The Effects of Exposure to Simulated Launch and Reentry Profiles on Chimpanzee Performance

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ONE OF THE MOST critical factors associated with space flight, insofar as it effects behavior, is the acceleration experienced during launch and reentry. This was demonstrated by the performance of HAM, the first chimpanzee to participate in the Project Mercury Program.[2] With the advent of this ballistic flight, and the acknowledgement by scientists as to its value in the subsequent manned ballistic flights, a research and training program was begun immediately to prepare a chimpanzee for an orbital flight (Mercury-Atlas 5) to precede that of man. In preparing for this flight it became essential to simulate, insofar as possible, the conditions of launch and reentry which exist at the time a capsule is placed into orbit, particularly with regard to the effects of accelerative forces on a key performance task. Thus, the purpose of this study was to determine the effects upon performance of exposure to accelerative forces likely to occur during launch and reentry, which could further serve as a basis for selecting subjects for an orbital flight.

METHODS

A. *Subjects*

Five male chimpanzees were used in this investigation. Three of these animals had been exposed to simulated launch profiles on the WADD centrifuge about one year previously. All of the subjects had been trained for a year or more on a continuous avoidance task and their response rate on this task was highly stable. Age and weight data for the subjects are presented in Table I.

TABLE I. SUBJECT AGE AND WEIGHT

Subject	Age Years-Months	Weight (Lbs.)
62	4 - 0	26
64	3 - 11	27
65	4 - 4	40
81	5 - 3	42
84	3 - 8	33

B. *Apparatus*

The University of Southern California Centrifuge was used for this study. This centrifuge has a 23 foot radius and is capable of producing a maximum of 12 G. A "shake" table mounted at the end of the centrifuge arm was programmed to produce vibration in both lateral and longitudinal planes at 6.75 cycles per second of one-fourth inch amplitude, without exceeding a one "G" peak during the time the centrifuge was in a resting state. A white noise generator was programmed to produce a pressure level inside a flight couch of approximately 110 decibels.

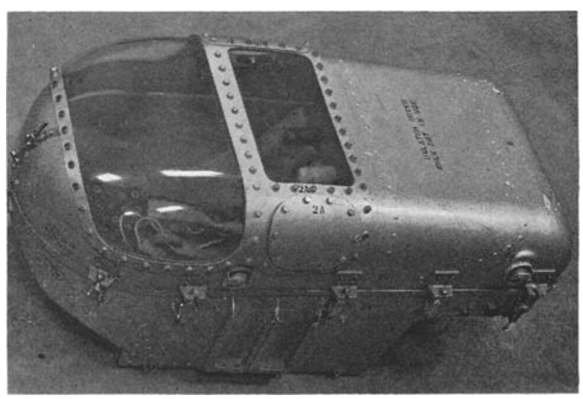

Fig. 1. Mercury flight couch.

The flight couch shown in Figure 1 was used in all simulations. Subjects were restrained in the couch by means of specially fitted flight suits and a harness inside the couch. Harness zippers joined the flight suit to the couch and, while the subject could be well re-

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strained, provision for movement of the upper extremities was optimal for the performance tasks. A metal skirt was located just below waist level to prevent the subject from reaching into the area of the catheters and electrical connections.

The performance equipment inside the couch consisted of a panel mounted directly above the metal skirt and perpendicular to the subject's body, and a water dispenser located immediately to the right of the subject's head. The panel was comprised of three In-line digital displays, three response levers and a feeder unit. While the water dispenser and feeder unit were an integral part of the apparatus assembly they were not used in the behavioral measures reported in this study. The arrangement of the display units, levers, and feeder is shown in Figure 2. The dimensions of each of the display units was one by one and one-half inches, providing for the presentation of visual cues of approximately one square inch. The display units were programmed to project colored lights and symbols. The units were spaced five inches apart with the response levers situated directly below them. The levers were 1¼ inches in diameter and protruded 2⅝ inches from the panel. Response data from the flight couch were obtained on a four channel Sanborn recorder with a tape speed of five mm. per second.

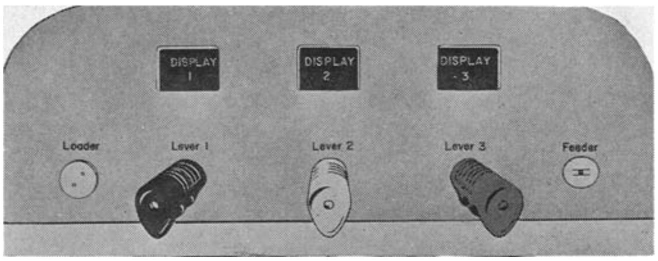

Fig. 2. Panel of Mercury couch showing display units, response levers, and feeder.

