, 1992. pp. 951-956.

[9] Carroll, James R., et al. Influence of the After Effects of Alcohol Combined with Hypoxia on Psychomotor Performance. Aerospace Medicine. October, 1964. p 990-993.

[10] Peters, R.A. Dynamics of the Vestibular System and their Relation to Motion Perception, Spatial Disorientation, and Illusions. Ames Research Center publication. Washington D.C. April, 1969. p 5.

yielding sensations of angular rate. If however, the acceleration is followed by rotation at a constant rate, the endolymph catches up with the rotating canal, and the deflected cupula is restored to its rest position by virtue of its own elasticity.[11] If audio and/or visual cues are not available then the subject erroneously thinks that he/she has stopped turning.[12] This phenomena has been used in the design of experiments for measurement of turning thresholds.

There are three manifestations of vestibular canal activity which have been used to determine threshold values. These are: (1) reports of feelings of rotation, (2) nystagmus, and (3) oculogyral effect (the apparent movement of a point of light in the dark).[13] While the effect of alcohol on nystagmus and oculogyral phenomena have received attention, the interaction of the sensations of rotation as affected by alcohol has not been studied (no known documentation). However, angular motion thresholds without the interaction of alcohol were tested by researchers as early as 1875.[14] The recorded thresholds of perception of turn motion varied between angular acceleration values of 8.2 to 0.035 degrees per second per second (deg/sec^2). Large variations between different determinations was attributed to the method employed and apparatus used for threshold

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[11] Gabriel, A. Orientation in Space, with Particular Reference to Vestibular Functions. Environmental Effects on Consciousness. New York: MacMillan Co. 1962, pp. 64-72.

[12] Peters, R.A. Dynamics of the vestibular system and their relation to motion perception, spatial disorientation, and illusions. Ames Research Center publication. Washington D.C. April, 1969, p. 9.

[13] Howard, I. P. and Templeton, W. B. Human Spatial Orientation. New York: John Wiley & Sons. 1966, p. 115-116.

[14] Ibid.

measurements.[15] Some of the recorded threshold values (without the interaction of alcohol) are stipulated in Table 1 shown below.

Table 1.

Recorded Threshold Values

INVESTIGATOR	THRESHOLD (deg/sec2)
Mach (1875)	2.0
Dodge (1923)	2.0
Tumarkin (1937)	0.2
Hilding (1953)	< 1.0
Clark (1962)	0.12
Clark (1967)	0.035 - 8.2
Howard (1986)	0.24 - 0.45

(Data Source: Ref. footnote No. 13)

A recent study carried out in Germany[16] revealed that horizontal rotational motion detection thresholds observed in the experiments were 0.2 deg/sec^2 to 1.0 deg/sec^2. It was not surprising to note that there was so much variation between different determinations. The reason cited by Howard and Templeton (1966) was that it is not easy to accelerate a human subject smoothly, and avoid all extraneous sources of stimulation,

[15] Ibid.

[16] Schweigart, G., et al. Interaction of vestibular and proprioceptive inputs. Journal of Vestibular Research. Spring 1993. pp. 41-57.

and therefore, experimenters have differed in their threshold determinations. It was also observed by Ek, Jonkees, and Klijn that thresholds were a function of the signal-to-noise ratio, and reduction of noise reduces threshold.[17] This factor was important for designing the task load commensurate with the optimal values of the threshold measuring apparatus.

Duration of stimulus was also studied by researchers and it was determined that the product of acceleration and time remain constant.[18] Thus for shorter times of application, greater accelerations are required to reach a given threshold. This product, known as Mudler's constant, remains fairly constant for stimulus times of about 5 seconds or less. The observed values of Mudler's constant range between 0.2 and 8.0 deg/sec^2, depending upon the subjects and methods used to determine it.[19] This aspect of vestibular threshold was also considered in the design of the threshold determination procedure.

Ryback and Dowd (1970) found that positional alcohol nystagmus (PAN), as well as Coriolis induced nystagmus lasts as long as 34 hours after consuming alcohol. Oosterveld (1970) reported that PAN could be observed up to 48 hours in some subjects. Goldberg (1966) had reported similar results lasting several hours. In designing the present study, the author considered the possibility that if nystagmus could stay long after the detectable Blood Alcohol Content goes to zero, then the threshold of turn perception could also remain impaired for some length of time after the BAC dropped to zero. To explore this

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[17] Boff, Kenneth R., et al. Handbook of Perception and Human Performance. New York: John Wiley and Sons. 1986. pp. 18-12, 18-21.

[18] Ibid.

[19] DeHart, R.L. Spatial Disorientation in Flight. Fundamentals of Aerospace Medicine. Philadelphia: Lea & Fabiger. 1985. p. 325.

possibility, post alcohol administration threshold measurements at zero BAC were recorded in the experiments conducted in this study. (While it was also considered possible to extend the study to several hours after the initial drop of BAC to zero, this particular study was restricted up to a time period corresponding to the initial drop of BAC to zero after alcohol ingestion.)

Schroeder (1971) had observed that subjects exhibited enhanced nystagmic responses during angular accelerations after ingesting alcohol. It was inferred that the effect was due to the subjects' inability to maintain visual fixation rather than an increase in vestibular sensitivity. The method involved rotational speed of 80 rpm and stimulus duration of 15 seconds. High acceleration and rotational speeds could have contributed to this conclusion.[20]

The adverse effect of alcohol on visual fixation during angular accelerations as well as the deterioration of tracking performance was also investigated by Gilson, Schroeder, Collins and Guedry (1972). Tracking performance was observed to be significantly poorer after alcohol consumption [even at low BAC (0.027%)]. The increase in nystagmus and decrease in tracking performance was observed in the yawing as well as the pitching plane.

The Coriolis effect, also called the Coriolis illusion, is another false precept that can result from unusual stimulation of the vestibular duct system.[21] The phenomena occurs when the subject has been rotating long enough for the endolymph in those ducts to attain

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[20] Howard, I. P. et al. Human Spatial Orientation. New York: John Wiley & Sons. 1966, p. 126.

[21] Gillingham, K.K. and Wolfe, W. Spatial Disorientation in Flight. Fundamentals of Aerospace Medicine. 1985. pp. 346-348.

the same angular velocity as his head, and the sensation of rotation has ceased. If the subject moves his head in a different plane from the plane of rotation, the other two sets of semicircular canals would be activated and a resultant sensation of rolling and/or pitching would be manifested. The speed of rotation and the rate and degree of head movement are responsible for the intensity of the Coriolis illusion. The effect of alcohol on Coriolis was studied by Ryback and Dowd (1970) and Hill, Schroeder and Collins (1972). While Ryback and Dowd indicated that their subjects reported increased sensation of tumbling after ingestion of alcohol, Hill, Schroeder and Collins reported that no consistent alcohol effects were found on the intensity or the duration of Coriolis sensations.

With reference to the effect of alcohol and tracking performance some interesting results / implications were observed by Gilson, et al, (1972). They reported that with alcohol, a dramatic impairment in tracking performance was observed only in the dynamic environment (and not in the static environment)[22]. This shows the insidious nature of this effect. A pilot who drinks lightly may be able to convince himself on the ground that his abilities are unimpaired and thus may feel safe to enter the cockpit. The study goes on to say that while flying, particularly at night with dim display illumination, the pilot who encounters vestibular stimulation as a result of maneuvers, turbulence or some inner year dysfunction may experience some blurring of vision. The visual control of the eye movements is reduced by the effect of alcohol, and vestibular control could then be predominant. (While the effect of alcohol on the turning sensation was not studied, it is

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[22] Gilson, Richard D. Effects of Different Alcohol Dosages and Display Illumination on Tracking Performance During Vestibular Stimulation. Aerospace Medicine. Volume 43, No. 6. June, 1972. p. 660.

possible that the vestibular system of the pilot, and thereby, the thresholds of turn perception could also be adversely affected).

Although the sensory systems (vestibular and visual) involved in spatial disorientation, or pilot's vertigo, would appear to be affected by the ingestion of alcohol, the locus and nature of the effect are not established.[23] While some authors report that alcohol enhances vestibular responses, others indicate response suppression.

Alcohol related accidents, policies and regulations. With regard to accidents related to alcohol and disorientation, a special report[24] quoting US National Transportation and Safety Board (1979), indicated that out of 678 plane crashes nation wide, alcohol impairment was identified in 30 fatally injured pilots involved in these accidents, most of whom had BACs above 0.10 percent. An overload of alcohol is a known contributory factor to the common pilot error of the spatial disorientation.[25] The concern that alcohol ingestion compromises the flying ability of pilots is manifested in the FAA regulation (FAR 91.11)[26] and further revision of the regulation (FAR 91.17) with more stringent restrictions.

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[23] Schroeder David. Alcohol and Disorientation Related Responses. (Extract) FAA report no. FAA-AM-71-6. February, 1971.

[24] Fifth Special Report to the US Congress on Alcohol and Health. Secretary of Health and Human Services. December, 1983.

[25] Murphy, Kevin. Pilot errors: the ten most common. Private Pilot. November 1987. pp. 24-29.

[26] Schroeder, D. J. The Influence of Alcohol on Positional, Rotary and Coriolis Vestibular Responses Over 32 Hour Periods. FAA report no. V. FAA-AM-71-6. February, 1971.

Unlike illegal drugs, alcohol is a legal substance that may be used or abused without sanction. The FAA has long enforced a cautious policy towards the use of alcohol by crew members. The threat to aviation safety posed by the misuse of alcohol continues to be a major concern of the FAA.[27] Although the FAA regulations on BAC is specified at 0.04% for general aviation pilots, it was interesting to note that some states have permitted a higher BAC level as the minimum level required to legally fly. The states that established such provisions related to flying are tabulated below:

Table 2.

State Laws and Provisions Related to Flying while Impaired.

STATE	BAC LEVEL	FWI LAW
Alaska	0.10 %	AK Stat. 2.30.030
Kansas	0.10 %	KS S Ann. 3-1001
Louisiana	0.10 %	LA RS Ann. 14-98
Massachusetts	0.10 %	MA GL Ann. ch90 ss.94
Nebraska	0.05 %	NE RS 28-1465

Data Source: NTSB publication PB2-917008 NTSB/SS-92/03 dated October 14, 1992.

