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THE EFFECTS OF MULTIPLE AEROSPACE ENVIRONMENTAL STRESSORS ON HUMAN PERFORMANCE

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ABSTRACT

An extended Fitts' law paradigm reaction time (RT) task was used to evaluate the effects of acceleration stressors on human performance in the Dynamic Environment Simulator (DES) at Armstrong Laboratory, Wright-Patterson AFB, OH. The DES is a 19 foot radius man-rated centrifuge. This effort was combined with an evaluation of the standard CSU-13 P anti-G suit versus three configurations of a "retrograde inflation anti-G suit" (RIAGS) manufactured by the David Clark Company. Seven subjects participated in four (4) "blend" runs and four (4) data runs on the centrifuge. The 4 blend and data runs corresponded to the number of anti-G suits evaluated (1 standard and 3 RIAGS). A blend run consisted of the initial combining of the RT task with G_z acceleration for each suit configuration. A data run was identical to a blend run, but it was assumed subjects were now familiar with the experimental set-up. Each run consisted of the following acceleration profiles: 1) a 4 G_z warm-up for 15s, 2) a 1 minute rest at baseline (1.4 G_z), and 3) a modified simulated aerial combat maneuver (SACM) consisting of +4 G_z to +7 G_z alternating plateaus, each 15 seconds in length. The SACM was performed until peripheral light loss (PLL); physiological discomfort occurred (usually due to anti-g suit configuration), or fatigue. Results indicated that RT and error rates increased 17% and 14% respectively from baseline to the end of the SACM and that the most common error was pressing too few buttons.

INTRODUCTION

Reaction Time Task

The modeling of the human information processing system using reaction time (RT) techniques dates back over 100 years ago to the work of the Dutch physician Donders (4,8,13,14). Donders proposed that RT is a "composite" score that includes stages of perception/discrimination, a choice process, and a reaction from the subject. These three stages have usually been defined as occurring serially (12,14). The use of RTs as an index of human information processing is based on the concept which assumes "...the time from stimulus to response will be sensitive to the speed of the [central neurological] processing responsible for [response] selection..."(13).

RTs obtained from choosing between alternative stimuli came to be known as choice RT (14,15). The relationship between the choice RT and the number of stimulus alternatives were mathematically described as a $\log_2$ function by both Hick (6) and Hyman (7), known formally as the Hick-Hyman law.

$$\text{Choice RT} = a + b[\log_2 (N)] \quad (1)$$

where N is the number of stimulus-response alternatives and *a* and *b* are empirical constants.

The Hick-Hyman law states that there is a linear relationship between the response time of the subject and the $\log_2$ of stimulus alternatives. This highlights one of the major concepts contained within this law: it is assumed that the time required to make a decision about a response is linearly related to the amount of information needed to make that decision (4).

As we have made use of the term *information* earlier while describing what humans do (*human information processing*), some kind of definition seems warranted. Here, information is strictly defined as the amount of uncertainty that is reduced by the fact that a signal was presented.

The amount of information conveyed is a direct function of the amount of uncertainty prior to the presentation of the signal, as well as by the amount by which uncertainty is reduced. In general, the amount of information (H) is given by:

$$H = Log2(1/Pi) \quad (2)$$

where Pi is the probability that a given event (i) will occur.

H is measured in *bits* where one *bit* is defined as the amount of information necessary to reduce the original uncertainty by half or one alternative of choice. Relating this to the Hick-Hyman law, every time the number of stimulus-response alternatives is doubled, the amount of information to be processed is increased by 1 bit (and presumably, choice RTs also increase by a *constant* amount).

In designing the choice RT task, two variables are important: (1) the nature of the relationship between the stimuli and the associated responses and (2) practice or experience with the task. The term, stimulus-response (SR) compatibility, is a measure of how natural the connection is between the stimulus and the response. The more natural the relationship between a stimulus and response, the less time required to process 1 bit of information (reflected in a smaller value of the slope of the RT function - *b*) and hence, an increased capacity of the human. The effect of practice may develop a high degree of compatibility between a stimulus-response pair normally considered incompatible.