C. *Performance Task*

As stated previously, each of the five animals had been highly trained on a continuous avoidance (CA) task. This particular task was chosen for study because of its stability and because it had previously been shown that it was a sensitive and reliable behavioral measure.

A red light on Display 3 signaled the subject that the continuous avoidance task was in effect. In response to this stimulus the subject was required to press the right lever at least once every twenty seconds in order to avoid shock. Each successive level press delayed the shock for twenty seconds. Each lever depression was followed in 0.3 seconds by a secondary reinforcer in the form of a flash of white light on Display 2. Failure to press the lever at least once every 20 seconds resulted in a 0.5 second shock of 140 volts 400 cycle AC at 2 milliamps applied to the soles of the subject's feet.

D. *Procedure*

Each of the animals was subjected to three centrifuge test profiles. Animals were scheduled in such a fashion

TABLE II

CENTRIFUGE TEST PROFILES

Test	Pre-Launch (20 Min)	Launch (4 Min 15 Sec)	Period of Orbital Flight	Re-entry (3 Min 30 Sec)	Post Re-entry (46 Min 30 Sec)	Post Launch - In Case Of Launch Only (50 Min)
1. Launch acceleration only.	S resting in Mercury couch. From launch -20' to launch -14' S worked on CA. S began work on CA once again at L-1.5'.	S continued to work on CA until launch +10.5'. Gradual acceleration to peak of 9.9 G at 2' 19" following launch.	Not accomplished	Not accomplished	Not accomplished	S worked on multiple schedule until removed from couch which rested at 1 G following launch.
2. Launch acceleration (with noise and vibration) and re-entry.	S resting in Mercury couch. From launch -20' to launch -14' S worked on CA. S began work on CA once again at L-1.5'. Vibration turned on at launch -1' and noise on at launch -30"	Same as 1	S worked on multiple schedule during flight. A 1 G state existed during this period. At 1.5' prior to re-entry S was "stepped" to CA program.	S continued to work on CA until re-entry +10.5'. Gradual acceleration to peak G of 7.7 at 1.5' after re-entry began.	S worked on multiple schedule during this period until removed from couch. A 1 G state existed.	
3. Launch acceleration (with noise and vibration plus blood pressure and urine catheterization) and re-entry.	S resting in Mercury couch. From launch -20' to launch -14' S worked on CA. S began work on CA once again at L-1.5'. Vibration turned on at launch -1' and noise on at launch -30". Plus catheterizations.	Same as 1.	Same as 2.	Same as 2.	Same as 2.	