The Federal Aviation Administration (FAA) rules contained in the Title 14 Code of Federal Regulations (CFR) Part 91 prohibits persons from acting as a crew member while under the influence of alcohol or while using any drug " that affects [the person's]

[27] Rigg, R.W., et al. Drug and alcohol programs. Aviation Safety Journal. Spring 1992. pp. 14-17.

faculties in any way contrary to safety." In addition, a subsection within the regulation, known as the " 8-hour rule," prohibits a person from acting or attempting to act as a civil aircraft crew member within 8 hours after consuming any alcoholic beverage.[28] The FAA amended the alcohol and drug regulations on April 17, 1985, by adding a prohibition against acting or attempting to act as a crew member with a BAC at or above 0.04 percent (Section 91.17). In spite of this more strict regulation, researchers questioned the new limit and suggested that any alcohol in the blood stream may seriously compromise flight safety.[29]

The percentage of alcohol involved and other alcohol free general aviation accidents fatal to the pilot in command, during the period 1983 through 1988 were studied by the FAA.[30] The accidents were classified in two groups, (1) Alcohol Involved and (2) Other Factors. The groups were further divided into primary contributory factors that led to the accidents. These were, (1) Aircraft malfunctions, (2) Flightcrew errors and (3) Environmental factors as the primary cause of the accident. In the Alcohol related group 64.7% of the accidents were due to Flightcrew errors as the primary contributory factor, while aircraft malfunction and environmental factors (albeit in the Alcohol group) were classified as primary causes of accidents in 2.9 % and 30.7 % respectively. A comparative study of accidents classified as 'Alcohol Involved' and 'Other Factors' reveals that 'alcohol' as a factor in Flightcrew error accidents has been significant. Furthermore, the

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[28] Title 14 CFR 19.11, General Operating and Flight Rules. Part 91 applies to civil aviation; general aviation pilots are subject to requirements in Part 91.

[29] Ross, L.E. Alcohol: Is the new limit too much? Aviation Safety. February 1, 1988. Vol. 7. No. 3.

[30] NTSB Safety Study. October, 1992.

accidents attributed to aircraft malfunctions and environmental factors as the primary cause of the accident, with alcohol as the secondary contributory element, was also noticeable. The percentage of 'Other Factors' was comparable to 'Alcohol Involved' accidents in all the subdivisions of the groups. Flightcrew errors, also referred to as the 'Human factor' errors were almost two third of all accidents in both the groups. The percentage of Alcohol Involved, Flightcrew errors and Environmental factors exceeded the Other Factors group. The study clearly indicates the magnitude of Flightcrew related accidents in aviation. The data extracted from the study is depicted in the histogram below:

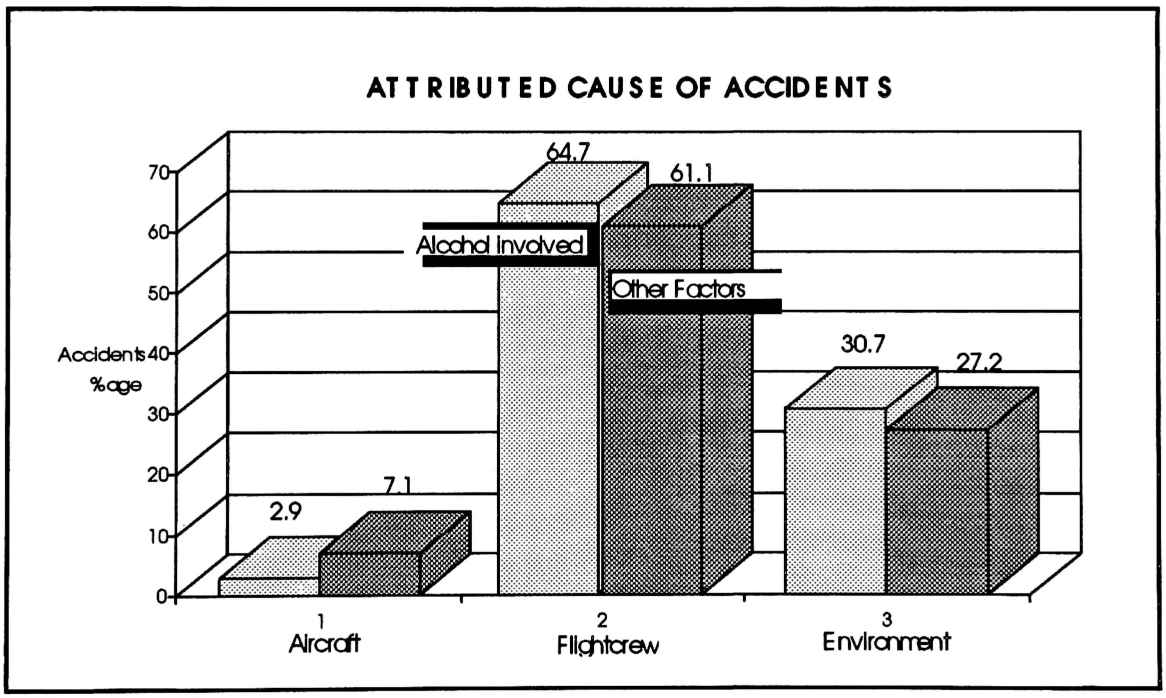

Figure 1. Data on Alcohol Related Accidents. Data Source: NTSB, Safety Study. October, 1992.

Drug testing regulations for transportation employees subject to Parts 121 and 135 (the Parts that regulate air carrier operations), require operators to conduct pre-employment, post accident, random, reasonable cause, and periodic testing of urine specimens for amphetamines, cocaine, opiates, and phencyclidine. An employer's testing must be separate and apart from the DOT-mandated drug testing program. The regulations did not require employer testing for beverage alcohol, the most commonly abused drug.[31]

The 1988 revision also includes an implied consent provision, contained in Section 61.16, that requires certificate holders subject to Parts 91, 121, and 135 to submit to an alcohol test when requested by a law enforcement officer and to furnish the results of alcohol tests to the FAA. Refusal or failure to provide a specimen for alcohol testing may result in certificate suspension or revocation and immediate grounding.

Just before and after the enactment of the rule, a number of controversial articles were published. 'Aviation Safety'[32] commented on the proposal that the FAA rule may be a non-solution chasing a non-problem, and considered that the proposal was a sweeping set of rules. The logic forwarded was based on poor reliability of testing processes and high cost to pilots/organizations, which in turn would be transferred to the passengers in the shape of higher fares. Furthermore, it was commented that all pilots know that the penalty for mixing flying and alcohol/drugs might be death, and the threat of license

[31] Public Law 102-143 enacted October 28, 1991, requires alcohol testing in commercial transportation operations, including aviation, mass transit, motor carrier, and rail. The DOT is in the process of promulgating regulations related to employee alcohol testing.

[32] Shugarts, David A. Drug tests: is FAA plan misguided? Aviation Safety. (Supplement). July 1, 1987. Vol. 7. No. 13.

suspension, or a fine after a test is proven positive, would have no greater deterrence than the potential of death.[33]

The essential provisions of the FAA's recently released final rule on alcohol testing of commercial aviation employees engaged in "safety-sensitive duties" are largely unchanged from the agency's original proposal. The Alcohol Misuse Prevention Program, which is patterned after the anti-drug program that has been in place for three and a half years, is slated to begin on January 1, 1995 and will cost FAR Part 121 and 135 operators an estimated $200 million over the next decade.[34] However, the new alcohol regulation entails somewhat less paperwork than originally anticipated and includes the economic incentive of reduced random testing if less than one half of one percent of industry employees test positive.[35]

Part 121 and large Part 135 operators (those with more than 50 employees performing safety-sensitive tasks) would have to conform to the regulation by January 1, 1995. The compliance deadline for Part 135 operators with 11 to 50 covered employees is June 1, 1995. Smaller Part 135 operators would have until January 1, 1996 to begin alcohol testing.[36]

Industry leaders are generally critical of the new alcohol rule. Regional Airline Association President Walt Coleman is quoted to have said, "the federally mandated

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[33] Ibid.

[34] Staff report. Observer. Alcohol Testing and Drug Testing: Playing the Percentages. Business and Commercial Aviation. April, 1994. p. 30.

[35] Staff report. Observer. Alcohol Testing and Drug Testing: Playing the Percentages. Business and Commercial Aviation. April 1994, p. 30.

[36] Ibid.

testing requirement ... contains no data that indicate the implementation of this costly rule will improve commercial aviation safety." While Coleman and other association officials welcomed the reduction in the random testing rate for illegal drugs, they are disappointed that DOT Secretary Federico Pena has refused to consider lowering that rate below 25 percent.[37] Based on this controversial aspect of alcohol and flying policy/regulation, a survey was carried out to determine the present state of corporate policies and views of aviation concerns on the subject. However, the main theme of the study lies in the experimental research to determine the interaction of alcohol and thresholds of turn perception.

Hypotheses

It is hypothesized that in the absence of visual cues, pilots' threshold of perceiving a change in angular motion, would be impaired at Blood Alcohol Content slightly below 0.04%. Furthermore, when blood alcohol level drops to zero (recorded after administering doses to attain a BAC of 0.04%), the pilots' ability to perceive angular motion would not return to the normal threshold value (i.e. threshold recorded before administering alcohol). It is also hypothesized that at increased work loads (task level) with BAC $\approx$ 0.04%, the degree of decay in the sensitivity to perceive angular motion would be further increased. If any of the above hypotheses are verified, then under the given conditions, a pilot's potential to enter a state of spatial disorientation would be increased.

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[37] Ibid.

Specific Objectives of Research/Study

The specific objectives of this research study were as follows:

a) Determine the Yaw Threshold of individual pilots in a simulated flight environment, under a given set of condition and task loads, with and without alcohol administration.

b) Compare individual pilot performance and threshold with the same individual's performance and threshold under the effect of alcohol as per hypotheses.

c) Relate the simulated research to the real time environment in flight, and draw logical conclusions.

d) From the findings of the research study, recommend measures to enhance flight safety.

e) Survey and study corporate regulations/policies with regard to 'alcohol and flying'.

f) Submit suitable recommendations.

Chapter Two

SIMULATION DESIGN AND PROCEDURE

Experiment/Research Outline

A simulated scenario was designed to approximate a real time situation in which a pilot inadvertently gets into a state of disorientation and fails to appreciate an ensuing angular acceleration which would in actual flight result in a change of direction and attitude. The aim of the simulation design was to measure the threshold of an individual's ability to detect angular acceleration, without visual references, under a canned scenario. This was accomplished by utilizing the rotating flight simulator (described later), where subjects (certified pilots) were asked to fly on partial panel, without attitude and heading indications available to him/her, (direction and attitude instruments masked). The simulator cockpit was entirely covered and outside references were not available. Specific simulation here, as related to real time, was that the pilot was assumed to be either in clouds or the natural horizon was obscured (simulation of IMC), and the pilot was not paying attention to the attitude and direction instruments. It was considered possible that during such a flight condition, the pilot could either be looking at the flip charts or reading the Instrument Approach Plates (IAP), while trying to maintain the altitude in a turbulent weather condition. To simulate the task of reading (a flip chart/IAP), a digital numeric display with randomly changing digits was used. Continually appearing digits on the display were monitored, and the assigned digits were called out by the pilot. To simulate turbulent weather conditions, computer generated turbulence was induced. During this period angular motion was induced at a measured rate. The pilot was asked to indicate the change in direction as perceived by his/her vestibular senses. The threshold or the minimum angular acceleration perceived by the pilot was noted.

