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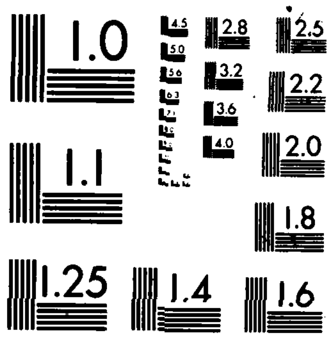
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COMPARISON OF RHESUS MONKEY AND
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by

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— STATISTICS —

— OPERATIONS RESEARCH —

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I. INTRODUCTION

As part of its research effort on impact acceleration injury prevention, the Naval Biodynamics Laboratory (NBDL) has collected a fairly extensive data base of 93 $-G_x$ accelerator runs using rhesus monkeys as subjects. Desmatics has used these data to formulate several statistical models which predict the probability of head/neck impact acceleration injury. The primary goal of this line of research is the establishment of human tolerance limits to $-G_x$ acceleration. These tolerance limits will, in turn, provide essential input to the process of evaluating proposed protection systems for naval aircraft.

Any statistical injury prediction model developed from data for a single primate species will be inadequate for the purpose of predicting injury for other primate species. However, if data from two or more species are used to develop a composite model which accurately fits the experimentally-obtained injury data from each species, empirical information about species-specific effects is obtained. This information should then be useful in efforts to extrapolate the injury prediction model to humans.

The only previous primate experiments using $-G_x$ indirect impact acceleration were carried out by Clarke et. al. [3-5] with baboons. They investigated tolerance to abrupt linear deceleration using various restraint systems. Only their last series of experiments, as described in [3], is of interest here. Those experiments used the Air Force shoulder harness-lap belt restraint and the primary cause of death was lower brain stem or cervical spinal cord trauma. Since these injuries are comparable to those found by NBDL scientists for rhesus monkeys, it seems reasonable to assume that the injury mechanism is the same. In this report we develop a statistical injury prediction model using the data for both rhesus monkeys and baboons. This model illustrates both the similarities and the differences in the responses of the two species to $-G_x$ acceleration.

II. METHODS

Several previous Desmatics technical reports have discussed the use of a logistic function in the development of impact acceleration injury prediction models. These functions are of the form:

$$P(\underline{x}) = \{1 + \exp[-(\beta_0 + \sum_{i=1}^{k} \beta_i x_i)]\}^{-1}$$

where:

$\underline{x} = (x_1, x_2, \ldots, x_k)$ denotes the set of predictor variables,

$(\beta_0, \beta_1, \ldots, \beta_k)$ denotes a set of parameter values,

and $P(\underline{x})$ denotes the true probability of injury corresponding to $\underline{x}$.

Desmatics has considered several variables as possible predictors of injury. Empirical data have been used to fit the models and evaluate their ability to accurately predict injury. The most recent Desmatics technical report [1] in this area considers a model based on peak sled acceleration and the initial yaw angle of the head. That model is compared to earlier models and shown to be a better predictor of injury. Therefore, in this investigation we use peak sled acceleration and initial yaw to predict injury for rhesus monkeys. These variables have been measured for 21 high-level accelerator runs and are given in Table 1.

Clarke et.al. conducted their tests on the Daisy Decelerator [2] with stopping distances varying from 0.5 to 3.5 ft at 6 in increments. The peak sled accelerations for those tests are given in Table 2. Prior

Run Number	Subject Number	Injury Code	Peak Sled Acceleration (g)	Initial Yaw (deg)
LX0660	A03146	0	107	0
LX0661	A03146	1	158	0
LX1359	A04099	0	110	-30
LX1360	A04099	1	128	90
LX1362	A03935	0	108	30
LX1363	A03935	1	123	0
LX1365	A03921	1	109	90
LX1893	A03924	0	110	30
LX1894	A03933	0	108	-30
LX1895	A03951	1	131	-90
LX1896	A03946	1	131	0
LX1905	A04101	1	126	0
LX3015	AR0764	0	97	90
LX3016	AR0764	1	124	90
LX3026	A03923	1	127	-60
LX3031	AR4115	1	127	0
LX3032	AR3936	0	125	0
LX3033	AR3936	1	163	0
LX3188	AR8863	0	104	-30
LX3192	AR8866	1	105	60
LX3709	AR8790	1	88	60

Table 1. High-Level Rhesus Accelerator Runs.

Injury Code=1 Denotes Fatal Run.

