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Aircrew Upper Extremity Reaches While Flying the UH-60 Flight Simulator: Risk of Airbag-Induced Injury

By

John S. Crowley
Amate Vizcaya
B. Joseph McEntire
Philip Johnson
Fred Brozoski

Aircrew Protection Division

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U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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John Crowley, Amate Vizcaya, B. Joseph McEntire, Philip Johnson, and Fred Brozoski

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Inflatable restraints such as airbags are being designed for military helicopters. To investigate the potential for extremity injury during airbag deployment, 1-hour videotapes of 12 U.S. Army Black Hawk pilots flying a training simulator were reviewed. The flights were unmodified training sorties and consisted of instrument and visual flight over varying terrain. Every time the aviator appeared to move outside the resting "flight" position, the nature and destination of the movement were recorded. The total proportion of time spent reaching for various control consoles ranged from 1.8 percent to 5.2 percent. Copilots in instrument flight conditions spent the greatest proportion of their time reaching, and pilots in visual flight conditions spent the least. Despite limitation to this brief retrospective simulator study, these results will be useful in estimating the risk of extremity injuries related to helicopter airbag deployment.

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Introduction

The leading cause of serious or fatal injury in survivable helicopter accidents is contact between personnel and cockpit structure (Shanahan and Shanahan, 1989). A cockpit airbag system (CABS) is currently under development for use in the UH-60 Black Hawk as a supplemental restraint system. The deployment of CABS during a crash sequence is projected to reduce the incidence of fatalities due to head and upper torso trauma by up to 23% (Shanahan, Shannon, and Bruckart, 1993).

Cockpit airbag research and developmental efforts have been conducted by several organizations within the U.S. Army. In-house research and development efforts were initiated by the U.S. Army Aviation Applied Technology Directorate (AATD) in early 1988 and the U.S. Army Aeromedical Research Laboratory (USAARL) later the same year. The AATD effort resulted in a Small Business Innovative Research (SBIR) award in August 1989 to Simula, Inc., to conduct a paper analysis and develop a conceptual design. In Phase II, the working system was demonstrated in two AH-1 fuselage crash tests (Bark and Zimmerman, 1995). In 1993, USAARL conducted a study that concluded that CABS installation could potentially reduce aviator fatalities by 23% and non-fatal injuries by 50% (Shanahan, Shannon, and Bruckart, 1993) (Alem et al., 1992). Results were briefed to the Joint Aeronautical Commanders Group (JACG) in August 1993, which directed that the Army assume lead responsibility for the development of the Joint Cockpit Airbag System (JCABS). These findings and others resulted in a Phase III SBIR contract in 1994 to complete advanced development and produce a CABS demonstration on the UH-60 helicopter. The CABS program has now reached the final stages of engineering and manufacturing development.

Ensuring correct function of the CABS in a crash is of obvious importance. Another important consideration is minimizing the likelihood and consequences of inadvertent airbag deployment. Although engineering analyses predict an infinitesimal chance of such an event, safety practice demands that the potential outcomes of inadvertent deployment be analyzed nonetheless.

Of prime concern in inadvertent CABS deployment is the potential for pilot incapacitation due to airbag-related injury or other interference with aircraft control. Experience with automotive airbags clearly indicates that injury is more likely when the occupant is out of ideal position, especially when body parts are placed in proximity to the airbag module (Shanahan, Shannon, and Bruckart, 1993). The aviator in a relaxed flying posture is relatively far from the CABS module (and therefore safe), but it is reasonable to suspect that in the course of performing their flying tasks, aviators move various body parts in proximity to the airbag module. Should the CABS deploy at these times, the occupant would be at increased risk of injury.

The purpose of this study was to estimate the proportion of a typical mission that UH-60 aviators' extremities are "out of position" and therefore potentially at increased risk of injury in the event of CABS deployment.

Methods

Subjects

As part of an unrelated 1995 study (Wildzunas et al., 1999), numerous aviators were videotaped while flying a UH-60 flight simulator (Figure 1). Six of these simulator flights (12 subjects) were randomly selected and made up the sample for the present study. None of the aviators were aware of being recorded. Since informed consent was not required for the 1995 study, none was required for this study.

Videos and analysis

Altogether, six 1-hour flights were selected for analysis: three in VFR (visual flight rules) conditions and three in IFR (instrument flight rules) conditions. The VFR flights consisted of nap-of-the-earth (NOE), contour and low level flight. Various emergency procedures were also implemented during the flights. For the purposes of analysis, the "pilot" was the person flying the aircraft at that particular time regardless of seating position, and the "copilot" was the non-flying crewmember.