After sustained and consistent readings of the threshold in repeated sessions, the subject pilot was tested under similar conditions but with BAC of slightly less than 0.04%. Difference in threshold, if any, was noted. Once the BAC dropped to zero, the threshold was again observed in another session. The experiments were conducted on six placebo and six alcohol administered subjects. The placebo group was tested at the same times and with same procedures as alcohol administered subjects except that their drinks contained no alcohol. The experiments were conducted to validate the hypotheses that threshold of perception decayed with Blood Alcohol Content < 0.04% and remained impaired after the BAC dropped to zero. The experiments also looked at the thresholds with increased work load on a similar pattern with same subjects. These experiments were conducted to establish a relationship of high task loads and threshold variations as hypothesized. The high task load design was introduced by adding an audio task (discussed later) to the task performed in the first experiment.

The objective of the study was to determine the magnitude of change in an individual's performance and threshold compared to his/her own performance with the BAC slightly less than 0.04%. Subsequently the residual effect of alcohol on the subject was noted by observing the deviations in performance and threshold at zero BAC (post alcohol administration).

During the experimentation phase of the research, the author was cognizant of factors like sleep deprivation, tiredness, mental fatigue, physical condition etc., between individual subjects, and within subjects between sessions of an experiment. As far as practicable, the experiments were conducted on subjects displaying minimum variations of such factors during the experiments in order to preclude chances of bias in the derived results.

Concurrently a survey/research was also conducted to ascertain the current policies being followed by various aviation concerns with regard to alcohol and flying. Finally, the ramifications of a change in regulations/policies were studied to submit suitable recommendations.

Design Objectives

The experiment design precepts were developed to meet the following objectives:

(a) To calibrate the system, in order that the yaw threshold of individual subjects can be quantitatively and objectively measured.

(b) To design simulation parameters that relate to actual flying scenarios as far as possible.

(c) To reduce random variables as far as practicable, so as to ensure a reasonable degree of consistency in an individual's threshold under a set of conditions.

(d) Having achieved the first three objectives, compare the changes if any, in the individual subject's threshold with BAC at pre-determined levels. (Set analysis parameters).

Equipment Calibration

An extensively modified ATC 610 Flight Simulator was used for the experiment. The simulator was mounted on an electrically driven motor that could rotate the simulator at a determined rate. The rate of rotation could be externally controlled by an adjustable potentiometer which was graduated to determine angular velocity and acceleration. The rate of movement of the potentiometer was synchronized with a Metronome for achieving a timed displacement, and a conversion chart was prepared to read the acceleration and deceleration value of the potentiometer scale/Metronome setting. The first step in the design phase of the experiment was to calibrate the simulator's rotational velocities and acceleration/deceleration values such that the range of acceleration measure lay in the normal acceleration threshold limits (perceptible angular motion) of a good percentage of subjects while they performed the given task. It was realized (after extensive trials on ten subjects in the pre-experiment design phase) that thresholds of eight sampled subjects were below 1.0 degrees per sec^2 while performing the prescribed task. The existing apparatus could not be utilized to accurately measure threshold values falling below 1.0 degrees per sec^2. Therefore, the electrical motor mechanism (mounted below the simulator for rotating the simulator enclosure) as well as the potentiometer (controlling the rotational velocity and acceleration/deceleration), were modified to attain greater precision required to measure lower threshold values. The apparatus was thus optimized for acceleration/deceleration in the range of 1.0 to 0.1 degrees per sec^2. However, the modification had sufficient margin to allow for measurement of thresholds of subjects who may show deviations from this range. After comprehensive trials (calibration), the system limits were established to be 0.066 to 2.56 degrees per sec^2. While it was considered best to measure the accelerations from stationary position, the system proved to be slightly inaccurate since initial acceleration due to inertia was not smooth and consistent. To account for this inherent anomaly in the system, the initial point of measure (steady state) was estimated to be approximately 3 rpm (rotations per minute), from where both acceleration and deceleration were found consistent and smooth. It was also observed that at this steady state, the effect of weight on acceleration and deceleration rate was not discernible with various potentiometer/Metronome settings for subjects weighing up to 240 lb. Subjects weighing higher than 240 lb. and less than 100 lb. were not tested. Apart from better control of accelerations and decelerations (from the determined 3 rpm angular velocity), it was also considered that the smooth acceleration of the subjects would not expose them to motion cues due to proprioceptive perception (non-vestibular cues through muscles, tendons ,etc.), or the effect would be minimal.

Using the Metronome (for timing) and potentiometer scaling (for measured displacement), angular accelerations between 0.066 degrees per sec^2 and 2.54 degrees per sec^2 could be recorded with reasonable accuracy (+ or - 0.0035 degrees per sec^2 at the minimum rate with inaccuracy increasing to + or - 0.033 degrees per sec^2 at the upper range of the spectrum).

Other Features/Ancillary Equipment

Cockpit instruments and controls were independent of the rotation of the simulator. Once the pilot was seated in the simulator, the cockpit enclosure was fully covered and outside references were not available to the pilot. A headset that received artificially generated engine and prop noise was worn by the subject; this masked external auditory inputs that could indicate a change in direction/angular acceleration. The subject could also receive transmissions from the experimenter through the head set receivers.

Changes in flight instrument indications as well as control movement inputs were recorded on an integral computer mounted on the simulator that used an Analog to Digital (AD) conversion card to collate data. The mike button on the yoke control column was connected to the computer, which when depressed indicated an event that the computer recorded. Depressing the button also illuminated a low wattage indicator light located on top of the enclosure. Additionally, an audio recorder was placed behind the seat to record calls initiated by the pilot. Head position of the subject could be adjusted by the experimenter to fit the subject's head in a normal vertical posture. To prevent head movement of the subject, a simple strap with Velcro was attached to the headrest. Having adjusted the head position, the subject retained the posture during the session. Deliberate head movement out of the adjusted headrest position was sensed by a capacitance system that illuminated a warning light displayed outside the simulator enclosure which was monitored by the experimenter.

Located at the center top of the instrument panel was an alphanumeric LCD display unit. The computer controlled the presentation of 1.4 cm by 0.7 cm numerals on the display. The distance of the display was 60 cm from the pilot's eye. The enclosure was dimly illuminated by a light behind the subject's head. The altimeter and the VSI (vertical speed indicator), were the primary task instruments and were back lighted. During trials the simulator turbulence was set to a moderate level (position 3 on a 1 to 5 scale). The turbulence adjustment knob was made nonfunctional to the subject.

In summary, the apparatus was modified to meet the design parameters. The ancillary equipment (computer, audio tape, visual warning lights, etc.) were utilized to indicate and record all deviations in the set parameters, via visual indication, audio recording, and extensive digitized data recording for analyses of subjects' responses and flight performance measures.

Task Design Objectives

It was observed in the pilot study phase of the experiment design that thresholds were a function of signal to noise ratio, (discussed in the review of literature). Therefore, the objectives set for the task design were:

(a) Degree of difficulty (of work load) should be just enough to ensure that the average thresholds fell within measurable ranges with reasonable degrees of freedom to record deviations.

(b) The degree of difficulty should be commensurate with the average experience of the subjects under study. (It was realized that if the task was increased beyond the capability or lay close to the upper limit of optimum performance of a subject, then there was a possibility that he/she may reject the task, thereby defeating the purpose of the task).

(c) The task had to be continuous with minimal lean periods.

(d) The task load was to be related to a possible real time situation.

Task Load Parameters

With these task design parameters (arrived after repeated tests and analysis in the pre-experiment design phase) the task load was set as follows:

(a) To maintain altitude. With turbulence set at a moderate level 3 (on a scale of 0 to 5), the pilot was required to maintain 10,000 feet of altitude with the help of only an altimeter and vertical speed indicator (VSI) as the primary instruments available to him/her. The attitude indicator as well as other turn indicating instruments were masked. This was done to preclude the chances of conflicting indications to the direction of movement, and to simulate the absence of visual cues for turning.

(b) To report designated numbers appearing on the digital display. Single digit numbers from 0 to 9 were programmed to appear randomly in the computer-controlled LCD display (described earlier in the apparatus description). The numbers were displayed for 5 seconds each with no time gap between the numbers. The sequence of numbers were changed for each session. Each sequence was such that a number that was required to be called out (task: look out for and report), was spaced so that the pattern could not be learned and anticipation was not feasible within the short span of the session. Furthermore, the change of sequence in each session precluded the chances of a learning curve within the given time frame of sessions.

Increased Task Load Design

The hypothesis that the subjects' threshold for detecting angular motion would be affected by the increased task load variable, required redesigning of the task such that their was a measurable increase in threshold while ensuring that that the objectives set for the task design were not violated. Furthermore, it was deemed important to ensure that the increase in task did not raise the threshold to a level that was not measurable by the apparatus in use. It was considered essential to design a task load that was more difficult than the previous task but the degree of difficulty was manageable by the subject. If the degree of difficulty was increased beyond the capability of a subject, there was a possibility that the subject could give up a given task, thereby electing to reduce the task load by not performing one of the tasks. After a number of task design trials and experiments with various task loads, it was decided to introduce an audio task along with the visual task being performed in the earlier experimentation design. At first, simple arithmetic was introduced, but it was found that subjects with faster arithmetic skills could solve the problem presented to them (both audio and visual presentations were tried) and there was a period of reduced activity before the next problem was presented. In periods of reduced activity the thresholds varied and it was difficult to ascertain the thresholds. Therefore, single digit numbers were audio-taped, (similar to visual task), but a different sequence was programmed and a faster rate was presented. Again, the task was to monitor the digits being heard through the head phone, and call out the assigned number and the number following it, whenever it came in the sequence being presented. The string of numbers were spaced two seconds apart, and the digit to call out (task) was randomly placed between 4 to 16 seconds apart. The task was continuous because all digits had to be monitored to pick out the assigned number. This task was an addition to the initial task that was required to be accomplished by the subjects in the first series of experiments performed earlier. Since the subjects for this experiment were not exposed to the previous experiment, the possibility of a learning curve was precluded. Furthermore, all sessions of the experiment had a different string of numbers with somewhat similar random variation which also reduced the probability of anticipation of the tasked numbers.

Threshold Measurement Methodology

The method adopted for threshold measurement was a modified version of "Adaptive Simple Up-Down method".[38] Some aspects of Least Noticeable Stimuli[39] and a variation of Staircase method[40] were also adapted while formulating the threshold measurement methodology. The measurement methodology was designed by the author to meet the following requirements:

(a) Adoption of a simple and accurate quantitative measurement procedure within the system limits.

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[38] Boff, Kenneth R. et al. Handbook of perception and human performance. New York: John Wiley and Sons. 1986. pp. 1-22-29.

[39] Woodworth R.S. and Schlosberg H. Experimental psychology. New York: Henry Holt and Co. 1960. pp. 196-197.

[40] Guilford J.P. Psychometric Methods. New York. Mcgraw Hill. 1954. pp. 114-115.

(b) Development of a methodology that could be used for measurement of thresholds in a minimum possible time frame, without compromising the number of minimum readings with high confidence level of accuracy.

(c) Establishment of a methodology that minimizes chances of error due to anticipation or expectancy by the subject during threshold measurements.

During the preliminary study and calibration phase, it was noted that 9 out of 10 subjects displayed consistent individual thresholds but there was noticeable threshold variability between the subjects. However, within subjects threshold comparisons showed that thresholds varied only with variations in task levels, (other factors remaining constant).