It was our intent to develop a performance task that could easily discern changes in cognitive ability as the subjects were affected by the stressors. Such a performance task must be extremely sensitive to elicit changes due to the combinations of the various stressors acting on the subject.

One such task developed at the Armstrong Laboratory involves an extension of the classical Fitts' law paradigm in a multidimensional sense, which can be considered as a subset of the Hick-Hyman law (2). This type of task investigates the tradeoffs of speed to accuracy as humans perform simple and complex reaction time tasks. The Fitts' law paradigm is ideal for this research in the sense that it includes both a metric to evaluate task difficulty as well as a measure of capacity (or baud rate) in the accomplishment of a task (in a temporal sense) as well as increase the amount of errors that occur.

Another advantage of using this extended Fitts' law paradigm is from the information contained in the errors. In the task developed in this study, four types of errors occur and they illustrate when (and under what circumstances) the task completion process breaks down. Analysis of these errors indicate "how" the capacity is compromised as the subjects are exposed to multiple stress situations.

The motivation for extending the Fitts' law paradigm in this paper is derived from the work of Agarwal, et al. (2). In this study, it was shown that by using multiple stimuli and responses, the task could be made more and more difficult to perform until finally the subject would break down and make a substantially larger number of errors. The manner in which the task was made more difficult was accomplished by presenting the stimuli at a faster and faster rate, thus producing a form of difficulty in a temporal sense. Task difficulty could also be increased by having larger numbers of stimulus response pairs in the task scenario.

The use of linear RT models to describe and evaluate human information processing capacities is not universally condoned; for example, generalizing RT results to complex human activities such as playing basketball or flying an airplane is at best incomplete (11). Nevertheless, RT methods have been used extensively in the past to quantify the effects of environmental stressors on human performance capabilities (1). As such, an RT method based on an extension of Fitts' law is used in the present study.

Attention

Another concept that must be dealt with, as it plays a major role in human performance, is attention. There are many definitions of attention, but most agree that it is sometimes serial, sometimes parallel, concentrated, limited, and focused. Attention is felt to have limitations in the capacity to handle information from the environment. This leads to the concept of interference where two tasks are performed simultaneously and the degree to which they interfere with each other are measured. If two tasks can be performed as well simultaneously as individually, then at least one task may not require attention and can be called *automatic*, or the tasks may be referred to as being independent in their access to certain types of processing resources. If there is some decrement in the performance of a task when performed with another, then both tasks are considered *attention demanding*, and not independent in resource "drain." There are two types of interference; structural and capacity. Structural interference occurs when two demands are placed on physical/ neurological structures (i.e., requiring the hand to be at two places at the same time). If no structural interference exists, then a capacity interference is inferred. This inference is based on the assumption that there is a limitation to some central capacity resource (attention).

There are multiple theories explaining attention; undifferentiated, fixed capacity (single channel), flexible allocation, multiple resource, and functional view (as the result of a choice all other processes are prevented from occurring or only with great difficulty, (18)). Several mechanisms of parallel sensory processing have been described (11). The *Stroop phenomenon* occurs when the same stimulus in two different conditions is relevant, but in one of the conditions a secondary stimulus is processed at the same time causing an increase in the RT. A classic example is where subjects are to respond to the color (red, blue, green, yellow) of different geometric forms (triangles, circles, squares), versus responding to the colors of words which correspond to the colors (i.e., responding to the word 'blue' when printed in yellow versus responding to the printed color red when it appears as the word 'green').

As other examples of attention phenomena, the *dichotic listening paradigm* describes how man can ignore one of two messages presented through headphones. However, there are certain messages that cannot be ignored i.e., when your name is spoken. The *psychological refractory period (PRP)* states that the reaction time (RT) to the second of two closely spaced stimuli is considerably longer than RTs to the first stimuli.