Every time a subject appeared to move outside the resting "flight" position (i.e., sitting in the cockpit with hands on the controls or in the lap), the nature and destination of the movement was recorded on a data sheet. Additionally, the time spent "out of position" was recorded in seconds. All videos were reviewed and scored by the same researcher for consistency.

Sigmastat® (SPSS Corporation, 1997) was used to conduct a three-way analysis of variance (ANOVA) on the frequency counts of reaches to the various cockpit consoles. The three factors were: duty (pilot, copilot), visual condition (VFR, IFR), and console (forward, overhead, and center). The data were transformed prior to analysis (1/x) to achieve a normally distributed data set. Significant results from the ANOVA were further analyzed using an appropriate pairwise multiple comparison procedure (Tukey Test).

Results

The reach frequency data are presented in Table 1. Overall, most reaches were to the center console (216 or 55.8%), followed by the overhead (94 or 24.3%) and forward consoles (77 or 19.9%). A three-way ANOVA on reach frequency (duty x visual condition x console) revealed main effects for all three variables examined: duty ($F(1,24)=14.68$, $p<0.001$), visual condition ($F(1,24)=6.20$, $p=0.02$), and console ($F(2,24)=11.67$, $p<0.001$), but no significant interactions. Posthoc tests revealed that copilots reached more frequently than pilots did, reaches occurred more frequently during IFR flight than during VFR flight, and the center console was reached for more frequently than the front console or the overhead console (Figure 2).

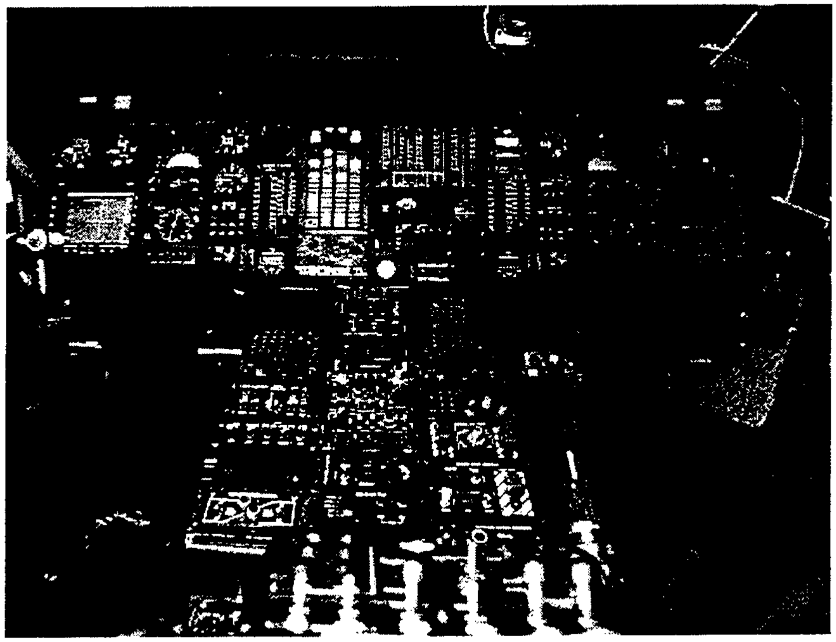

Figure 1. UH-60 flight simulator instrument panel showing the lower and forward consoles.

Table 1.
Frequency of reaches during 1-hour flight.

		Pilot			Copilot		
Condition	Flight #	Forward	Overhead	Center	Forward	Overhead	Center
	1	3	5	12	7	5	22
VFR	2	4	6	8	4	9	12
	3	7	6	5	7	4	13
	Mean	4.67	5.67	8.33	6.0	6.0	15.67
	1	3	4	9	18	12	47
IFR	2	6	5	12	6	21	26
	3	5	8	16	7	9	34
	Mean	4.67	5.67	12.33	10.33	14.0	35.67
Total # reaches		28	34	62	49	60	154

Note: Table entries represent the number of reaches per 1-hour flight.

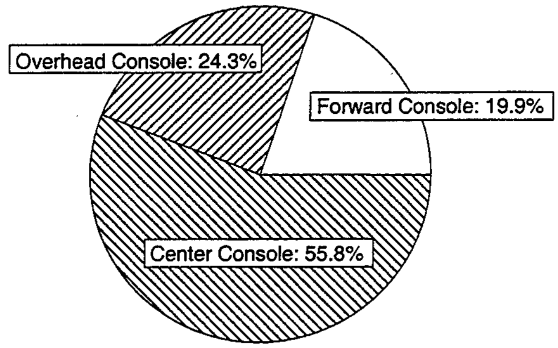

Figure 2. Proportion of reaches to the three consoles studied.