The simulator was optimized for a clockwise rotation, and an acceleration was manifested as a right turn and conversely, a deceleration was perceived as a left turn by the subject.

Threshold Measurement Procedure

Subjects were spun in the Rotating Simulator, to a stabilized clockwise rotational velocity of three RPM, from where measured angular acceleration and deceleration were initiated. Acceleration values above the individual's threshold were reported as right turns while declarations were sensed as left turns. Subjects were asked to report sensations by verbally calling out "turning left" or "turning right" while simultaneously depressing the mike button located on the yoke. The threshold determination was done by initiating the stimulus (acceleration/deceleration) at an average value $\cong 0.25$ degrees per sec^2 (determined through previous pilot study experiments). Each stimulus was maintained for ten seconds and approximately one minute (+ or - 15 sec.) stabilization time was given between stimuli. (This time was enhanced if a false positive was reported during the stabilization time). Furthermore, the variation in stabilization time also precluded the chances of error of habituation and the error of anticipation[41]). If the subject's response was positive (reported turn) after initiating acceleration/deceleration, the rate of turn was reduced in the subsequent acceleration/deceleration; and if the subject did not respond, the. rate of turn was increased. The time period for each acceleration or deceleration was 10 seconds. This was achieved by utilizing a chart (prepared specifically for this purpose) that read out potentiometer digits to reduce/increase with the Metronome settings used to keep 10 seconds acceleration and deceleration period constant for all values of acceleration or deceleration. The initial increments were $\cong 0.05$ degrees/sec^2 and increments were reduced as positive responses were reported, until such time the reduced acceleration/deceleration value was not sensed by the subject (no response reported). From the last detected value of acceleration/deceleration at 0.05 degrees/sec^2 increment, a reduced step value of 0.025 degrees/sec^2 for ten seconds was initiated, and if the subject detected angular motion, the next step was further reduced to 0.0125 degrees/sec^2 until the subject failed to detect angular motion. The final value of the last detected angular motion was considered as the threshold for deceleration. The least reported response was considered as the threshold for the individual. Two threshold readings for acceleration

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[41] Woodworth R.S. and Schlosberg H. Experimental Psychology. New York: Henry Holt and Co., 1960; pp. 196-197.

and two for deceleration were recorded in each session. After determining one threshold reading for the session, another independent reading was obtained by initiating acceleration/deceleration at the maximum identified no detection value and repeating the least detection value. The methodology followed was to alternate acceleration and deceleration steps so as to remain at a mean stabilized angular velocity of three rpm. Each acceleration/deceleration was initiated after a stabilization period of approximately one minute (+ or - 15 seconds to prevent anticipation on the part of the subject). Within a period of 20 to 30 minutes the subject's threshold could be determined with two deceleration (left) and two acceleration (right) threshold measurements. While the experimenter noted the subject's responses in real time, he could later cross check from the audio recording of the subject's 'response call' of turning left/right and digital recording on the computer (depression of mike button). All readings were recorded separately for each session for further analyses. The procedural concept of threshold measurement is depicted on the next page.

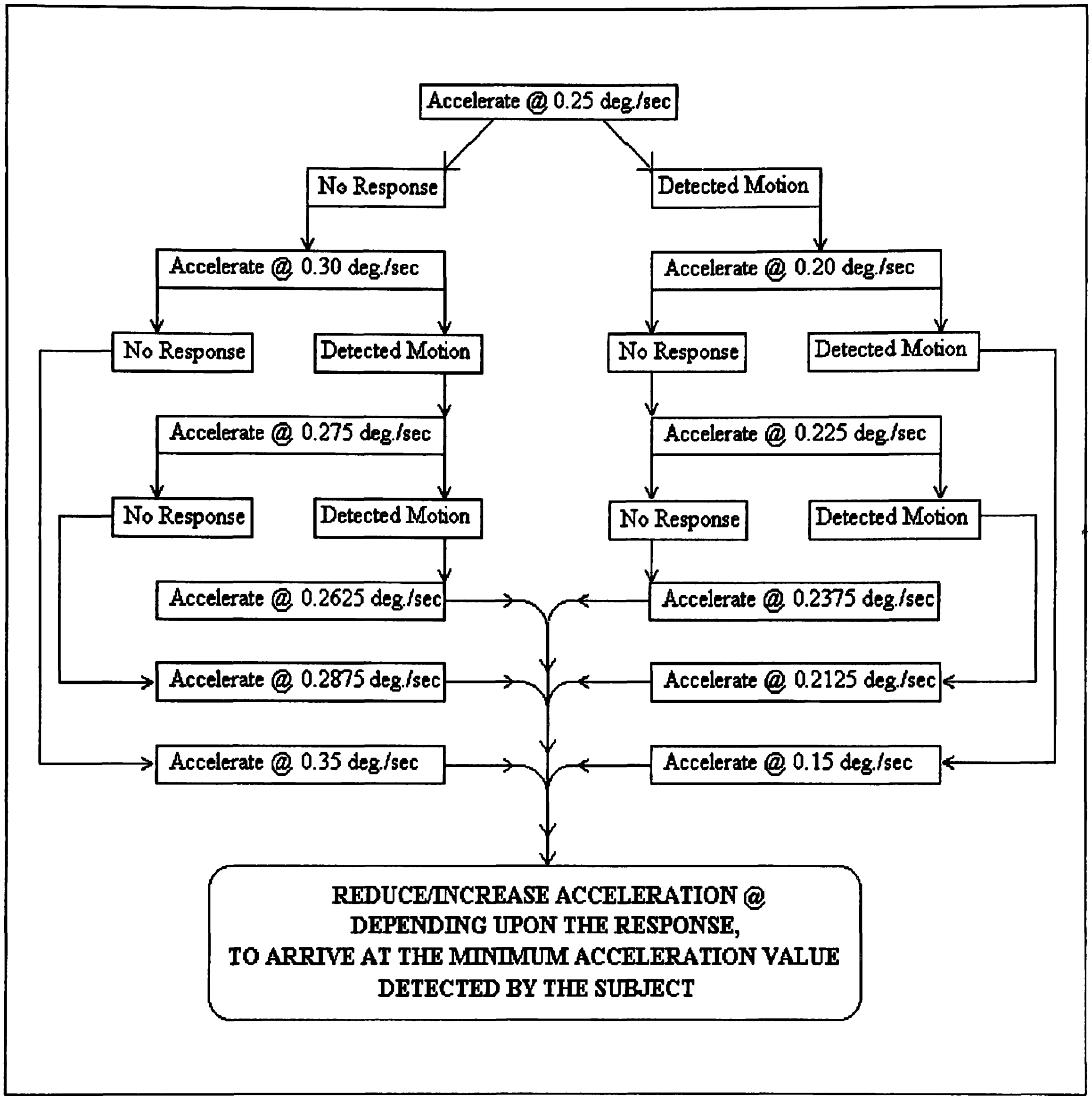

Figure 2. **Threshold Measurement Concept.**

[NOTE: The term acceleration is used generically to indicate both positive acceleration and negative acceleration (deceleration)].

Threshold Measurement Schedule

A two day experiment was designed for each subject. The first day was a qualifying day during which the subject was tested in two sessions separated by an interval of approximately 10 minutes. The first session lasted about 30 minutes while the second session was approximately 20 minutes. Each session was further divided in two sub-sessions. One sub-session was with the standard task load, henceforth referred to as 'low task', and the other sub-session was with increased task load design referred to as 'high task'. Three subjects in each group (alcohol and placebo), were given high task first while. the other three were asked to perform the low task first in each session. All subjects were tested for their angular motion thresholds under high and low task schedules.

In each sub-session two separate readings for left turn threshold and two for right turn threshold were taken. (Subjects indicating large variations in their threshold or displaying inconsistent performance were not considered for further experimentation). On the second day, three sessions, each lasting about 20 minutes were conducted. The first session (second day), was with zero BAC. The second session was conducted with either placebo/alcohol of slightly less than 0.04% BAC. The third session was executed after the subject's BAC had dropped to zero, or in case of placebo, approximately two hours after the second session (average time required by alcohol subjects to reach zero BAC).

The task in all sessions was: (a) to maintain altitude with a predetermined computer generated turbulence level; and (b) to call out some specific repetitive numbers that appeared on the programmed digital numeric display. For high task sub-sessions, specific audio numbers were monitored and called out in addition to the above task schedule.

Other Evaluation Methods and Procedures

On the first day subjects were given a subject consent form, a medical questionnaire, the Michigan Alcohol Screening Test (MAST), and a questionnaire concerning the manner in which they thought alcohol might affect pilot performance. No subject was continued who was abstaining or attempting to abstain from alcohol, had any medical condition that forbade alcohol consumption, or gave indications that he/she had a drinking problem. Following completion of the questionnaires, the subject was taken into the experimental room familiarized with the equipment and instructed concerning the task. Threshold values were then determined as described earlier.

On the second day (i.e., the test day), the subject was weighed, questioned about the time last food was consumed, and given a breath test to confirm that his or her BAC was zero. The subject was then taken to the experimental room for the first session (of the test day), and two threshold measurements for each sub-session of high and low task load were made under both acceleration and deceleration conditions. Alcohol or placebo drinks were then administered as described later. Threshold measurements were taken as soon as the subject's BAC dropped below 0.04%, and again after BAC reached zero. Following the last threshold determination the subject was asked to indicate the severity of any discomfort symptoms experienced during each of the three threshold sessions of that day. The subject then filled out a questionnaire in which (1) the number of drinks consumed (equivalent to the number of the subject's favorite alcohol drink) was estimated and 2) that subject rated, on a five-point scale, his or her ability to hold altitude, the effort required to hold altitude, the degree of sense of movement, and the effort required to sense movement during the threshold determinations made immediately after drinking alcohol or placebo drinks.

Subjects

Twelve subjects were assigned to two groups. One group consisted of those that received alcohol, while the participants of the other group were given a placebo treatment. (The alcohol/placebo administration is described later). Both groups had equal numbers of subjects with similar drinking habits. Of the Placebo Group, four had instrument ratings while the other two had only private pilot certificates; all except one subject did not have current flying status. The Alcohol Group had all instrument rated pilots, but two were not current. Placebo Group subjects (average age 27.0 years) had an average of 308 hours (h) flight time, range 100-750; while the Alcohol Group subjects (average age 25 years) averaged flight time of 302 h, range 160-720. Based on their responses on a modified version of the Quantity-Frequency-Variability (Q-F-V) approach developed by Cahalan, Cisin, and Crisley (1967), one subject in each group was classified as light alcohol user while three placebo group and two alcohol group subjects were moderate drinkers. There were two heavy drinkers in alcohol group and three in the placebo group.

Alcohol and Placebo Administration.

