Hangover Effects on Aircraft Pilots 14 Hours After Alcohol Ingestion: A Preliminary Report

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Using a repeated measures counterbalanced design, the authors had 10 Navy P3-C Orion pilots fly two carefully designed simulated flights under control (no hangover) and hangover conditions. For the control condition, pilots drank no alcohol within 48 hours before the simulated flight. For the hangover condition, they flew 14 hours after drinking enough ethanol mixed with diet soft drinks to attain a blood alcohol concentration of 100 mg/dl. Pilot performance was worse in the hangover condition on virtually all measures but significantly worse on three of six variance measures and one of six performance measures. The results indicate that caution should be exercised when piloting an aircraft 14 hours or less after ingesting similar quantities of alcohol.
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Regulations pertaining to the use of alcohol and the piloting of aircraft vary widely and have been determined without benefit of adequate empirical investigation of hangover effects. Federal Aviation Administration (FAA) regulations require a minimum 8-hour "bottle to throttle" rule (Federal Air Regulation 91.11); certain armed services require a 12-hour minimum, and some scheduled carriers require as much as 24 hours. Although these regulations involve thousands of private, military, and commercial pilots and millions of passengers, they are based on limited research. The question this study addresses is whether pilot performance is impaired 14 hours after a pilot has drunk enough alcohol to be considered legally intoxicated.

Approximately 50% of private pilots interviewed by Damkot and Osga (1) felt that it was safe to fly within 4 hours after drinking some amount of alcoholic beverage. Safety data, however, suggest such conceptions are dangerous. In a 1984 report (2), the National Transportation Safety Board cited alcohol use as a common factor involved in general aviation fatal accidents. Between 1975 and 1981, this board found that 10.5% of fatal general aircraft crashes resulting in 742 fatalities involved pilots whose autopsies showed blood tests that were positive for alcohol. An additional 6.4% of commuter airline crashes and 7.4% of air taxi crashes involved pilots with positive toxicologic evidence of alcohol use. Fatal crashes of major U.S. air carriers are rare, and no postmortem blood test of their pilots has been positive since 1964; however, an autopsy of the pilot of a Japan Airlines aircraft that crashed in Alaska in 1977 revealed a blood alcohol concentration of 210 mg/dl. We can only estimate the number of nonfatal aircraft accidents and near misses that involved alcohol. We felt it was important to determine when and under what conditions recreational use of alcohol impairs pilot performance.

The acute effects of alcohol on pilot performance have been studied for four decades (3–5). Although most studies have used simulations, one used actual aircraft flying an instrument approach (6). Typical of recent studies was an investigation of the immediate effects of three levels of alcohol on 22 pilots that found significantly affected performance in a cross-country flight in a Link GAT-1 simulator (7). Impairment increased with dose (0.3, 0.6, and 0.9 g/kg of body weight). The time course of the drug effect was not determined. A related study of 12 well-trained U.S. Air Force instructor pilots (8) found impairment of simulated flight performance on two Link GAT-1 simulator tasks when doses were at the moderate and high level but not at the low level. Again, the course and duration of the drug effect was not studied. On a flight-related compensatory tracking task, one study (9) found that performance was more strongly affected by alcohol when pilots experienced oscillation about their pitch and yaw axis than when they were stationary. In that study, subjects were tested 1, 2, and 4 hours after ingestion when their respective mean blood alcohol concentrations were 81, 75, and 47 mg/dl. Various degrees of performance impairment were found at each time period. Thus, there is evidence for acute impairment of pilot performance while alcohol is in the blood but few data on hangover effects.

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Hangover effects are distinguished from direct effects of alcohol on the basis of the presence of impaired performance after no measurable levels of alcohol remain in the body. Early studies on hangover effects showed that high doses of alcohol produce behavioral impairment several hours after drinking (10–13). One study (14) found significantly impaired performance on a choice reaction time test at 11, 13, and 15 hours after drinking high doses of alcohol (1.75 g/kg of body weight). A more recent study (15) found letter identification and letter-to-number coding tasks to be significantly impaired 14 hours after a high alcohol dose (1.43 g/kg). Others (16) have found decrements on four of nine cognitive tasks 14 hours after blood alcohol concentrations ranging from 100 to 200 mg/dl were obtained. One study (17) found that high doses of alcohol, along with the maximum mean blood alcohol concentrations of 147 mg/dl, resulted in an approximate 20% decrement on a driving task 3 hours after the blood alcohol concentration returned to zero. Thus, there is evidence that performance effects of alcohol last over 12 hours.