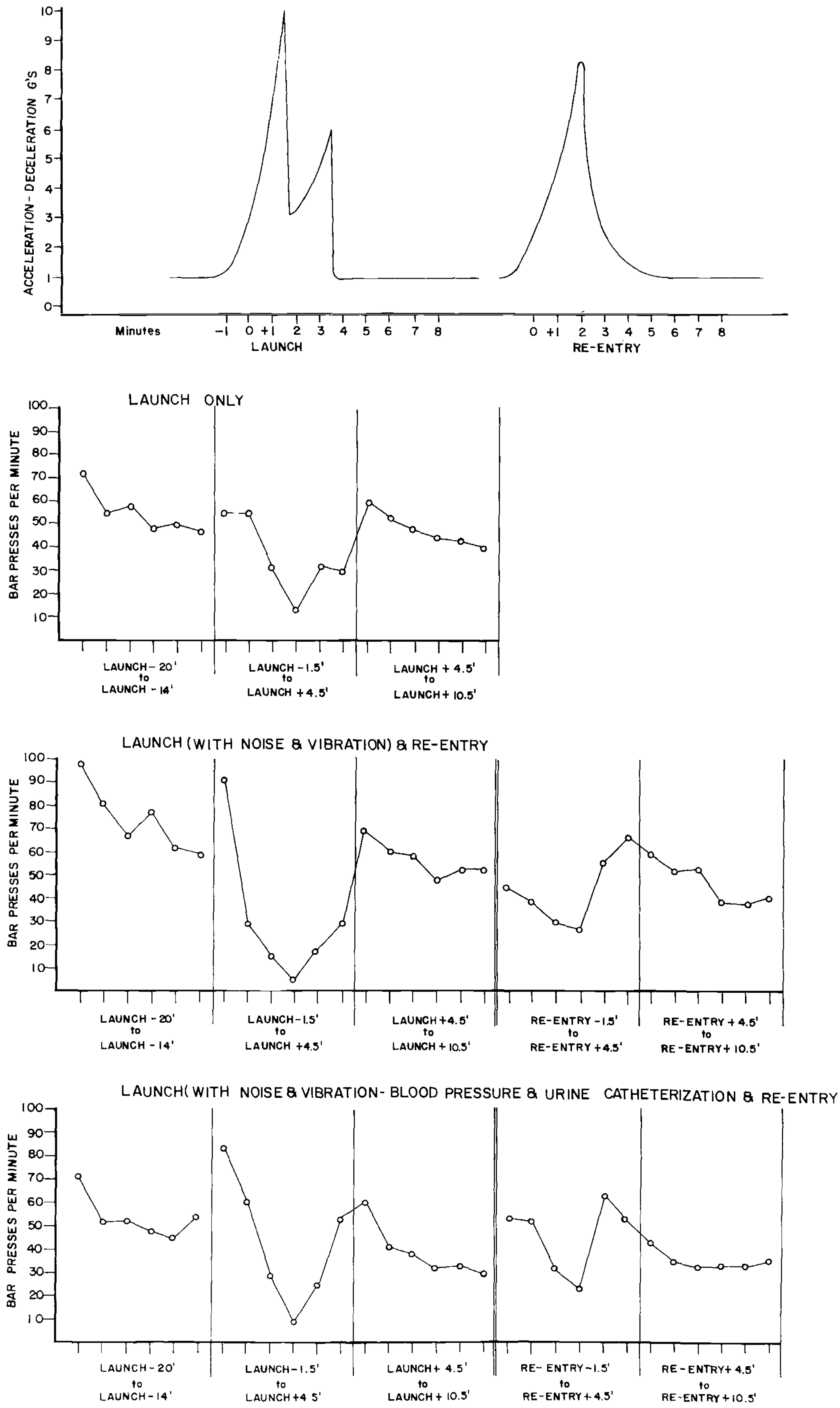

Fig. 3. Minute-by-minute analysis of CA performance during baseline, launch and reentry periods, also time periods following these.

that each had the same number of days in between tests. On the day an animal was to serve as a test subject, he was given a physical examination early in the morning, catheterized if appropriate for the test, and various physiological sensors placed on his body. Following this medical preparation, the subject was placed into his personal flight suit and restrained in the flight couch. The flight couch was then sealed, placed on the "shake" table, and bolted down securely. At launch minus 25 minutes the count-down began and final equipment checks were made. At launch minus 20 minutes the CA task was turned on and performance was measured according to the schedule outlined in Table II. All animals were centrifuged in a supine position, the accelerative forces occurring transversely from chest to back.

E. *Statistical Design*

Two Analyses of Variance were accomplished and, when required, Duncan's Multiple Range Test[2] was used as a measure of specificity. In the case of the three launches a 3 x 3 x 6 factorial design was used: three levels of launch acceleration, three major time periods (Launch 20′ to –14′, launch –1.5′ to +4.5′, and launch +4.5′ to +10.5′), six minutes during each time period, with five replications per condition. In the case of the two launches involving reentry a 2 x 5 x 6 factorial design was used: two levels of launch and reentry, five major time periods (the same three as for the previous factorial design plus: reentry –1.5′ to +4.5′ and reentry +4.5′ to +10.5′), six minutes during each time period, with five replications per condition.

TABLE III. ANALYSIS OF VARIANCE, THREE LAUNCHES

(1) SOURCE OF VARIANCE	(2) df	(3) MS	(4) F
BETWEEN LAUNCHES (A)	2	1,544.54	1,538
BETWEEN TIME PERIODS (B)	2	13,995.36	13.941**
BETWEEN MINUTES (C)	5	7,271.80	7.243**
(AxB)	4	2,840.28	2.829*
(AxC)	10	250.66	2.829*
(BxC)	10	1,406.75	1.401
(AxBxC)	20	178.37	0.178
ERROR (WITHIN)	216	1,003.89	
TOTAL	269		

* $P < .05$
** $P < .01$

RESULTS

Figure 3 provides a minute-by-minute analysis of CA performance during the baseline period and the critical periods of launch and reentry, as well as during the time periods immediately following these critical periods. Responses during these periods were collected on a continuous basis, but were divided into one minute periods in order to obtain a reliable response rate for a

TABLE IV. ANALYSIS OF VARIANCE, TWO LAUNCHES INVOLVING REENTRIES

(1) SOURCE OF VARIANCE	(2) df	(3) MS	(4) F
BETWEEN LAUNCHES (A)	1	3,407.07	3.66
BETWEEN TIME PERIODS (B)	4	6,553.18	7.04**
BETWEEN MINUTES (C)	5	6,332.62	6.80**
(AxB)	4	2,572.27	2.76*
(AxC)	5	88.80	0.09
(BxC)	20	1,567.10	1.68*
(AxBxC)	20	246.70	0.26
ERROR (WITHIN)	240	930.70	
TOTAL	299		