A double-blind procedure was used with alcohol administration. Threshold measurements were carried out in separate areas by different experimenters. After the pre-alcohol threshold measurements were taken on the test day, subjects in the alcohol group were given three drinks totaling 400 ml of alcohol and orange juice. The amount of alcohol in the drinks was calculated to result in a 0.04% BAC, thus ensuring that all subjects were on the descending limb of the BAC curve. The subject's BAC was tested by use of a calibrated Alco-Sensor III Intoximeter (Intoximeters, Inc. St. Louis, MO). Subjects in the placebo group also received three drinks totaling 400 ml, but each placebo drink contained only 3 ml of alcohol which was floated on the top of the orange juice. After the threshold values had been obtained the subject returned to the waiting area where BAC tests were conducted every 15-min. When a zero reading was obtained, the third set of threshold measurements were taken. Placebo and alcohol subjects were treated in an identical manner with BAC tests made at the same times and intervals. The interval between the second and third threshold measurements for the placebo subjects, tested prior to that time, to reach a zero BAC.

Chapter Three

RESULTS AND ANALYSIS

Methodology

The objective of the experiment, as indicated earlier, was to ascertain the angular acceleration (yaw plane) threshold and performance of an individual at zero BAC (pre-alcohol administration), and to compare the same with variations in threshold at 0.04 % BAC and thresholds when the individual's BAC dropped to zero (post-alcohol administration). It was hypothesized that there may be a positive correlation between performance levels and the indicated threshold. To this end, errors in maintaining the desired altimeter reading and elevator control inputs were recorded every 200 milliseconds during the session. Standard deviation of errors and RMS (root mean square) around the target altitude were calculated and graphically plotted to compare the thresholds and study the variances of these computer recorded data points. False positive (i.e. reporting a turn when there was no turn) indications during the session were also noted to compare deviations in different states (BAC levels) of a subject. For low task level sub-sessions, the visual digits missed (not reported) were noted and for high task load sub-session, audio and visual digits missed were recorded. Repeated measures method was used for the analysis of the recorded variables.

Thresholds and Task Performance Results

Deceleration and acceleration threshold values manifested as left and right turn perception thresholds (recorded in degrees per sec. per sec. rate of change of angular motion) are tabulated in the summaries, attached as Appendix "A" and "B" for Low Task and High Task Thresholds respectively. The appendices also show mean threshold values for alcohol and placebo subjects for the three measurement sessions of pre-alcohol, post-alcohol (average BAC of 0.038%) and when BAC dropped to zero tabulated under Sessions 1, 2, and 3.

The average values of threshold changes during the sessions for the Alcohol and the Placebo groups for high and low tasks is depicted graphically in Fig. 3 shown below.

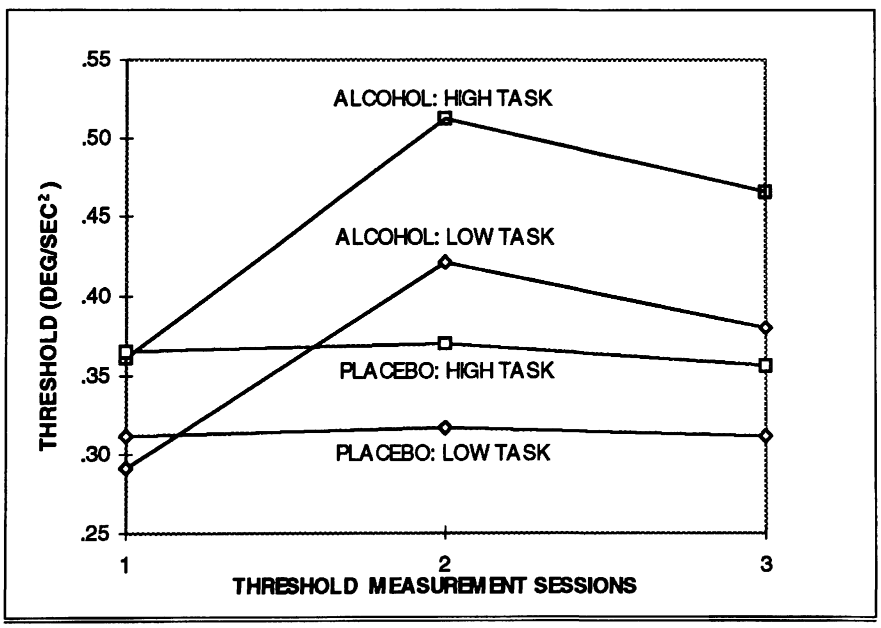

Figure 3. **Average Threshold Variations**: Alcohol Vs Placebo Groups

As can be seen, the alcohol subjects' mean threshold values increased substantially after ingesting alcohol and decreased only slightly when tested after each subject's BAC had reached zero. In contrast the placebo subjects, who experienced identical experimental procedures except for the absence of alcohol in their drinks, showed a stable mean threshold value. The effect of high task load was additive as can be noticed in the graph depicting Placebo: Low and High Task lines, and Alcohol: and Low and High Task lines across sessions, which are running almost parallel to each other. An analysis of variance involving the between subject factor of alcohol (versus placebo) and the repeated measures factors of sessions and work load versus thresholds is attached as Appendix "C".

The analysis shows a significant main effect of workload, $F(1,10) = 11.924$, $p<.01$, with higher thresholds under the heavy workload conditions than under the light workload conditions. The interactions of workload with other factors in the analysis were not significant. The main effect of the sessions, $F(2,20) = 13.794$, and the interaction of alcohol with sessions, $F(2,20) = 12.514$, were significant, $p<0.001$ for each. Subsequent t-tests found no significant difference between the Alcohol Group and Placebo Group threshold values during Session 1 prior to receiving drinks ($p>0.20$), but significant differences ($p<0.001$) on both Sessions 2 and 3. All alcohol subjects showed elevated thresholds on Session 2, with the smallest increase substantially greater than that of any placebo subject. For Session 3, all alcohol subjects continued to show considerably elevated thresholds at low as well as high task loads as can be seen in the graph (Figure 3) and supporting data in Appendices A and B.

The deceleration versus acceleration factor (manifested as left and right turn perception) was not significant, F(2,20) = 0.9617 and .3292 for high and low task conditions respectively, with similar patterns of threshold increases, as a function of alcohol shown for both kinds of angular velocity changes. The number of false positive responses (see Appendix "D" for details), increased in Session 2 and decreased in Session 3 for both alcohol and placebo subjects. An analysis of variance of the number of false positives of rotation showed a significant effect of workload, (F1,10) =8.2653, p<.025 with more false positives present under light task conditions (40 vs 31). None of the other main effects or interactions were significant.

Altitude Control. Accuracy in maintaining altitude and altitude control input variability could not be ascertained for this experiment due a malfunction in the integral computer system during the experiment phase. However, results of a similar experiment (without increased task load) conducted by the author prior to this experiment are summarized here. The accuracy in maintaining altitude was examined by computing each subject's mean altitude error, which was sampled every 200 milli-second (msec), during each session. An analysis of variance of the root mean square of the data points found no significant effect of the alcohol-placebo or sessions factors, nor was their interaction significant (all Fs<1). Similarly, subjects' altitude control input variability was calculated by computing the standard deviation of the yoke position as sampled every 200 msec. during each session. While input variability of Alcohol Group subjects was slightly less than Placebo Group for each session, it was noted that an analysis of variance involving the standard deviation of each subject's input movements for each session showed no significant alcohol-placebo, session, or interaction effect (all Fs<1).

Visual Task: Digit Reporting. Most of the Placebo Group as well as the Alcohol Group subjects correctly reported all of the assigned target numbers when they were displayed. Only two subjects in the Alcohol Group and two in the Placebo Group did not report one/two numbers out of 240 presentations per session during the experiments. In Session 1 all subjects (both groups) reported all numbers. In Session 2, both groups showed a slightly higher miss rate (average 0.8 for the Alcohol Group and 0.4 for the Placebo Group). During High Task, the average miss rate was 0.6 for alcohol subjects, and 0.2 for placebo subjects. Low Task miss rate average for both the groups was 0.2. In the third session, the average miss rate dropped to 0.2 for Alcohol as well as the Placebo Group. The data on visual digits missed are placed at Appendix "E".

Audio Task: Digit Reporting. Reporting of specified audio digits was the only task added to the other tasks that made the High Task sub-session different from the Low Task sub-session. Audio digits missed (not reported), were significantly higher than the visual digits missed. The average digits missed per subject for Alcohol and Placebo Groups (all three sessions combined) were 3.51 and 2.33 respectively. Compared to the first session both placebo and alcohol subjects showed a higher miss rate. However, the miss rate of placebo subjects was significantly higher than the alcohol subjects compared to their first sessions, although in absolute terms the number of digits missed by the alcohol group was higher. In the third session, however, both groups averaged 0.67 digits missed. A summary of Audio Task Performance is placed at Appendix "E".

Discomfort and Performance Questionnaire Data.

Following the final threshold determination subjects filled out two questionnaires; one was concerned with discomfort symptoms experienced during each session, and one in which the number of drinks consumed was estimated and performance on various aspects of the tasks rated (self analysis based on subject's own perception). Results of perceived discomfort level during sessions for alcohol and placebo subjects are given in Appendices "F" and "G".

The discomfort scale values ranged from slight (1) to severe (5). Nine symptoms were included: Malaise, Nausea, Drowsiness, Increased Salivation, Dizziness, Sweating, Increased Warmth, Headache, and Epigastric Discomfort. Ratings were made for each symptom for each of the three threshold measurement sessions. Four alcohol subjects and three placebo subjects reported symptoms for the pretest session (Session 1), with the placebo subjects indicating slightly more level of discomfort (weighted average of 2.5 versus 1.83). All alcohol and placebo subjects reported that they experienced discomfort symptoms during the second session. Dizziness was the most common discomfort symptom for all subjects. Alcohol subjects' weighted average discomfort level was 8.67 compared to 6.33 for the placebo subjects out of a maximum possible discomfort level of 45. In the third session one alcohol subject and two placebo subjects did not report any discomfort symptoms. The average discomfort level for placebo subjects was 3.0, while the alcohol subjects retained a higher level of discomfort at 5.17. Thus it can be seen that while the alcohol subjects indicated slightly more discomfort symptoms the difference was small.

In their responses to the post-experimental questionnaire concerned with the amount of alcohol consumed and its effects, Alcohol Group subjects estimated that they had received a number of alcoholic drinks (equivalent to their favorite alcoholic beverage) ranging from 2 to 3.5, with a mean of 2.75. Estimates by Placebo Group subjects ranged from 1.5 to 3, with a mean of 2.42. A summary of results of the questionnaire on Perceived Alcohol Level and Performance is given in Appendix "H".

All of the subjects receiving alcohol, and 4 of the 6 placebo subjects, reported feeling physical effects of the drinks. In the remaining four items on the questionnaire the subjects rated their ability to hold altitude and sense of movement, and the effort required for each task. Mean scale values (much worse - 2, somewhat worse -1, same, somewhat better +1, and much better +2) for alcohol and placebo subjects were, respectively, -0.83 and -0.5 for ability to hold altitude and -1.33 and -0.5 for sense of movement.