Injury Code	Peak Sled Deceleration (g)	Injury Code	Peak Sled Deceleration (g)	Injury Code	Peak Sled Deceleration (g)
		0.5 ft Stopping Distance			
0	21.15	0	44.14	0	98.88
0	29.02	0	61.16	1	113.6
0	35.03	0	67.27	1	118.4
0	42.14	0	81.99	1	133.6
		1.0 ft Stopping Distance			
0	11.34	0	25.38	0	45.74
0	16.96	0	34.17	0	54.71
0	24.86				
		1.5 ft Stopping Distance			
0	12.96	0	32.13	0	52.20
0	24.80	0	40.32	0	61.20
		2.0 ft Stopping Distance			
14 tests no injury	6.50 to 26.19*	0	69.36	0	107.3
		0	82.46	1	109.9
0	35.89	0	87.01	1	113.4
0	43.87	0	87.79	1	113.6
0	44.47	1	92.86	1	118.0
0	48.33	1	97.14	1	118.2
0	56.63	1	97.42	1	121.8
0	60.80	0	102.1	1	130.6
0	67.52	1	105.1		
		2.5 ft Stopping Distance			
0	11.43	0	32.19	0	53.01
0	21.34	0	37.43	0	59.44
		3.0 ft Stopping Distance			
0	8.08	0	26.04	0	52.07
0	20.00	0	38.82	0	62.22
		3.5 ft Stopping Distance			
0	9.70	0	60.63	1	99.12
0	18.97	0	74.61	1	100.80
0	26.11	1	89.76**	1	111.36
0	37.79	0	90.36	1	112.10
0	50.52	0	97.42		

*Not used in logistic estimation since exact accelerations unknown.

**Lap belt severed during impact. Not used in logistic estimation.

Table 2: Baboon Decelerator Runs

Injury Code=1 Denotes Fatal Run

to experimentation, each animal's head was fixed in place with masking tape, eliminating any dependence of injury on initial head position. We therefore consider only stopping distance and peak sled acceleration as possible predictions of injury for the baboon experiments.

III. RESULTS AND DISCUSSION

Clarke et.al. fit probit models to their data and conclude that impact acceleration injury depends solely on peak sled acceleration for the range of impact parameters used in their study. They base this conclusion on the fact that the calculated LD_{50}s (the sled accelerations where injury is predicted for 50% of the subjects) vary little over the range of stopping distances. Here we conduct a formal significance test of the hypothesis that the probability of injury does not depend on stopping distance.

If stopping distance has no effect on the probability of injury then a single logistic model based on all of the data should fit as well as a model which employs a separate logistic function for each stopping distance. We therefore calculate the following quantities:

L_1 = -2 log likelihood for the model using only peak sled acceleration

L_2 = -2 log likelihood for the model which considers both peak sled acceleration and stopping distance.

Under the null hypothesis that stopping distance has no effect, L_1-L_2 has an approximate Chi-square distribution with 12 degrees of freedom. For this data set, the calculated quantities are:

$$L_1=19.3,\ L_2=13.6,\ L_1-L_2=5.7.$$

The 90th percentile of a Chi-square distribution with 12 degrees of freedom is 18.55. Since the calculated statistic is less than this value, there is no evidence that stopping distance affects the probability of injury. We therefore use only peak sled acceleration as a predictor of fatality for baboons.

In order to compare the probability of injury for rhesus monkeys and baboons, we fit the following model:

$$P(I,A,Y) = \{1 + \exp[-(\beta_0+\beta_1 \cdot I+\beta_2 \cdot A+\beta_3 \cdot I \cdot A+\beta_4 \cdot Y)]\}^{-1}$$

where:

$I = 0$ if rhesus monkey, 1 if baboon,

A = peak sled acceleration,

Y = initial yaw angle of the head,

and $(\beta_0, \beta_1, \ldots, \beta_4)$ are parameters to be estimated.

This model fits separate logistic functions of peak sled acceleration for the two species and also includes the effect of the initial yaw angle of the head. One question of interest concerning the model is whether the estimate of β_3 is significantly different from zero. The following quantities are calculated:

L_1 = -2 log likelihood for the model with $\beta_3 \equiv 0$

and L_2 = -2 log likelihood for the model with β_3 unrestricted.