Contrary to these hangover effects, some studies report no significant effects 8 hours after subjects drank 0.85–1.71 g/kg of alcohol. One group (18) found that neither high nor low congener alcohol significantly changed performance on a simple perception and attitude control task in a centripetal accelerator. Others (19) found no impairment on a tracking task 8 hours after alcohol was consumed and a mean blood alcohol concentration of 93 mg/dl was attained. This same group (20) found no hangover-related performance impairment on a tracking task or on visual reaction time 7½ hours after alcohol was consumed and a mean blood alcohol concentration of 91 mg/dl was attained. While there are many possible explanations for null effects, we suspect that these studies did not require complex enough performance tasks to reveal the hangover effects found by others.

Given the linkages between drinking and aircraft accidents and the prolonged cognitive effects of alcohol found in many studies, we decided to gather further information about the duration of alcohol's effects on piloting. Because the literature we reviewed suggested that the more complex the task studied, the longer the effects, we chose to study a complex flying task and used quantification procedures that would ensure the most accurate measurement of changes likely to occur several hours after ingestion.

METHOD

Subjects and Procedures

The subjects were 10 Navy P-3C Orion pilots. The P-3C is a four-engine antisubmarine aircraft similar to the Lockheed Electra (L-188) commercial aircraft. All pilots were under the age of 32 and in excellent health, with an average flying experience of 1115± 649 hours in the P-3C. All pilots drank alcohol socially; by self-report their use ranged from two drinks per week to more than two drinks per day, averaging 0.97± 0.52 drinks per day. All subjects volunteered for the program and gave informed consent according to Department of the Navy and Department of Health and Human Services procedures.

The study had a repeated measures counterbalanced design. Pilots flew a carefully designed flight simulation involving a series of precise maneuvers created by an experienced Navy aviation safety officer. Each flew one of two scenarios under the control (no hangover) condition and the other scenario under the hangover conditions. For the control condition, pilots drank no alcohol within 48 hours before flying the simulator. In the hangover condition, they flew 14 hours after drinking enough ethanol mixed with diet soft drinks to attain a blood alcohol concentration of 100 mg/dl.

For the hangover condition, alcohol was administered in the form of 95% ethanol (1.0 g/kg) diluted in diet soft drinks over a period of 1½ hours. The blood alcohol concentration was measured during this period, and if it was not over 100 mg/dl after the pilot drank the initial estimated dose, another drink containing 14 g of ethanol was given. Total dose of alcohol ranged from 70 to 98 g (equivalent to five to seven 6-oz. glasses of wine). All subjects attained a blood alcohol concentration of over 100 mg/dl within 2.0 hours (range, 101–121 mg/dl). All blood alcohol concentrations were measured at least 20 minutes after alcohol ingestion, and all were still above 100 mg/dl when the administration session was terminated at 2.0 hours. This level is accepted as evidence for driving while intoxicated in many states. The measurement of blood alcohol concentrations was obtained with the Alcosensor III from Intoximeters, Inc. The coefficient of variation on the test is less than 5%. The machine was calibrated for each session by means of standards. Tests were also performed the morning before a flight test. At that time, 14 hours after the last dose of alcohol had been consumed, all readings were zero. Drinking was designed to start at 5:00 p.m. and end at 7:00 p.m., the typical time of an evening cocktail party. The subjects were not allowed to operate a motor vehicle after the administration session. Flights were performed at 9:00 the following morning. To increase the generalizability of the findings, we encouraged the subjects to maintain their normal eating and sleeping patterns during the experiment.

In the control condition, the pilots performed the same maneuvers after abstaining from alcohol for at least 48 hours. There was a 1-week separation between flights in the hangover and control conditions.

Flying Task and Quantification

The two flight scenarios included two crucial maneuvers: 1) a takeoff and loss of two of four engines on one side of the aircraft and 2) return to the airport and the same runway with an instrument approach to landing, also with loss of two engines from one side of the aircraft. The two scenarios varied as to which side of the aircraft lost the engines so that the pilots could not anticipate how to react. The normal reaction to such power losses is a rapid increase of rudder pressure opposite to the power loss to prevent an uncoordinated turn of the aircraft toward the side of the power loss (yaw). Thus, the scenarios stressed the impact of hangover effect on the execution of unusual emergency procedures.

Data were obtained directly from the Naval Air Station (Moffett Field, Calif.) P-3C simulator in the form of eight flight parameters and were collected each second of flight: latitude, longitude, altitude, air speed, heading, roll, pitch, and yaw. These raw data were further transformed by means of a Corvus 68000-based microcomputer to compare the pilot's actual flight path to the ideal flight path. For example, ideal performance on takeoff after losing power to two of the engines would be zero yaw while maintaining the assigned air speed and heading. Thus, we quantified the average yaw of the aircraft after the power loss until 300 feet of altitude had been reached as well as the average deviation from the assigned heading during that same time. A graph of output from a typical flight is presented in figure 1.