Corresponding mean ratings of less or more effort were 1.0 and 0.83 for holding altitude and 1.5 and 0.5 for sensing movement for alcohol and placebo subjects respectively. Thus the pattern of ratings were similar with both alcohol and placebo subjects reporting reduced performance but more effort required to perform the tasks. While alcohol subjects reported poorer estimated performance and greater effort required, the alcohol-placebo difference was not significant overall ($F<1$), nor did the groups differ significantly in their ratings on any question (all $ps>0.20$).

Data Analyses and Discussion of Results

Appendix "C" gives the details of the analyses of variances of the thresholds for a three way analyses of alcohol versus placebo, trials, and workload, recorded in each session for each subject in the Alcohol and the Placebo group. Repeated measures method was used for the analysis.

The threshold values, discomfort levels, false positives and visual digits missed, across all sessions recorded during the current experiment were comparable to the corresponding values registered in the previous experiment carried out by the author. (Ross and Mughni, May 1994, in press).

The overall mean threshold value for placebo subjects and for alcohol subjects before they received alcohol, was 0.301 deg/sec^2 with a range of 0.082 to 0.460 deg/sec^2 for low task and 0.363 deg/sec^2 with a range of 0.098 to 0.681 deg/sec^2 for high task load threshold measurement. A large number of studies have been conducted to determine the threshold for perception of angular acceleration. Clark (1967) surveyed 21 studies that reported angular acceleration thresholds obtained under widely differing procedures and found values between 0.035 deg./sec^2 and 8.2 deg./sec^2. Howard (1986) in discussing angular motion thresholds, cited studies reporting mean values of 0.44 deg./sec^2 (range 0.05 - 3.18) for rotating chair experiments involving first reports of rotation. Thus, it can be seen that the present results are comparable to those of past studies although procedures differed considerably.

The increase in subjects' thresholds following alcohol ingestion was substantial. Not only was the mean threshold for session 2 significantly greater for alcohol as compared to placebo subjects, but all alcohol subjects showed a threshold increase, the smallest increase being 20.14% . The maximum increase found in one alcohol subject was 73.1%

while the average increase for all alcohol subjects was 44% between session 1 and session 2. The average increase in threshold for placebo subjects was 2%.

The fact that the majority of the Alcohol Group subjects continued to show an elevated threshold after their BAC's reached zero is not surprising in the light of the long lasting effects on vestibular functioning as demonstrated by the occurrence of PAN as long as 48 hours after alcohol ingestion. While the mean threshold value of alcohol subjects was significantly above those of placebo subjects during the third test session, the average threshold values for alcohol subjects declined to 30% from 44% as compared to their pre-alcohol level thresholds. The placebo subjects remained at a steady threshold throughout the sessions with small insignificant variations. Comparison of alcohol and placebo group, and examination of the BAC curves, number of false positives, and estimates of task difficulty and effort of these subjects did not suggest a basis for bias in the elevated thresholds of alcohol subjects and steady thresholds depicted by the placebo group.

One possibility with respect to alcohol's effect on the subjects' threshold for detecting angular motion changes is that alcohol increases the difficulty of the altitude and digit reporting tasks, i.e., perhaps acted functionally to increase workload, or resulted in discomfort symptoms such that less attention was directed toward angular motion cues. Alternatively, alcohol could effect the sensitivity of the inner ear to angular motion, e.g. through changes in the specific gravity of the endolymph.

The performance of Alcohol Group subjects on the altitude and number reporting tasks does not, however, appear to be different enough from that of the Placebo Group to account for the threshold differences (a previous study by the author also showed insignificant relationship). Further, alcohol subjects reported that more effort was required both to hold altitude and sense movement than did placebo subjects, although the alcohol-placebo subject differences were not statistically significant. These data, showing that alcohol subjects required as much or more effort to perceive angular motion as did placebo subjects, do not support the notion that the increased threshold values of alcohol subjects were the result of directing attention away from the threshold task to that of maintaining altitude or reporting the assigned digits.

The placebo procedures were quite effective as shown by the Placebo Groups' (mean) estimate of having 2.42 drinks (Appendix "H"), when in fact only a few ccs of alcohol were floated on the tops of their orange juice drinks. In addition, their discomfort scores approximated those of the alcohol group for Session 2. It should be noted that while the Placebo Group's discomfort scores increased dramatically for Session 2 their threshold values did not increase. By Session 3, placebo subjects discomfort scores had dropped close to their pre-drink levels while the alcohol subjects' discomfort continued at a slightly lesser degree.

Thus, to entertain the hypothesis that the threshold values of alcohol and placebo subjects tracked their discomfort levels, it would be necessary to assume that the tracking takes place for actual (alcohol subjects) discomfort but not for perceived discomfort that resulted from the placebo procedures.

An elevated threshold that resulted from the alcohol administration could, however, regardless of its origin, have implications for situations in which detection of angular motion is important. Such a situation might arise, for example, if an aircraft begins a descending turn due to autopilot malfunction or any other cause when the pilot was not attending to his or her instruments. Failure to identify such a departure from straight and level flight can be dangerous in high performance aircraft since airspeed can increase rapidly. Since the threshold for detecting motion around the yaw axis is generally less than that for detecting pitch motion (Gilllingham & James, 1985), less sensitivity to angular motion would delay detection of such flight path deviations. If the elevated threshold effect continues significantly beyond the time BAC reaches zero, it could have deleterious effects beyond the time interval between drinking and flying that is generally considered safe, as has been suggested with respect to lingering PAN and other nystagmic alcohol effects (Gibbons, 1988).

Thresholds for detection of acceleration and deceleration of angular motion were obtained from subjects who had been given alcohol (mean BAC = .038%) or placebo drinks (details of individual BAC levels are given in Appendix "I"). Thresholds readings for high and low task loads clearly indicate that thresholds are a function of signal-to-noise ratio. Increased task was manifested by an increase in thresholds across all sessions. However, the increase in task did not apparently have the same effect on all subjects since the ability of performing the task understandably varied between individuals. More importantly, the effect of alcohol was significant for both high and low task loads. Placebo subjects' thresholds remained relatively constant throughout the sessions while the alcohol subjects' thresholds peaked in the second session and declined only slightly in the third session. Performance in maintaining altitude and reporting digits were similar for alcohol and placebo subjects, as was the reporting of discomfort symptoms experienced during the sessions.

Survey Results

A survey conducted to inquire about the current corporate policies of aviation companies regarding alcohol and flying revealed that their was no standard policy being followed in the independent corporations. In fact, a large variation was observed in the policies. The response rate of the survey was only 50%, (12 out of 24 companies responded to the queries). The survey questionnaire was dispatched to six major airlines, six regional, six charter commuter corporations, and six flying institutions/FBOs. Specific questions asked were regarding corporate policy were on:

a) Permissible Blood Alcohol Content before flight.

b) Minimum hours between consumption of any alcoholic beverage and flying.

c) Random checks on BAC.

The entire questionnaire was explicitly aircrew related. A summary of the questionnaire results is tabulated on the next page (Table 3).

Table 3.

Survey Result of Corporate Policies on Alcohol and Flying.

SURVEY QUESTIONNAIRE RESULTS			
Company Name	***Ploicy on BAC***	***Ploicy on min. hrs.***	***Policy on random chk***
DELTA AIRLINES	0	8	Yes
AMERICA WEST	x	8	No
SOUTHWEST AIRLINES	x	8	No
AMERICAN AIRLINES	0	8	Yes*
TOWER AIR INC	0	13.5	No
RICH INTERNATIONAL AIRWAYS	x	12	No
PARADISE ISLAND AIRLINES	.04	12	No
AIR TREK INC	0	8	No
AV ATLANTIC	0	12	No
HAWTHORNE LAKELAND	0	8	No
EPPS AIRSERVICES INC	.04	8	No
DECATUR AVIATION	0	24	No

Policy on BAC. Surprisingly two major airlines and one regional airline had no specific corporate policy regarding minimum Blood Alcohol Content (indicated as "x" in Table 2). One regional and one commuter service followed the standard FAA regulation for General Aviation, while all the rest indicated that their companies did not permit any trace of alcohol in the blood before flying.

Policies on minimum hours between bottle and throttle. Three regional airlines and one charter commuter operator had specified more than 12 hours as the minimum time lapse between drinking an alcoholic beverage and flying. One FBO's policy on the subject was glaringly different than others; it had a laid down 24 hours as its minimum requirement in this regard. All major airlines surveyed, indicated 8 hours as their corporate policy on time lapse between bottle and throttle (same as the FAA General Aviation regulation).

Policy on random checks on BAC. Except Delta Airlines, all the surveyed companies indicated that they do not perform random checks on BAC. American Airlines, however, remarked that they would incorporate the policy of random checking by January, 1995 (YES* in Table 2).

Chapter Four

CONCLUSION AND RECOMMENDATIONS

As anticipated and hypothesized, the research results indicate that in the absence of visual cues, pilots' thresholds for perceiving a change in angular motion is adversely affected by alcohol in the blood. Furthermore, when blood alcohol level dropped to zero, (recorded after administering doses to attain a BAC of 0.04%), the pilots' ability to perceive angular accelerations remained impaired. The effect of increased work load on threshold was only additive and alcohol work load interaction was insignificant. Thus, the hypothesis that threshold increases with work load holds good, but the experiment did not empirically support the notion that the increase in work loads would alter the degree of impairment in threshold with alcohol ingestion.

An elevated threshold that was exhibited from alcohol administered subjects, regardless of its origin, can have serious implications in situations where detection of angular motion is important. Such a situation might arise if, for example, an aircraft begins a descending turn due to auto pilot failure, asymmetric fuel feeding, or any other cause when the pilot is not attending to the primary flight instruments. Failure to identify such a departure from straight and level flight can be dangerous in high performance aircraft since airspeed can increase rapidly to unsafe levels. As the thresholds for detecting motion around the yaw axis is generally less than that for detecting pitch motion,[42] less sensitivity to angular motion would delay detection of such flight path deviations. If the elevated threshold effect continues significantly beyond the time BAC reaches zero, it would have deleterious effects beyond the time interval between drinking and flying that is generally considered safe.

The result of the survey conducted to inquire about the current corporate policies of aviation companies revealed that 58% of the surveyed companies followed a zero BAC policy for conducting flight operations. Interestingly, 25% did not have an explicit policy on BAC, while the rest observed the FAA stipulated 0.04 % BAC as their minimum. The minimum time lapse between bottle and throttle, showed an average of 11 hours. None of the surveyed enterprises indicated a policy in this regard of less than 8 hours and the maximum time observed by one company was 24 hours. Except for Delta and American Airlines, no other company in the survey favored a random alcohol test as a corporate policy. Large variations on policies regarding alcohol and flying are indicative of the fact that opinions and convictions on alcohol and flying differ to a large extent.

The results of the simulation study and the survey conducted to ascertain the corporate policies followed by aviation concerns reveals that there is a definite need to rethink and restructure the policies at the federal, state, and corporate level. Individual pilots also need to be aware of the deleterious implications of alcohol and flying. Managers in particular have to realize the ramifications of policies on alcohol and flying as well as the safety aspects associated with it. Safety in aviation is also related to image,

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[42] Clark, B. Thresholds for the perception of angular acceleration in man. Aerospace Medicine. Vol. 38. 1967. p.443.

reputation, and good will. It is directly linked to consumer orientation, and essential safety procedures, and good corporate policies can lead to a sustained competitive advantage resulting in long term profits for the company in particular, while concurrently enhancing the confidence level and reliability of all aviation concerns.