A final area to address is the relationship between attention, stress, motivation, and arousal. Arousal or activation are usually considered neutral terms that describe the energy level of the individual. The term neutral is used because arousal represents the amount of effort being applied to whatever action is being accomplished. It can range from deep sleep to the highly energized state characteristic of an individual fighting for survival or competing in an important sporting event (13). Stress and motivation have a directional component where stress is considered negative while motivation implies movement towards a goal (13). A classic relationship exists between arousal and performance as discovered by Yerkes and Dodson (20) commonly referred to as the *inverted-U hypothesis*. There is an optimum arousal level to obtain peak performance. Any more or less will cause a decrease in performance.

RT and Acceleration

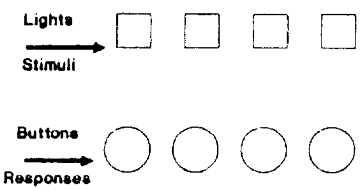
What do these theories have to do with the present study? It is hypothesized that acceleration (the presence of a greater than 1 G stressor) will have a detrimental effect on a serial RT processing paradigm, specifically an extended Fitts' law processing task. Under acceleration, error rates should increase. RT should also increase. However, the RTs to each of the response conditions used below, one (1), two (2), or three (3) button choices, may or may not retain their differences. In other words, whereas under normal conditions the RTs increase as the number of button choices increase (a positive slope), this relationship may not hold under acceleration (a 'flat' slope) due to attentional resources being diverted to the task of maintaining physiological integrity under high-G (9).

METHODS

Task Equipment and RT

Figure 1 illustrates the RT device used by the subjects in this experiment. The stimuli presented were combinations of *one, two, or three out of four possible lights in this diagram. The subjects kept two fingers (the index and middle finger) of each hand on the four buttons. To complete the task, the buttons corresponding to the illuminated lights had to be pressed. RT was calculated as the time between the onset of the stimuli (lights) and the corresponding button presses. The stimuli were presented at different *interstimulus times* (t_i), where the time between the presentation of each stimulus was varied. The three values for this variable were 800 msec, 400 msec, and 200 msec. SR compatibility was considered high because of the spatial relationship between the "on-screen" stimulus lights and response buttons. Practice with the task at normal 1 G_z was accomplished until each subject was able to maintain greater than 80% accuracy.

FIGURE 1
Reaction Time Task



Errors

There were four classes of errors a subject could make:

(1) The subject could wait too long (any response more than two seconds after the stimulus onset was dubbed "sleep time").

(2) The subject had to press the buttons *simultaneously*. This meant that if a subject pressed any two or three keys more than 50 msec apart, an error was recorded. This helped the subjects to approximate a "simultaneous" response when more than one button was to be pressed.

(3) The subject could press the wrong number of buttons (either too few or too many), or the incorrect buttons.

(4) If a subject responded within 100 msec of stimulus onset, an "anticipation time" error was recorded. This was used to reject any responses smaller than the human choice RT limitation of approximately 160 msec.

Subjects

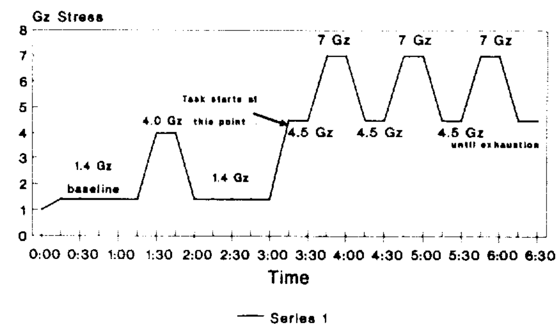
Subjects were four (4) males and three (3) females, aged 23 to 40 years, obtained from the Sustained Acceleration Panel (qualified subject pool). All subjects had undergone extensive medical screening before acceptance on the panel.

Experimental Variables

To fully describe the experiment, the forms of the environmental stressors (acceleration and anti-G suit configuration) need to be elaborated. The acceleration stressor and the anti-G suit configurations were independent variables, while an attempt was made to control for individual variability through randomization.