Table 2 presents the average dwell time per reach for pilot and copilot over the course of the 1-hour flight. There are no apparent differences in dwell time between crew position or flight condition.

Table 2.
Average duration of reach during 1-hour flight for pilot and copilot.

Condition	Flight #	Pilot	Copilot
	1	3.5	5.0
VFR	2	4.2	3.5
	3	2.5	4.0
	Mean	3.5	4.2
	1	3.0	2.8
IFR	2	3.5	2.6
	3	2.5	4.0
	Mean	3.0	3.1

Note: Table entries represent the average duration (dwell time) of the reaches counted within visual condition and duty position.

By multiplying the mean number of reaches (Table 1) by the mean reach duration (Table 2), the total time spent "out of position" can be calculated (Table 3). Expressed as a percentage of the 1-hour flight, crewmembers' total reach time ranged from 0.39% to 3.1%, depending on flight condition, duty, and console.

Table 3.
Average total reach time during 1-hour flight.

		Pilot				Copilot			
Condition	Console	Forward	Overhead	Center	All	Forward	Overhead	Center	All
VFR	Time (sec)	16.3	19.8	29.1	65.2	25.2	25.2	65.8	116.2
	%	.45	.55	.81	1.81	.70	.70	1.83	3.23
IFR	Time (sec)	14.0	17.0	37.0	68.0	32.0	43.4	110.6	186
	%	.39	.47	1.0	1.9	.89	1.21	3.07	5.17

Note: Total Reach Time = mean number of reaches to each console (Table 1) x mean duration of reach (Table 2). Data in the "All" consoles column represent the sum of reach times to the three consoles. The percentage of time spent reaching during a 1-hour flight (% row) = Total Reach Time / 3600 sec x 100.

Discussion

General

In the six flights reviewed, the total proportion of time spent by either pilot reaching for various control consoles ranged from 1.8% to 5.2% of the flight (Table 3). Copilots in IFR flights spent the greatest proportion of their time reaching, and pilots in VFR conditions the least. Although the greatest proportion (55.8%) of reaches overall were to the center console (Figure 2), the inboard location of this panel is the furthest from the airbags (of the three reach areas studied), and is least likely to expose the extremity to risk of injury (Figure 3). However, reaches to the center console can place the chest in proximity to the airbag module, potentially increasing risk of thoracic trauma. Reaches to the forward and overhead panels are more relevant to extremity injury; combined, these dwell times varied from 1.0% to 2.1% of the flight. Here again, copilots in IFR conditions accounted for the greatest proportion of "out of position" reaches.

Figure 3. Reaching for the center console.

These results are important to safety analyses of the UH-60 CABS, as there appears to be a significant possibility of occupant injury if the airbag should deploy into an extended extremity. The decision whether a 2.1% chance of the aircrew's upper extremity being in a vulnerable position is excessive or not is a matter for the aviation safety community to decide.

These data could also be useful to accident investigators who may be interested in location of extremities at the initiation of an accident sequence (e.g., in determining the cause of an arm fracture).

Study limitations

There are several limitations to this brief retrospective study:

First, extremity movements to only the three specified zones were included. This ignores rarely occurring reaches to other areas (e.g., scratching the face, picking up a pencil from the floor), that would undoubtedly be hazardous in the event of CABS deployment. Also, it is well known that some UH-60 pilots rest their arm by grasping an overhead handgrip that puts the arm in danger of airbag contact (Figure 4), but none of the pilots in this study adopted this posture. (One pilot known to the authors rests in this posture for long periods of time when not on the controls.)

Second, this study examined a wide variety of operational VFR and IFR flight conditions, but did not include other important flight regimes such as night or NVG flight. It is likely that pilot arm movements would vary in these environments.

Third, by restricting the analysis to extremity movements, other aviator activities that might put the occupants at risk for airbag injury were not considered. For example, the "helicopter hunch" posture places the crewmember's torso closer to the front airbag module, and turning the head to look out the side window, as in clearing the aircraft for a turn, puts the face in proximity to the lateral airbag module.

Figure 4. Resting position favored by some UH-60 pilots, but not encountered in this study.

Conclusions

In this brief study of simulated IFR and VFR flight, UH-60 pilots spent between 1.8% and 5.2% of flight time reaching with an upper extremity for various cockpit consoles, depending on the flight condition. The highest exposure levels occurred to the non-flying pilot in instrument conditions, and the lowest to the flying pilot in visual flight conditions. Despite limitations to this retrospective simulator study, these results will be useful to those calculating the risk of extremity injuries in inadvertent airbag deployment scenarios.

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