Under the null hypothesis that $\beta_3 = 0$, L_1-L_2 has an approximate Chi-square distribution with 1 degree of freedom. The calculated values are:

$$L_1=36.85,\ L_2=36.78,\ L_1-L_2=0.07.$$

Clearly, β_3 makes no important contribution to the model. Therefore, the reduced model (with $\beta_3=0$) may be used to describe the data. The fitted model is given by:

$$\hat{P}(I,A,Y) = \{1 + \exp[-(-22.204+4.4293I+.18202A+.054381Y)]\}^{-1}$$

One consequence of removing β_3 from the model is that the logistic curves for rhesus monkeys and baboons never cross. Furthermore, the differential effect of peak sled acceleration is the same for the two species. That is, the increase in peak sled acceleration needed to raise the probability of injury from x to x+Δ is the same for each species, for any value of x. This agrees with the conclusions reached by Smith [6] on theoretical grounds.

The fitted logistic response curves are plotted in Figure 1 for each species and various values of initial yaw. For ease of reference, the LD_{50}s have been marked for each curve. It can be seen from the plot that for an initial yaw angle of zero degrees, the LD_{50} for rhesus monkeys is approximately 24 g higher than that for baboons. In addition, the LD_{50} for rhesus monkeys is seen to decrease about 9 g for every 30 degrees of initial yaw. Recall that the effect of initial yaw on the probability of injury for baboons could not be determined because each animal's head was taped prior to experimentation.

It should be noted that the estimated logistic response curve given here for rhesus monkeys differs slightly from that reported in [1]. This difference results from the use of both rhesus and baboon data to estimate the parameters in the current model. However, since the differentail effect of peak sled acceleration is not significantly different for the two species, there is very little difference between the two models. The estimated response functions are:

$$\hat{P}_1(A,Y) = \{1 + \exp[-(-18.5+.152\cdot A+.0442\cdot Y)]\}^{-1}$$

and

$$\hat{P}_2(A,Y) = \{1 + \exp[-(-22.2+.182\cdot A+.0544\cdot Y)]\}^{-1}.$$

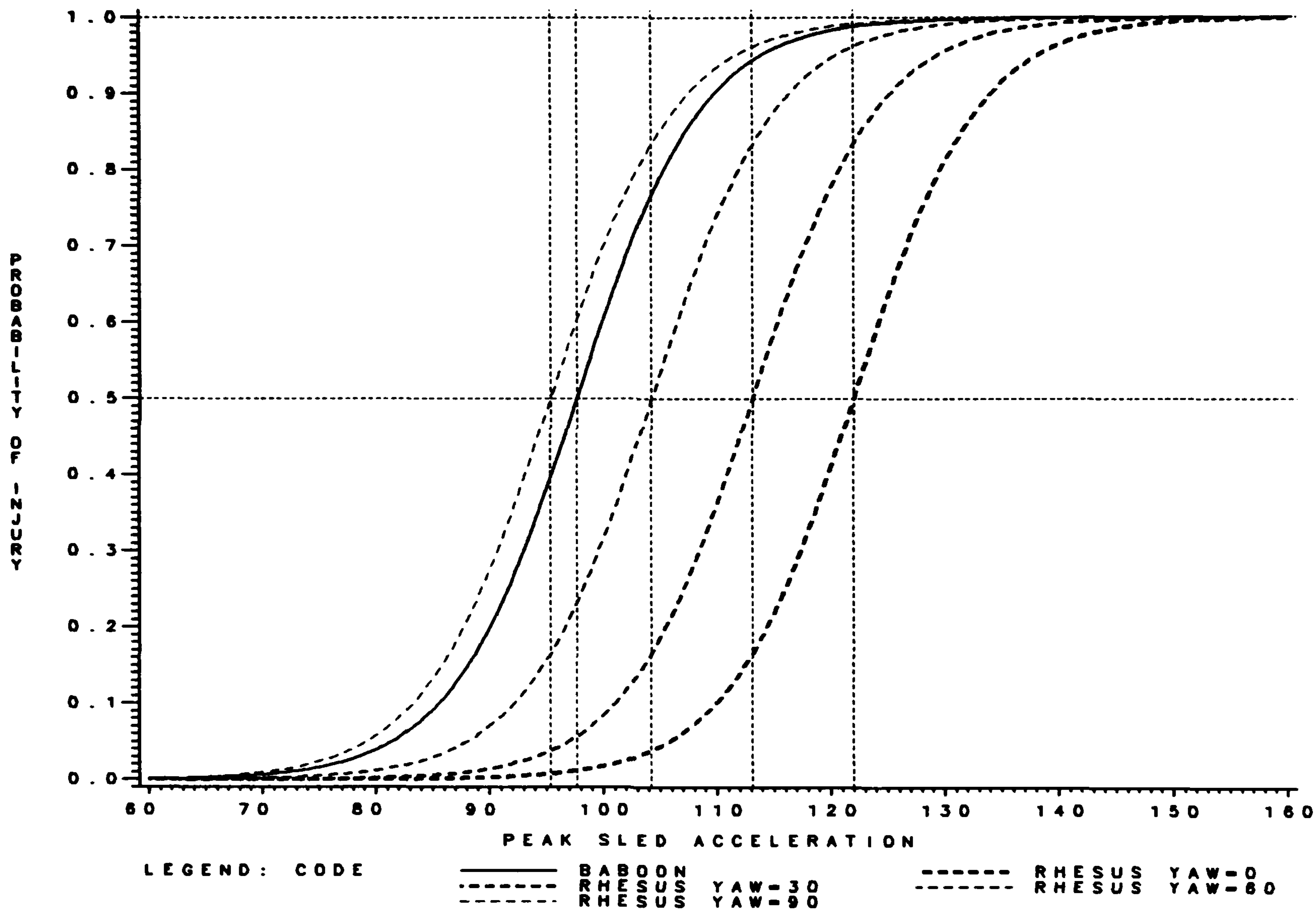

Figure 1: Comparison of Fitted Logistic Functions for Rhesus and Baboon

It is very difficult to evaluate the effect of small changes in the estimated parameters of a logistic model, especially when several parameters are changed simultaneously. Figure 2 shows plots of both estimated response curves as a function of peak sled acceleration with the initial yaw angle set to zero. It can be seen from the plot that there is little difference between the two response functions. The maximum difference between them is less than .05. Furthermore, the estimated effect of the initial yaw angle of the head is similar for the two models. For $\hat{P}_1(A,Y)$, the estimated LD_{50} decreases by 8.72 g for every 30° of initial yaw while for $\hat{P}_2(A,Y)$, the decrease is 8.98 g. Clearly, the differences between the two models are of no practical significance.