Acceleration: The modified simulated aerial combat maneuver (SACM) was selected as the acceleration stressor and represents a typical combat scenario. Figure 2 displays the alternating 7.0 G_z to 4.5 G_z SACM profile. The term G_z refers to that component of the acceleration stressor acting from head to foot. The end result is decreased blood profusion (pressure) at head and eye level resulting in visual degradation and ultimately loss of consciousness unless steps are taken to maintain sufficient blood pressure at higher G_z levels. This is accomplished through the appropriate use of the anti-G straining maneuver (AGSM) in conjunction with an anti-G suit.

FIGURE 2
ACCELERATION STRESS CONDITION



Modified SACM

Anti-G Suits: The experiment was also designed to evaluate several different configurations of anti-G suits and how they impacted subject performance. The standard anti-G suit in use today (the CSU-13P) is composed of 5 bladders that are inflated caudalward with pressure increasing linearly as G increases, compressing the abdomen, both thighs (quadriceps), and both calves. The retrograde inflation anti-G suit (or RIAGS) has the same bladder configuration but inflates cephaladward and is considered a *full-coverage* suit (has the appearance of a pair of pants, not *cutaway* as the standard). Perhaps the most uncomfortable aspect of the suit is abdominal pressure, which is an important factor providing protection when combined with leg pressure (19). The degree of discomfort is a function of the fit of the suit, placement of the abdominal bladder against the subject's diaphragm, and the individual's personal opinion .pa concerning increased abdominal pressure. The pressures maintained in these suits were approximately 8.5 psi at 7.5 G_z. These pressure levels are very uncomfortable at 1 G_z, but are tolerable at the higher G levels depending upon the individual. In addition to the full-coverage RIAGS, there were added two different types of arm counterpressure, namely, occlusion cuffs and pressure sleeves. This arm counterpressure was assumed to reduce the amount of blood pooling into the arms during acceleration. However, each of the two arm configurations were based on different counterpressure techniques, specificially an arterial occlusion technique (cuff) and a more widespread counterpressure technique along the length of the arm (sleeve). In summary, four different types of anti-G suit configurations were used:

1) standard CSU-13 P anti-G suit
2) RIAGS alone
3) RIAGS with sleeves, and
4) RIAGS with cuffs.

The mechanisms used to explain the effectiveness of anti-G suits for human G-protection are: (1) anti-G suits increase peripheral resistance, thus improving eye-level blood pressure under G; (2) anti-G suits help prevent rapid extravasation of plasma from the blood vessels into tissue during G stress by offering immediate counterpressure; (3) anti-G suits may play a role in increasing venous return, particularly with simultaneous inflation of both leg and abdominal bladders; and (4) anti-G suits support and raise the diaphragm, thus mechanically supporting the heart and decreasing the heart-to-eye distance (3,19).

Obviously, the bottom line for protection is effective counterpressure during G (presumably, the more the better (19)). However, human factors issues must be taken into consideration (16,17). Increased abdominal pressure via the inflated bladders may cause discomfort even under high-G (19). There are wide individual differences concerning discomfort; some subjects are not bothered at all while others devote more energy trying to breathe during a high-G run than while performing the more strenuous AGSM.

Individual Variability; Withstanding High-G Until Exhaustion: This brings us to the issue of individual variability. The level of experience on the centrifuge is a factor in how the subject devotes attention to the AGSM while performing another task (9). The subject's level of G-tolerance also dictates how well he or she will be able to maintain the AGSM while concentrating on another task.

G-tolerance is a function of physical fitness, time elapsed from last G-exposure, and miscellaneous other factors contributing to the general stress level each subject experiences (5). There is a wide discrepancy in subject response to anti-G suits, as well as different experiences with peripheral light loss (PLL) (10). Much of the research in acceleration has used PLL as an objective measure of individual stress levels. When PLL reaches the point of a 60 degree cone around the central visual axis, the subject normally terminates the run. However, not all subjects have symmetrical PLL. Thus, when we say that a subject continued the SACM to exhaustion and include this as the "end-point" within our design, we implicitly assume wide individual differences in the definition of "exhaustion" (i.e, 60% PLL, abdominal and other bodily pain, fatigue, etc.).