Benefits of the Study

The results offer an insight to a possible cause of many alcohol related accidents and spatial disorientation cases. Being the first documented research on the specific scenario designed to explore the effect of alcohol on turn perception thresholds with workload as an additional variable, the study could be a source of inspiration for other researchers to explore other possible areas/aspects of such simulation. Effect of residual alcohol on thresholds a few hours after BAC drops to zero could be explored as a continuation of this study. Effect of higher BAC levels on threshold could be another area that deserves attention. Latency time of thresholds under such simulated conditions could also be explored. Other possible benefits that were accrued from this simulation study could be as follows:

a) It was an extremely cost-effective study. If the study was conducted in actual flight conditions it would have not only posed a serious flight safety hazard, but could also be cost prohibitive.

b) Pilots in particular and aviation businesses at large would benefit from the results of the study by being more cognizant of the impact of even low doses of alcohol on the flying ability of pilots.

c) While the hypotheses were positively confirmed, further study with a larger sample size is recommended to confirm the results.

Recommendations

With supportive evidence inferred through the simulation study and survey conducted on corporate policies, the following recommendations are submitted.

a) Federal Aviation Regulation 19.17 needs to be re-evaluated. The permissible BAC should be reduced to 0.00%.

b) The "bottle to throttle rule" may be increased to at least 12 hours instead of the prevalent 8 hours. Minimal-wait period rules beyond eight hours are already mandated by some corporations and airlines. (Survey result).

c) Additionally, the minimal-wait period rule should explicitly state that flying is prohibited within 24 hours after the consumption of five or more standard alcoholic drinks or in the presence of any after effects of drinking, like hangover, head ache, etc.

d) In order to convince the operators about the reason for a change in the regulations and rules, the authorities need to provide a rationale for a more strict rule on the subject.

e) A large scale educational program highlighting the hazardous effects of alcohol on pilot performance needs to be instituted at all levels to ensure willful acceptance of the rule.

f) Regulations must also have strict penalties for flying under the influence of alcohol so that violations are minimized.

h) Pilots must be required to demonstrate their knowledge of alcohol related regulations, as well as the understanding of the effect of alcohol on short term and long term performance of a pilot.

j) Effective ways to identify and rehabilitate persons with alcohol problems should be an essential component of the program both at the state and federal level.

k) It may be noted, however, that education and legislation alone may not be sufficient to deter a pilot from flying under the influence of alcohol. (Efficacy of driver education and drunk-driving laws provide a strong argument in support of this statement). Therefore, it is strongly recommended that the flying institutions, corporate management, and the state and federal authorities must endeavor to cultivate and foster an ***"alcohol free culture"*** in the aviation community in the larger interest of safety for all.

GLOSSARY

Aftereffect:
An effect or sensation that follows at some interval after the stimulus which produces it has been withdrawn.

Ampulla:
The dilated portion of a semicircular canal containing the cupula and crista.

Coriolis Force:
A hypothetical force which accounts for the apparent deflection of a particle or body moving in a rotating coordinate system.

Coriolis illusion:
An illusion involving a sensation of body rotation and an apparent motion of objects in the visual field which is caused by tilting the head about one axis while the head is undergoing passive rotation about another axis.

Cupula:
A gelatinous structure situated over and supported by the crista. The cupula forms a moving seal across the ampulla and is deflected by a flow of endolymph through the semicircular canal.

Cupulogram:
A graph of the duration of the sensation of rotation versus the magnitude of the stimulus (a step input in angular velocity).

Egocentric localization:
The act of determining the direction of an object relative to oneself.

Endolymph:
Fluid contained in the semicircular canals, utricle, and saccule.

False Positive:
With reference to the experiment, False Positives were defined as an incorrect sensation of turning reported by the subject.

Habituation:
A gradual adaptation to a repeated stimulus. The adaptation involves a change in the response of the organ or organism stimulated.

Latency time:
The time between onset of motion stimulation and the initiation of a response.

Nystagmus:
Any rhythmic involuntary motion of the eyes is known as Nystagmus. Nystagmus induced or increased by head tilt is referred to as positional nystagmus. Positional nystagmus due to Alcohol ingestion is called Positional Alcohol Nystagmus or PAN. This probably results from a disturbance of the specific gravity of the endolymph. (Money & Miles, 1974).

Ocular:
Of or pertaining to the eye.

Oculogyral illusion:
A visual illusion involving an apparent vertical movement of objects in the visual field and which is caused by a downward acceleration yielding a G vector of magnitude between O and 1.0; a special case of the elevator illusion.

Optokinetic:
Of or pertaining to a movement of the eye elicited by a visual stimulus as in optokinetic nystagmus.

Positional Alcohol Nystagmus (PAN):
See nystagmus.

Proprioceptive sensations:
Sensations transmitted through non-vestibular components like muscle spindles, tendons, joints, etc.

Semicircular canal:
Any of the three curved tubular canals in the labyrinth of the ear, associated with sensing of angular motion.

Threshold:
That value at which a stimulus just produces a sensation or comes just within the limits of perception.

Vertical axis:
The axis, in the head axis system, defined by the intersection of the frontal and sagittal planes. The vertical axis is aligned with the gravitational vertical and

directed downward in an erect head.

Vertigo:

A feeling of dizziness associated with sensations of rotary motion of the body or surroundings. As used by pilots, vertigo means any feeling of spatial disorientation during flight, or a confusion with respect to the attitude or motion of the aircraft.

Vestibular:

Of or pertaining to the vestibule, in particular the motion sensing apparatus of the inner ear.

Vestibule:

Vestibulum auris, an oval cavity in the middle of the bony labyrinth, communicating in front with the cochlea and behind with the semicircular canals, and containing the utricle and saccule.

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APPENDICES

APPENDIX A

LOW TASK THRESHOLDS

ALCOHOL SUBJECTS

	SESSION 1			SESSION 2			SESSION 3		
SUBJECT	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG
Sub 1	0.4397	0.4578	0.4488	0.5303	0.5480	0.5392	0.5173	0.5146	0.5160
Sub 2	0.2457	0.2540	0.2499	0.3363	0.3475	0.3419	0.2748	0.2807	0.2778
Sub 3	0.3686	0.3776	0.3731	0.6467	0.6449	0.6458	0.4979	0.5313	0.5146
Sub 4	0.3751	0.3910	0.3831	0.5949	0.5915	0.5932	0.5723	0.6015	0.5869
Sub 5	0.0970	0.0668	0.0819	0.1487	0.0835	0.1161	0.1293	0.0869	0.1081
Sub 6	0.2086	0.2155	0.2121	0.2975	0.2941	0.2958	0.2651	0.2807	0.2729
Average	0.2891	0.2938	**0.2915**	0.4257	0.4183	**0.4220**	0.3761	0.3826	**0.3794**

PLACEBO SUBJECTS

	SESSION 1			SESSION 2			SESSION 3		
SUBJECT	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG
Sub 1	0.4527	0.4678	0.4603	0.4591	0.4678	0.4635	0.4527	0.4678	0.4603
Sub 2	0.4397	0.4344	0.4371	0.4527	0.4378	0.4453	0.4397	0.4411	0.4404
Sub 3	0.3039	0.3275	0.3157	0.3104	0.3342	0.3223	0.3039	0.3275	0.3157
Sub 4	0.3751	0.4010	0.3881	0.3945	0.4010	0.3978	0.3880	0.3977	0.3929
Sub 5	0.1293	0.1470	0.1382	0.1293	0.1437	0.1365	0.1293	0.1470	0.1382
Sub 6	0.1358	0.1203	0.1281	0.1358	0.1404	0.1381	0.1293	0.1203	0.1248
Average	0.3061	0.3163	**0.3112**	0.3136	0.3208	**0.3172**	0.3072	0.3169	**0.3120**

NOTES:

1. ALL DIGITS DENOTE THRESHOLD VALUES MEASURED IN DEGREES PER SEC^2
2. "LEFT" DENOTES DECELERATION THRESHOLD VALUE
3. "RIGHT" DENOTES ACCELERATION THRESHOLD VALUE
4. "SESSION 1" DENOTES PRE ALCOHOL/PLACEBO SESSION
5. "SESSION 2" DENOTES POST ALCOHOL/PLACEBO SESSION
6. "SESSION 3" DENOTES POST ALCOHOL/PLACEBO SESSION AT BAC=0
7. THE FIRST THREE SUBJECTS IN EACH GROUP WERE GIVEN THE HIGH TASK FIRST, WHILE THE LAST THREE SUBJECTS PERFORMED THE LOW TASK FIRST

APPENDIX B

HIGH TASK THRESHOLDS

ALCOHOL SUBJECTS

	SESSION 1			SESSION 2			SESSION 3		
SUBJECT	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG
Sub 1	0.6661	0.6951	0.6806	0.8148	0.8287	0.8218	0.776	0.7953	0.7857
Sub 2	0.3298	0.3409	0.33535	0.4365	0.4612	0.4489	0.3686	0.391	0.3798
Sub 3	0.3815	0.401	0.39125	0.6758	0.6617	0.6688	0.5238	0.5614	0.5426
Sub 4	0.4171	0.4311	0.4241	0.679	0.675	0.6770	0.6402	0.6617	0.6510
Sub 5	0.1164	0.0802	0.0983	0.1746	0.1003	0.1375	0.1584	0.1053	0.1319
Sub 6	0.2328	0.2439	0.23835	0.3169	0.3208	0.3189	0.2878	0.3108	0.2993
Average	0.3573	0.3654	**0.3613**	0.5163	0.5080	**0.5121**	0.4591	0.4709	**0.4650**

PLACEBO SUBJECTS

	SESSION 1			SESSION 2			SESSION 3		
SUBJECT	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG	LEFT	RIGHT	AVG
Sub 1	0.5173	0.5347	.5260	0.5173	0.5246	0.5210	0.5076	0.5246	0.5161
Sub 2	0.4591	0.4545	.4568	0.4721	0.4511	0.4616	0.4591	0.4344	0.4468
Sub 3	0.3363	0.3542	.3453	0.346	0.3743	0.3602	0.3233	0.3409	0.3321
Sub 4	0.5367	0.5547	.5457	0.5432	0.5681	0.5557	0.5367	0.548	0.5424
Sub 5	0.1617	0.1805	.1711	0.1617	0.1738	0.1678	0.152	0.1704	0.1612
Sub 6	0.1423	0.1404	.1414	0.1487	0.1537	0.1512	0.1358	0.1337	0.1348
Average	0.3589	0.3698	**0.3644**	0.3648	0.3743	**0.3696**	0.3524	0.3587	**0.3555**

NOTES:

1. ALL DIGITS DENOTE THRESHOLD VALUES MEASURED IN DEGREES PER SEC^2
2. "LEFT" DENOTES DECELERATION THRESHOLD VALUE
3. "RIGHT" DENOTES ACCELERATION THRESHOLD VALUE
4. "SESSION 1" DENOTES PRE ALCOHOL/PLACEBO SESSION
5. "SESSION 2" DENOTES POST ALCOHOL/PLACEBO SESSION
6. "SESSION 3" DENOTES POST ALCOHOL/PLACEBO SESSION AT BAC=0
7. THE FIRST THREE SUBJECTS IN EACH GROUP WERE GIVEN THE HIGH TASK FIRST, WHILE THE LAST THREE SUBJECTS PERFORMED THE LOW TASK FIRST

APPENDIX C

ANALYSIS OF VARIANCE

ANOVA

Factor	D of Freedom	Sum of Squares	Mean Sum	F-Test
Alcohol	1	0.067	0.067	0.361
Subjects within Alcohol	10	1.846	0.185	
Sessions	2	0.085	0.043	13.794
Alcohol Sessions	2	0.077	0.039	12.514
Subj.within Alcohol Sessions	20	0.062	0.003	
Workload	1	0.064	0.064	11.924
Alcohol workload	1	0.002	0.002	0.319
Subj.alcohol Workload	10	0.054	0.005	
Workload Sessions	2	0.003	0.001	1.377
Alcohol Workload Sessions	2	0.004	0.002	2.044
Subj.within Workload Session	20	0.018	0.001	
TOTAL	71	2.281		

T TESTS: ALCOHOL VS. SESSIONS INTERACTION

Means	Session	Session 2	Session 3	Error: 0.023
Alcohol	0.308	0	0.422	D of Freedom: 20
Placebo	0.337	0	0.334	
T-Test	-1.303	5	3.898	

APPENDIX D

FALSE POSITIVES

ALCOHOL SUBJECTS

	Session 1		Session 2		Session 3	
	Low	High	Low	High	Low	High
Subject 1 (1st Task-High)	1	2	1	2	1	0
Subject 2 (1st Task-High)	1	0	1	1	1	1
Subject 3 (1st Task-High)	1	1	1	1	0	0
Subject 4 (1st Task-Low)	1	2	1	0	1	0
Subject 5 (1st Task-Low)	2	1	3	4	1	0
Subject 6 (1st Task-Low)	0	0	0	2	2	1
Mean per sub-session	1.00	1.00	1.17	1.67	1.00	0.33
Mean per session [(Hi+Lo)/2]	1.00		1.42		0.67	

PLACEBO SUBJECTS

	Session 1		Session 2		Session 3	
	Low	High	Low	High	Low	High
Subject 1 (1st Task-High)	0	0	1	0	0	0
Subject 2 (1st Task-High)	1	2	1	0	1	0
Subject 3 (1st Task-High)	0	0	1	1	0	0
Subject 4 (1st Task-Low)	4	4	6	6	2	0
Subject 5 (1st Task-Low)	1	0	1	0	0	0
Subject 6 (1st Task-Low)	0	0	1	0	1	0
Mean per sub-session	1.00	1.00	1.83	1.17	0.67	0.00
Mean per session [(Hi+Lo)/2]	1.00		1.50		0.33	

APPENDIX E

VISUAL AND AUDIO DIGITS MISSED

VISUAL

ALCOHOL SUBJECTS			PLACEBO SUBJECTS		
SESSION 1		**Average**	**SESSION 1**		**Average**
LOW TASK	0 0 0 0 0 0	**0**	LOW TASK	0 0 0 0 0 0	**0**
HIGH TASK	0 0 0 0 0 0	**0**	HIGH TASK	0 0 0 0 0 0	**0**
SESSION 2			**SESSION 2**		
LOW TASK	0 1 0 0 0 0	**0.2**	LOW TASK	1 0 0 0 0 0	**0.2**
HIGH TASK	0 1 2 0 0 0	**0.6**	HIGH TASK	0 0 1 0 0 0	**0.2**
SESSION 3			**SESSION 3**		
LOW TASK	0 0 0 0 0 0	**0**	LOW TASK	1 0 0 0 0 0	**O.2**
HIGH TASK	0 0 1 0 0 0	**0.2**	HIGH TASK	0 0 0 0 0 0	**0**

AUDIO

ALCOHOL SUBJECTS			PLACEBO SUBJECTS		
		Average			**Average**
SESSION 1	3 1 0 1 1 1	**1.17**	**SESSION 1**	0 0 1 0 0 1	**0.33**
SESSION 2	2 2 3 1 1 1	**1.67**	**SESSION 2**	0 0 2 3 1 2	**1.33**
SESSION 3	1 1 1 0 1 0	**0.67**	**SESSION 3**	0 0 1 1 1 1	**0.67**

APPENDIX F

DISCOMFORT LEVEL QUESTIONNAIRE RESULTS

ALCOHOL SUBJECTS

Session 1

SYMPTOM	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	AVERAGE
Malaise	0	0	0	0	0	0	0.00
Nausea	0	0	0	0	0	0	0.00
Drowsiness	1	0	0	0	0	0	0.17
Increased Salivation	0	0	0	0	3	0	0.50
Dizziness	0	0	1	0	1	1	0.50
Sweating	0	0	0	0	0	0	0.00
Increased Warmth	0	0	0	0	2	0	0.33
Headache	1	0	0	0	0	1	0.33
Epigastric Discomfort	0	0	0	0	0	0	0.00
							1.83
TOTALS	2.00	0.00	1.00	0.00	6.00	2.00	

Session 2

SYMPTOM	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	AVG.
Malaise	0	1	0	1	0	0	0.33
Nausea	0	0	1	1	0	0	0.33
Drowsiness	2	2	1	3	2	2	2.00
Increased Salivation	0	0	0	1	2	0	0.50
Dizziness	2.5	3	1.5	3	2	2	2.33
Sweating	0	1	0	0	0	0	0.17
Increased Warmth	2	1	0	2	3	0	1.33
Headache	4	0	0	2	2	1	1.50
Epigastric Discomfort	0	0	0	1	0	0	0.17
							8.67
TOTALS	10.50	8.00	3.50	14.00	11.00	5.00	

Session 3

SYMPTOM	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	AVG.
Malaise	0	0	0	0	0	0	0.00
Nausea	0	0	1	0	0	0	0.17
Drowsiness	2	0	1.5	1	1	1	1.08
Increased Salivation	0	0	0	1	2	0	0.50
Dizziness	1.5	0	1	1	3	1	1.25
Sweating	2.5	0	0	0	0	0	0.42
Increased Warmth	2.5	0	0	0	2	0	0.75
Headache	3	0	0	1	1	1	1.00
Epigastric Discomfort	0	0	0	0	0	0	0.00
							5.17
TOTALS	11.50	0.00	3.50	4.00	9.00	3.00	

APPENDIX G

DISCOMFORT LEVEL QUESTIONNAIRE RESULTS

PLACEBO SUBJECTS

Session 1

SYMPTOM	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	AVERAGE
Malaise	1	0	0	0	0	0	0.17
Nausea	1	0	0	0	0	0	0.17
Drowsiness	2	1	0	0	0	0	0.50
Increased Salivation	1	3	0	0	0	0	0.67
Dizziness	1	1	0	0	0	0	0.33
Sweating	1	0	0	0	0	0	0.17
Increased Warmth	1	0	0	0	0	0	0.17
Headache	1	0	0	0	0	0	0.17
Epigastric Discomfort	1	0	0	0	0	0	0.17
							2.50
TOTALS	10.00	5.00	0.00	0.00	0.00	0.00	

Session 2

SYMPTOM	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	AVG.
Malaise	1	0	0	0	0	0	0.17
Nausea	1	0	0	0	0	0	0.17
Drowsiness	1	2	1	0	1	0	0.83
Increased Salivation	1	3.5	2	0	0	0	1.08
Dizziness	3	3	3	0	1	1	1.83
Sweating	1	1	2.5	0	0	0	0.75
Increased Warmth	2	0	2	0	1	0	0.83
Headache	2	0	1	0	0	0	0.50
Epigastric Discomfort	1	0	0	0	0	0	0.17
	13	9.5	11.5	0	3	1	6.33
TOTALS	13.00	9.50	11.50	0.00	3.00	1.00	

Session 3

SYMPTOM	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	AVG.
Malaise	1	0	0	0	0	0	0.17
Nausea	1	0	0	0	0	0	0.17
Drowsiness	1	1	1	4	0	0	1.17
Increased Salivation	1	1	0	0	0	0	0.33
Dizziness	1	1	1	0	0	0	0.50
Sweating	1	0	0	0	0	0	0.17
Increased Warmth	1	0	0	0	0	0	0.17
Headache	1	0	0	0	0	0	0.17
Epigastric Discomfort	1	0	0	0	0	0	0.17
							3.00
TOTALS	9.00	3.00	2.00	4.00	0.00	0.00	

APPENDIX H

SUBJECTS' PERCEIVED ALCOHOL LEVEL AND PERFORMANCE

ALCOHOL SUBJECTS	1	2	3	4	5	6	Average
Alcohol Level*	3	2.5	2	2.5	3.5	3	**2.75**
Ability to hold altitude	-1	-1	-1	-1	1	-2	**-0.83**
Effort to hold altitude	2	1	1	1	0	1	**1**
Sense of movement	-1	-1	-1	-2	-2	-1	**-1.33**
Effort to sense movement	2	1	1	2	2	1	**1.5**

PLACEBO SUBJECTS	1	2	3	4	5	6	Average
Alcohol Level*	2.5	2	2.5	1.5	3	3	**2.42**
Ability to hold altitude	0	-1	-1	1	-1	-1	**-0.5**
Effort to hold altitude	1	1	1	0	1	1	**0.83**
Sense of movement	-1	0	-1	1	-2	0	**-0.5**
Effort to sense movement	2	0	-1	0	2	0	**0.5**

Note: * Alcohol level = Number of drinks perceived to have consumed.

APPENDIX I

BAC LEVELS AND DRINKING CATEGORIES

ALCOHOL SUBJECTS

	Sub.1	Sub.3	Sub.5	Sub.7	Sub.9	Sub.10	Avg.
1st task	High	High	Low	Low	Low	High	
BAC at Session 2	0.039	0.037	0.037	0.039	0.038	0.038	**0.038**
BAC after Session 2	0.036	0.032	0.027	0.028	0.023	0.028	**0.0292**
Waiting Period (min.)	120	135	120	105	120	150	**125**
Drinking Category	Heavy	Medium	Light	Medium	Heavy	Heavy	

PLACEBO SUBJECTS

	Sub.2	Sub.4	Sub.6	Sub.8	Sub.11	Sub.12	Avg.
1st task	Low	Low	High	High	Low	High	
BAC at Session 2	0	0	0	0	0	0	**0**
BAC after Session 2	0	0	0	0	0	0	**0**
Waiting Period (min.)	120	135	120	105	120	150	**125**
Drinking Category	Heavy	Heavy	Light	Medium	Medium	Medium	

NOTE:

1. Subject numbers are given in order of their participation sequence.
2. Waiting period is the time BAC of alcohol subjects went down to zero.
3. Drinking category is based on QFV approach developed by Cahalan, et al.