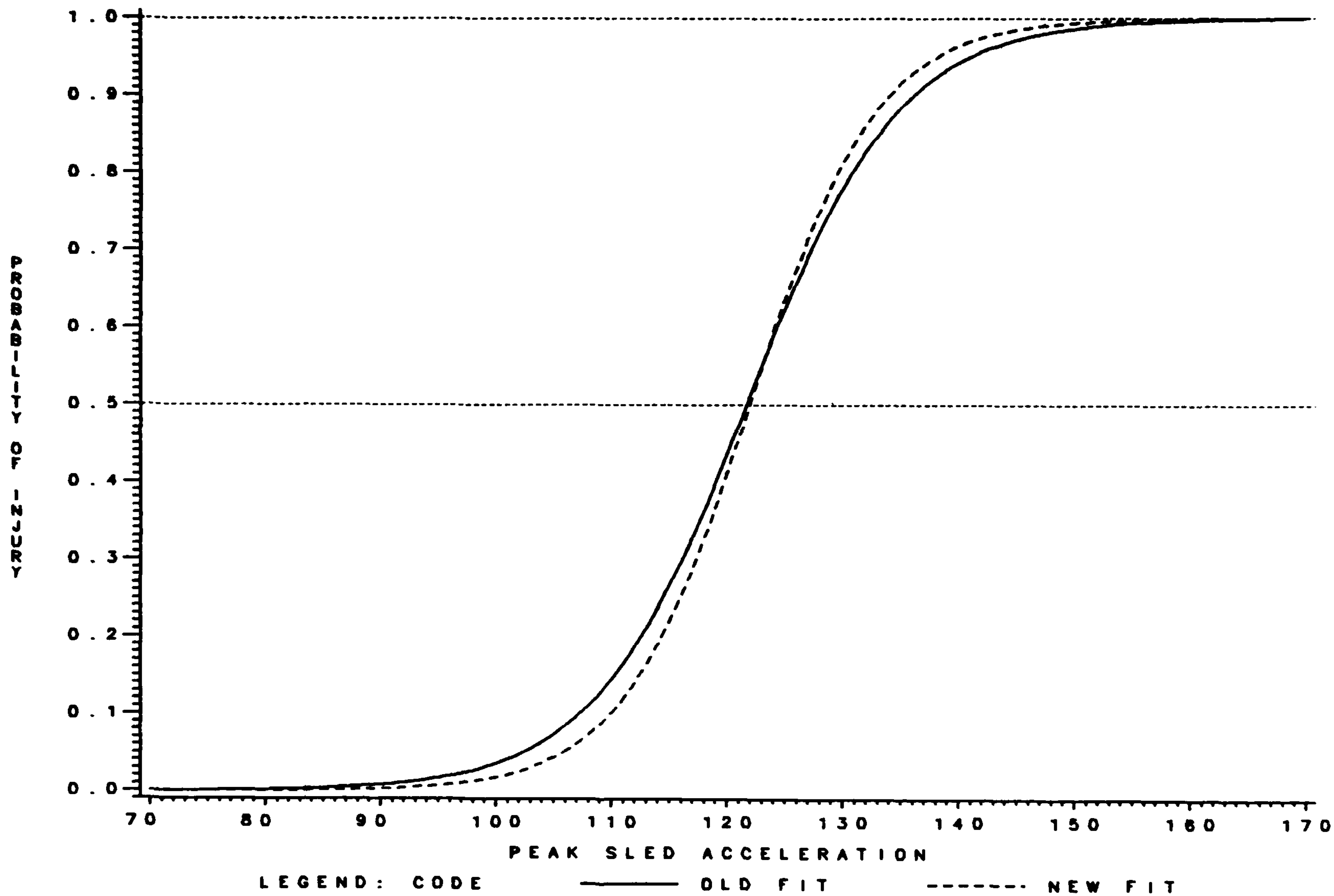

Figure 2: Comparison of Old and New Fits for Rhesus Data

IV. SUMMARY

In this report we have compared data from NBDL $-G_x$ experiments on rhesus monkeys with the results of Clarke et.al. on baboons using the Air Force shoulder harness-lap belt restraint system. Although the restraint systems differ for the two sets of experiments, the types of injury, and by implication the injury mechanisms, are similar.

In an earlier Desmatics technical report, peak sled acceleration and the initial yaw angle of the head were shown to be the best predictors of injury for rhesus monkeys. Those variables were therefore used in the model developed here. For the baboon experiments we considered peak sled acceleration and stopping distance. (Those experiments were carried out on the Daisy Decelerator.) We found no statistical evidence that the occurrence of fatal injury depended on stopping distance. Thus, only peak sled acceleration was used to predict injury. In the baboon experiments, each animal's head was taped prior to experimentation, precluding the use of initial head conditions as predictor variables.

A model was fit to the combined data from both sets of experiments, and the baboons shown to be significantly more susceptible to the effects of $-G_x$ acceleration. The difference in LD_{50}s for the two species was estimated to be about 24 g. However, the differential effect of acceleration was found to be the same for these species. In terms of tolerance limits, this implies that the mean tolerance differs for the two species but that the within-species variability in tolerance is the same. This supports an hypothesis advanced earlier by Smith, and if applicable to other primate species, should considerably simplify the task of extrapolating to humans.

V. REFERENCES

[1] Burns, Kevin C. and Dennis E. Smith (1983). "Statistical Impact Acceleration Injury Prediction Models Based on $-G_x$ Accelerator Data and Initial Head Conditions," Desmatics, Inc. Technical Report No. 112-13.

[2] Chandler, R.F. (1967). "The Daisy Decelerator," ARL-TDR-67-3, Holloman AFB, New Mexico.

[3] Clarke, T.D., J.F. Sprouffske, E.M. Trout, C.D. Gragg, W.H. Muzzy, and H.S. Klopfenstein (1970). "Baboon Tolerance to Linear Deceleration ($-G_x$): Air Bag Restraint," Proceedings, 14th Stapp Car Crash Conf., pp. 263-278.

[4] Clarke, T.D., D.C. Smedley, W.H. Muzzy, C.D. Gragg, R.E. Schmidt, and E.M. Trout (1972). "Impact Tolerance and Resulting Injury Patterns in the Baboon Air Force Shoulder Harness-Lap Belt Restraint," Proceedings, 16th Stapp Car Crash Conf., pp. 365-411.

[5] Clarke, T.D., J.F. Sprauffske, E.M. Trout, H.S. Klopfenstein, W.H. Muzzy, C.D. Gragg, and C.D. Bendinon (1970). "Baboon Tolerance to Linear Deceleration ($-G_x$): Lap Belt Restraint," Proceedings, 14th Stapp Car Crash Conf., pp. 279-298.

[6] Smith, Dennis E. (1976). "Research on Construction of a Statistical Model for Predicting Impact Acceleration Injury," Desmatics, Inc. Technical Report No. 102-2.

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NBDL $-G_x$ acceleration rhesus experiments are compared to the results of Clarke et.al. with baboons using the Air Force shoulder harness-lap belt restraint. Baboons are shown to have significantly less tolerance to $-G_x$ acceleration. The differential effect of peak sled acceleration is shown to be the same for each species. The statistical models used are logistic response functions of peak sled acceleration and the initial yaw angle of the head.

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