Dependent Measures: Subjects were intrumented with arterial oxygen saturation (SaO_2) plethysmography (mounted on the earlobe), a transcranial Doppler (TCD) sensor mounted at the temple, and electrocardiographic (ECG) chest leads. Data collected were time at G until exhaustion and termination of the session, heart rate obtained from the ECG, the time course and level of SaO_2, the time course and level of blood velocity obtained from the TCD, error rate and type, RT, and subjects' ratings of suit comfort. However, only the RT and error rate data are reported here.

Experimental Design

During a complete session, subjects began with 180 "warm-up" practice trials on the RT task at 1 G_z (termed "pre acceleration"). This normally took less than five minutes to accomplish. Immediately following these practice trials, subjects were then accelerated to a baseline of 1.4 G_z for 1 minute, followed by a 4 G_z run for 15 seconds (which hopefully provided some physiological pre-adaptation to G). Subjects remained at baseline for 60 seconds after which time the SACM profile began (Figure 2). At the first 4.5 G_z peak, the task was presented and continued for the duration of acceleration until exhaustion, when the subject terminated the exposure (termed "peak acceleration"). In addition, the task continued for approximately 50 more trials after exposure so as to provide data during the recovery phase (termed "post acceleration").

A complete session was accomplished 8 times; 4 "blend" sessions and 4 data sessions were accomplished (one blend session and data session each for the four anti-G suit configurations outlined above). The four blend sessions were completely randomized within subjects, as were the four data sessions. A blend session was the initial coupling of task performance with high-G. Data sessions were identical to the blend sessions, except subjects were now familiar with performing the task under high-G. All results reported below were obtained from the data sessions.

RESULTS

Initial evaluation of the data indicated that interstimulus times (200, 400, or 800 msec) had no significant effect on either RT or error rate/type, regardless of the number of stimuli (1, 2, or 3 lights/buttons). Thus, RT and error rate/type data were collapsed across interstimulus times in the results presented below.

RT

Our first analysis concerned the overall effect of the pre, peak, and post acceleration conditions on RT. All three conditions were significantly different from one another, $F(2,12) = 17.21$, $p < 0.0003$. RTs occurred in a descending order: peak was larger than post, which in turn was larger than pre (peak=504.4; post=464.4; pre=425.8).

Table 1 shows the statistical results of the effects of suit configuration and the number of lights/buttons on RT for each of the pre, peak, and post acceleration conditions. As can be seen, there were no interactions between suit configuration and lights/buttons for either the pre, peak, or post acceleration conditions. However, there was an effect of suit configuration on RT during post acceleration. RTs were longer for the RIAGS with cuffs configuration than for RIAGS with sleeves.

For the pre acceleration condition, there was a significant main effect for lights/buttons, where RT increased as number of lights/buttons increased (which of course was expected according to the Fitts' law paradigm, see Figure 3a). What is interesting is that this lights/buttons effect was not significant during peak acceleration (or more correctly, at exhaustion, see Figure 3b). The effect returned at post acceleration (Figure 3c).

To further examine this effect, we performed individual F-tests for each of the suit configurations for the pre, peak, and post acceleration conditions. Table 2 shows the statistical results. For pre acceleration, all four suit conditions show significant effects for lights/buttons, <u>in the same pattern</u> (3 is larger than 2, which in turn is larger than 1). For the peak acceleration condition, there were no significant differences for lights/buttons. At post acceleration, the effect returns, but with a difference. For the RIAGS alone and the RIAGS with cuffs conditions, RTs for 3 lights/buttons are significantly larger than for 1, but not from 2. The standard and RIAGS with sleeves show the same pattern as for pre acceleration (3 > 2 > 1).

Error Rate/Type

The types of error generated at peak (exhaustion) for the entire experimental design are shown in Table 3. As can be seen, sleep time errors occurred the least, while pressing too few buttons was the most common type of error. There were no errors where subjects pressed multiple keys more than 50 msec apart and are not shown in Table 3.