Similar assessments of yaw and heading were performed on landing. In addition, on landing the pilot was to perform an instrument approach in which he would follow an electronic localizer and glideslope, which provide horizontal and vertical guidance to the runway. We calculated the average deviation horizontally and vertically from the ideal, using data collected each second during descent from 1750 to 200 feet on approach to the runway. The pilots were also asked to rate their subjective impressions of the quality of their performance on takeoff and landing using a 10-point scale.

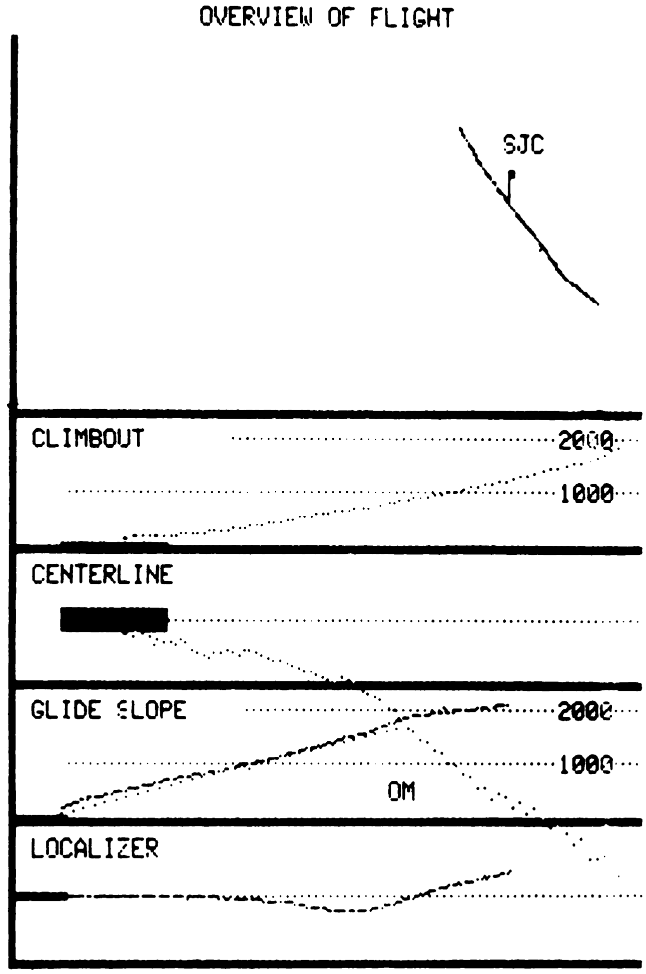
Two types of data analyses were performed: 1) we examined mean scores on all relevant performance measures, and 2) we examined differences in variability of performance under control and hangover conditions. Significant increases of variability under the hangover condition would indicate individual differences in susceptibility to alcohol hangover effects.

RESULTS

Pilot performance was worse in the hangover condition on virtually all measures, with significant differences on three of six variance measures and on one of six performance measures (by one-tailed paired t tests). The results are graphically presented in figure 2. Since the results are reported in different units (e.g., feet from glideslope and degrees from headings), figure 2 shows a percent of change measure comparing hangover with control conditions.

With respect to takeoff, the average yaw with two engines out increased from 1.79 degrees in the control

FIGURE 1. Computer Printout of Performance of a Typical Pilot Flying a Flight Scenario[a]

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FILE NAME: P107.A2

TAKEOFF/TURN/VOR TRACKING

 AV DEV FROM HDG 300   :   9.11
 AV DEV FROM TAS 190   :  12.45
 AV R, P AND YAW:    3.79    4.72    2.11
 SD R, P AND YAW:    2.01    2.87    1.21

 ILS APPROACH

  No. BALLOONING EPISODES 1.
  No. LANDING BOUNCES      0.
  AV DEV FROM LOC        : 1179.54
  AV DEV FROM GS         :   86.41
  AV DEV FROM TAS 150    :    5.27
  AV DEV FROM HDG 300    :    5.99
  AV R, P AND YAW:    3.04    2.22    2.96
  SD R, P AND YAW:    2.88    1.13    1.14
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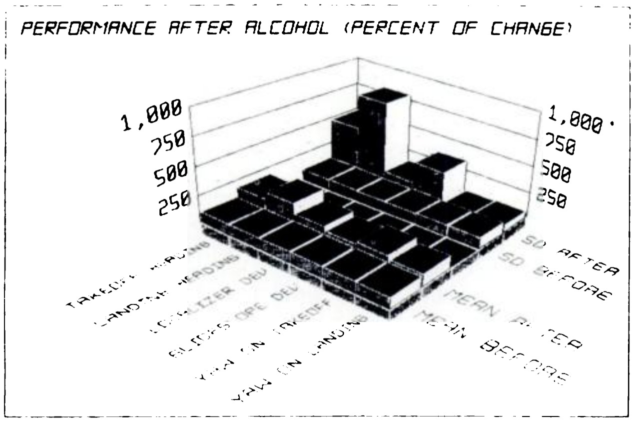
[a]Graphic data (top) show position and deviation from ideal course and altitude on takeoff and landing; digital quantifications (bottom) are of the same maneuvers.