* $P < .05$
** $P < .01$

TABLE V. DETAILED ANALYSIS OF THREE LAUNCHES VIA DUNCAN'S MULTIPLE RANGE TEST

Significant Main Effect B (Time Periods)

	B_1	B_2	B_3
B_1	—	*	*
B_2		—	*
B_3			—

Significant Main Effect C (Minutes Within Time Periods)

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	—	*	*	*	*	*
C_2		—		*		
C_3			—			
C_4				—		
C_5					—	
C_6						—

Significant A x B Interaction

Level A_1

	B_1	B_2	B_3
B_1	—	*	*
B_2		—	*
B_3			—

Level A_3

	B_1	B_2	B_3
B_1	—		*
B_2		—	
B_3			—

* $P < .05$

TABLE VI. DETAILED ANALYSIS OF TWO LAUNCHES INVOLVING REENTRY VIA DUNCAN'S MULTIPLE RANGE TEST

Significant Main Effect B (Time Periods)

	B_1	B_2	B_3
B_1	—	*	*
B_2		—	
B_3			—

Significant Main Effect C (Minutes Within Time Periods)

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	—	*	*	*	*	*
C_2		—		*		
C_3			—			
C_4				—		
C_5					—	
C_6						—

Significant A x B Interaction

	Level A_1						Lever A_2				
	B_1	B_2	B_3	B_4	B_5		B_1	B_2	B_3	B_4	B_5
B_1	—	*	*			B_1	—				*
B_2		—				B_2		—			
B_3			—			B_3			—		
B_4				—		B_4				—	
B_5						B_5					

Significant B x C Interaction

	Level B_2							Level B_3					
	C_1	C_2	C_3	C_4	C_5	C_6		C_1	C_2	C_3	C_4	C_5	C_6
C_1	—	*	*	*	*	*	C_1	—	*	*	*	*	*
C_2		—		*			C_2		—		*		
C_3			—				C_3			—			
C_4				—			C_4				—		
C_5					—		C_5					—	
C_6						—	C_6						—

$*P < .05$

relatively short period of time and to achieve the interval level of measurement.

The results of the analyses of variance are presented in Tables III and IV. In the case of significant main or interaction effects, detailed analyses of differences were made using Duncan's Test; these are presented in Tables V and VI. The significant main effects in both analyses of variance indicate that there is a difference in performance over the major time periods and that the difference is due to the accelerative forces occurring during launch and reentry. The significant A x B interactions (Launches and Time Periods) indicate a differential response to the launches during a particular time period. The significant B x C interaction (Time Period and Minutes) in the second analysis indicates a differential response occurring at given minutes within a time period. Figure 3 reflects these statistical findings quite clearly.

DISCUSSION

The discussion and major conclusions can best be summarized as follows:

A. When noise and vibration of the sort expected in the actual launch are introduced, behavior is not additionally affected (beyond that evolving from launch alone); nor is behavior additionally affected when blood pressure and urine catheterization are "added" to noise and vibration.

B. Performance during the three launches and two reentries differed from the Launch −20′ to Launch −14′ baseline performance period at the .01 level of statistical significance. However, performance following launch and reentry indicates that the subjects experienced a normal recovery.

C. During the third and fourth minutes of launch acceleration (peak G of 9.9 reached at Launch +2′ 19″) animals showed greater impairment in performance than at any other time. Approximately 58 per cent of all the shocks the five chimpanzees received during the fifteen centrifuge runs came about during this two minute period, but a total of 80 per cent occurred during launch or immediately thereafter. By the end of four minutes following peak launch "G," animals are back "in stride" although not up to their baseline performance previous to launch.

D. During the second, third and fourth minutes of reentry (peak "G" of 7.7 reached at Reentry +1′ 30″) animals showed an impairment in performance, but not of the magnitude experienced during launch. It is pertinent to reiterate at this time that normal earth gravity existed during the "weightlessness" phase of these profile runs. Reentry from an actual state of weightlessness may very well bring about behavior different from these findings. In any event, the data from this investigation show that the animals only took some 20 per cent of the total shocks during reentry as compared with 80 per cent during launch.

The results of the USC centrifuge tests suggest rather clearly that acceleration has the greatest effect on performance of any of the variables studied. In fact, insofar as the data here are concerned, it is the only variable which brought about a significant behavioral change. In addition, repeated exposure to acceleration did not appear to be of significant value, at least when only three and two replications for launch and reentry, respectively, were accomplished.

Future investigations involving the effect of unusual environmental variables on animal behavior should be designed in such a fashion that independent variables may be widely manipulated in order to explore greater parameters. Only through experimental designs wherein various conditions of several levels are studied will it be possible to determine the full capacity of animals to serve as space subjects.

REFERENCES

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