TABLE 1. The Effects of Suit Configuration and Number of Lights/Buttons on RT

ACCELERATION CONDITION:	PRE	PEAK	POST
* TEST:			
Suit*Button	NS	NS	NS
Suit	NS	NS	RIAGS/c > RIAGS/s $F(3,36) = 5.31$, $p < .0085$ 490.8 > 420.4
Button	3 > 2 > 1 $F(2,12) = 157.87$, $p < .0001$ 472.1 > 430.7 > 374.8	NS	3 > 2 > 1 $F(2,12) = 90.13$, $p < .0001$ 508.1 > 463.9 > 420.4

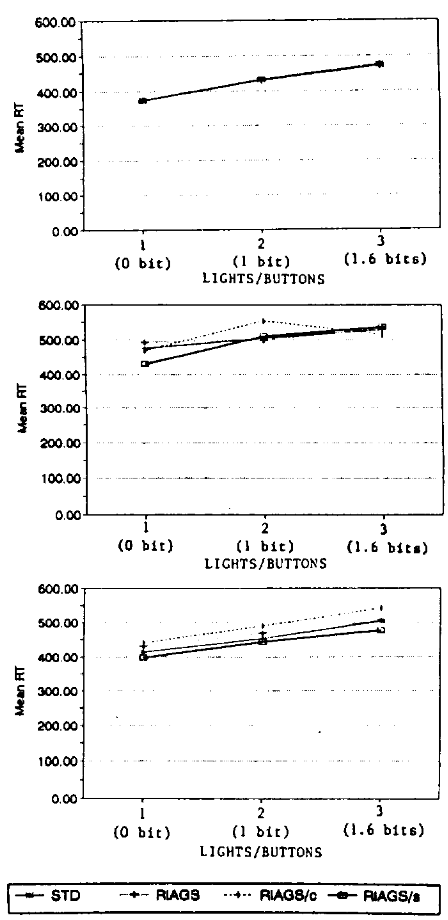
* Suit*Button: suit configuration by lights/buttons interaction; Suit: suit condition main effect; Button: lights/buttons main effect.

TABLE 2. The Effects of Acceleration Condition on Lights/Buttons RT by Suit Configuration

ACCELERATION CONDITION: * TEST:	PRE	PEAK	POST
STD	F(2,12) = 91.24, p < .0001 3 > 2 > 1 427.89 > 430.28 > 374.86	NS	F(2,12) = 80.10, p < .0001 3 > 2 > 1 504.95 > 453.07 > 413.15
RIAGS	F(2,12) = 308.51, p < .0001 3 > 2 > 1 468.86 > 428.47 > 375.18	NS	F(2,12) = 12.03, p < .0014 3 > 1 507.25 > 429.79
RIAGS/s	F(2,12) = 83.01, p < .0001 3 > 2 > 1 471.34 > 431.41 > 373.75	NS	F(2,12) = 32.52, p < .0001 3 > 2 > 1 477.87 > 443.83 > 398.39
RIAGS/c	F(2,12) = 92.08, p < .0001 3 > 2 > 1 475.47 > 432.54 >375.46	NS	F(2,12) = 13.10, p < .0001 3 > 1 542.31 > 440.44

* STD: standard anti-G suit; RIAGS: retrograde inflation anti-G suit; RIAGS/s: RIAGS with sleeves; RIAGS/c: RIAGS with cuffs.

FIGURE 3



a PRE

b PEAK

c POST

TABLE 3 - Type of Errors at Peak (Exhaustion)

Type*	Total
Sleep Time	3
Anticipation	12
Too many buttons	16
Wrong buttons	18
Too few buttons	65

* see text for explanation of error types.

Total error rates at peak acceleration (from sleep time to inaccurate button presses) for each of the four suit configurations are shown in Table 4. The pre acceleration condition is used as a "baseline" here, and each of the error rates for the suit conditions were compared to this baseline. Error rates for the standard anti-G suit and for the RIAGS with cuffs conditions were significantly larger at peak acceleration than at pre acceleration. RIAGS alone and RIAGS with sleeves did not differ in error rate from pre acceleration.

Comfort and Time to Termination

Subjects' rankings of suit comfort, and their total time under high-G before exhaustion and termination of the exposure, are shown in Table 5. As can be seen, these variables match each other in terms of superior rankings; in short, the RIAGS with sleeves was ranked highest, followed by RIAGS alone, the standard suit, and RIAGS with cuffs.