FIGURE 2. Computer Printout of Performance and Variability Results of 10 Pilots After They Ingested Enough Alcohol To Attain a Blood Alcohol Concentration of 100 mg/dl



condition to 2.71 degrees in the hangover condition ($t=-2.87$, $df=9$, $p<.01$). The yaw parameters did not significantly change under either condition: deviation from prescribed heading on takeoff was 4.56 degrees in the control condition and 8.59 degrees in the hangover condition (n.s.). The standard deviation of the heading errors increased from 1.68 degrees in the control condition to 2.56 degrees in the hangover condition ($t=-6.68$, $df=9$, $p<.005$). This large increase of variance in the hangover condition may in part explain the lack of significance of mean performance changes.

We found similar results on the landing parameters. The mean deviation from prescribed heading on landing was 5.49 degrees in the control condition and 8.40 degrees in the hangover condition (n.s.). The increase in variance, however, was again substantial. The standard deviation of the heading errors increased from 2.60 degrees in the control condition to 20.97 degrees in the hangover condition ($t=-11.33$, $df=9$, $p<.005$). The mean yaw with two engines out was 2.96 degrees in the control condition and 3.36 degrees in the hangover condition (n.s.), and the standard deviation of the yaw parameters did not significantly change under the hangover condition. The mean lateral distance from the localizer was 921.99 feet in the control condition and 1444.85 feet in the hangover condition (n.s.), and the standard deviation did not significantly change under the hangover condition. Finally, the average vertical distance from the glideslope was 82.14 feet in the control condition and 101.25 feet in the hangover condition (n.s.). Variability increased on this parameter from a standard deviation of 17.74 feet under the control condition to 61.43 feet under the hangover condition ($t=-4.45$, $df=9$, $p<.005$).

No significant correlations were obtained between measures of flight experience or subjective impressions of performance as rated on analog scales and objective measures of performance under the hangover condition.

DISCUSSION

Considerable attention in both professional and private aviation has focused on the drinking habits of pilots. Certain popular works romanticize the pilot who can fly after a full night of heavy drinking (21). However, careful reading of such works suggests many close calls; accident statistics suggest that the risks may be serious indeed. The present study adds to the objective data that performance may be impaired in a hangover situation.

The results of this study may be understood in part by alcohol's effect in reducing the ability to process information. There is much evidence that alcohol impairs many aspects of memory (22–25). If alcohol reduces working memory capacity, ability to divide one's attention between two or more mental tasks is likely to be altered; several studies (26–28) have found alcohol-induced divided attention decrements. Pilot performance is highly dependent on these components of human cognition. Pilots must maintain a variety of information in working memory during most phases of flight. In particular, during landings and takeoffs pilots must be cognizant of air speed, altitude, rate of descent or climb, heading, and so on. Thus, pilots in such conditions may experience an overload of processing demands when their processing capacity has been reduced by drinking.

Alcohol also reduces the ability to perform nonroutine acts and has even greater effects when subjects are required to respond with an incompatible act—i.e., an alternative, nontypical response (29). In terms of pilot performance, this suggests that in emergency (i.e., nonroutine) conditions the effects of alcohol may be most pronounced. The use of alcohol before flights would increase the likelihood of a potentially fatal interaction between hangover effects and task difficulty when an emergency or nonroutine procedure suddenly appears. Such situations are most likely to occur when pilots who are scheduled to fly particularly stressful flights drink to try to control their stress.

We were particularly concerned by the lack of awareness of hangover effects by some pilots. This may simply reflect denial of the impairment in a setting in which it is difficult to admit one's shortcomings. Nonetheless, this result replicates prior work from our laboratory in which a series of private pilots were unaware of hangover effects from marijuana (30). These results are consistent with survey findings indicating that most private pilots think it is all right to fly 4 hours after drinking some amount of alcohol (1).

Although our results suggest concern about the performance of those entrusted with complex behavioral and cognitive tasks within 14 hours after drinking enough alcohol to be considered legally intoxicated, they should be interpreted with caution. The dose of alcohol was high; five 1.5-oz. 80-proof cocktails would be needed to produce blood alcohol concentrations over 100 mg/dl in the average person. Hence, one may not generalize these results to situations in which less alcohol is consumed. On the other hand, such results may be applicable to other tasks—such as operating complicated heavy equipment, railway trains, and switching procedures—when similar doses of alcohol are consumed.

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