TABLE 4 - Pre Acceleration Error Rates Compared to Peak for Each Suit Configuration.

	Pre Acceleration	STD*	RIAGS	RIAGS/c	RIAGS/s
ratio of errors to total	2/78	7/78	6/71	25/78	5/83
percent	3%	9%**	8%	32%**	6%

* STD: standard anti-G suit; RIAGS: retrograde inflation anti-G suit; RIAGS/c: RIAGS with cuffs; RIAGS/s: RIAGS with sleeves.
** $p < 0.05$, one-tailed t-test comparison of pre acceleration to peak for each suit configuration.

TABLE 5. Rankings of Suit by Comfort and Time Until Termination of Acceleration Exposure (Exhaustion).

	RANKINGS	
Suit:*	Most Comfortable	Most Time Under Acceleration
RIAGS/s	1	1
RIAGS	2	2
STD	3	3
RIAGS/c	4	4

* STD: standard anti-G suit;
RIAGS/c: RIAGS with cuffs;
RIAGS: retrograde inflation anti-g suit;
RIAGS/s: RIAGS with sleeves.

DISCUSSION

The original hypothesis that RTs would be longer under acceleration than at pre or post acceleration was supported here, which strongly suggests that high-G interferes with the human's central information processing capacity. In addition, the linear relationship between number of lights/buttons and RT (as lights/buttons increase, so does RT in a linear fashion) was not supported under high-G at subjects' exhaustion point. A possible reason for this finding could be that subjects were greatly preoccupied with their physiological and bodily integrity at the point of exhaustion and were devoting few attentional resources to the completion of the task; at exhaustion, subjects are at their physiological and psychological limit. They need to divert more of their attention from the task (stimuli) to maintaining head level blood pressure through the use of anti-G straining maneuvers (AGSM) to prevent blackout and loss of consciousness. Other factors more difficult to quantify, and which may also serve to explain this effect, are the psychological consequences resulting from the situation subjects find themselves in (anxiety, fear, pain, ego, etc.). In future studies, some combination of these factors may fully explain the lack of attention given to the task under high-G at the point of exhaustion.

The type of suit configuration did not have an effect on RT, even though the comfort and time to termination rankings showed a definite pattern (the RIAGS with sleeves was superior to RIAGS alone or to the standard suit, while the RIAGS with cuffs seemed to be inferior). The error rates did show a corresponding pattern, however. The RIAGS suit with cuffs had the largest error rate of all suit conditions, while it was also ranked the most inferior in terms of comfort and time to termination. Most likely, this was due to the intense discomfort of the occlusion cuffs resulting in termination of the SACM secondary to numbness/pain rather than fatigue. It could be said that an additional stressor was added to the design matrix due to the nature of the cuffs. The cuffs occluded blood going to and coming from the lower arms. Over long periods of time, subjects reported that their arms would "go numb" and feeling would cease, or become an overriding "tingling pain" sensation.

Interestingly, the ranking of g-suits by error rate matches exactly the ranking of the suits by comfort as well as the total time to termination. The most comfortable suit had the least errors just prior to termination, as well as the greatest time under acceleration (RIAGS with sleeves).

In conclusion, acceleration stress indeed had an impact on the RT model. Because of the nature of the stressor, attention was diverted during peak Gz causing a loss in the ability to discriminate between stimuli responses. Implications to the Air Force in support of its mission are as follows: 1) how to quantify for each individual pilot the net effect of multiple stressors (physical fatigue, mental fatigue, length of sorties, type of profiles within a sortie, number of sorties per day) and predict the point at which peak Gz "exhaustion" occurs; and 2) what is the correlation of the fatigue status of pilots versus the sortie workload, both during high-g maneuvers and "normal" flight. These questions require further studies.

REFERENCES

1. Advisory Group for Aerospace Research and Development (AGARD, 1989), "Human performance and assessment methods" (Aerospace Medical Panel Working Group 12, AGARD/NATO-AG-308), AGARD/North Atlantic Treaty Organization: Neuilly Sur Seine, France.

2. Agarwal GC, Agrawal P, Corcus D, .lm5 Gottlieb GL, Repperger DW, "Cognitive performance measures VIA response equivocation", Proceedings of the 23 Annual Conference on Manual Control, 1987.

3. DeHart RL, ed. FUNDAMENTALS OF AEROSPACE MEDICINE, Philadelphia: Lea & Febiger, 1985.

4. Dupin, COURS DE GEOMETRIE ET DE MECANIQUE APPLIQUEE, cited from L. Walther, LA TECHNOPSYCHOLOGIE DU TRAVAIL INDUSTRIEL, Paris, 1926, pg 13.

5. Grissett JD, "Physical fitness to enhance aircrew g tolerance," USAF-SAM-SR-88-1, Naval Air Station, Pensacola, FL.: United States Air Force Scholl of Aerospace Medicine and the Naval Aerospace Medical Research Laboratory, 1987 Joint Service G-tolerance Conference. (NTIS No. ADA-204689).

6. Hick WE, "On the rate gain of information", QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 4, pg 11-26, 1952.

7. Hyman R, "Stimulus information as a determinate of reaction time", JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 45, pg 188-196, 1953.

8. Pieters JPM, "Sternbergs' additive factor method and underlying psychological processes: Some theoretical considerations," PSYCHOLOGICAL BULLETIN, 93, 411-426.

9. Ponomarenko VA, Oboznov AA, Arkhangel'skiy DYu, "Mental control of physiological state under effect of sustained longitudinal accelerations", KOSMICHESKAIA BIOLOGIIA I AVIAKOSMICHESKAIA MEDITSINA, 21(2):24-7, Mar-Apr, 1987. FTD-ID(RS)T-0112-90.

10. Popper SE, "Unequal narrowing of the visual field in a $+G_z$ environment", AVIAT. SPACE ENVIRON. MED., In Press.

11. Rumelhart DE, McClellan JL, PARELLEL DISTRIBUTED PROCESSING: EXPLORATIONS IN THE MICROSTRUCTURE OF COGNITION, Volume 2, Foundations, Cambridge, MA: The MIT Press, 1986.

12. Sanders AF, "Stage analysis of reaction processes, In G.E Stelmach and J. Requin (Eds.). TUTORIALS IN MOTOR BEHAVIOR, pg 331-354, Amsterdam: North-Holland, 1980.

13. Schmidt RA, MOTOR CONTROL AND LEARNING: A BEHAVIOR EMPHASIS, 2nd Edition. Human Kinetics Publishers, Inc., Champaign, IL. 1988, pg 75-139.

14. Sternberg S, "The discovery of processing stages: Extensions of Donder's method, In W.G. Koster (Ed.), ATTENTION AND PERFORMANCE II, Amsterdam: North-Holland, 1969.

15. Turvey MT, "Preliminaries to a theory of action with reference to vision", PERCEIVING, ACTING, AND KNOWING, R. Shaw and J. Bransford (Eds), 1977.

16. Viteles, MS, Editorial Foreward, "Human Engineering for an Effective Air Navigation and Traffic Control System," Paul Fitts (Ed), National Research Council, Air Navigation Development Board, March 1951.

17. Wiener EL, Nagel, DC, (Eds), HUMAN FACTORS IN AVIATION, Academic Press, Inc., San Diego, CA., 1988.

18. Wickens, CD, ENGINEERING PSYCHOLOGY AND HUMAN PERFORMANCE, Charles Merrill Publishing Co., Columbus, OH, 1984.

19. Wood EH, Lambert EH, Code CF, Baldes EJ, "Factors involved in the protection afforded by pneumatic anti-blackout suits," National Research council, Division of Medical Sciences, Committee on Aviation Medicine, Report No. 351, 24 Aug 44.

20. Yerkes RM, Dodson JD, "The relationship of strength of stimulus to rapidity of habit-formation," JOURNAL OF COMPARATIVE NEUROLOGY AND PSYCHOLOGY, 18, 459-482. 1908.