NASA TM X-1255

EFFECTS OF ACUTE AND CHRONIC HYPOHYDRATION ON TOLERANCE TO $+G_Z$ ACCELERATION IN MAN:

II. IMPRESSIONS OF SUBJECTS

By S. A. Raymond, J. E. Greenleaf, and M. Matter, Jr.

Ames Research Center
Moffett Field, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $2.00

EFFECTS OF ACUTE AND CHRONIC HYPOHYDRATION ON TOLERANCE TO $+G_Z$ ACCELERATION IN MAN: II. IMPRESSIONS OF SUBJECTS

By S. A. Raymond, J. E. Greenleaf, and M. Matter, Jr.
Ames Research Center

SUMMARY

The purpose of this paper was to assess and summarize the postcentrifugation comments of young male, water depleted subjects following $+G_Z$ acceleration. Two methods of water depletion were utilized: a sauna bath (acute group) and 48-hour water restriction (chronic group). The acute group lost 3.4 percent of their total body weight and the chronic group, 3.8 percent. Blackout tolerances were measured following the two hypohydration (dehydration) periods and also during normohydration (ad libitum control) at an acceleration buildup of 3.7 G/min. The main conclusions based upon the subjective comments were: (1) Moderate hypohydration, both chronic and acute, is associated with tolerance decrements; (2) the decreased tolerance is traceable to increased fatigue brought about by the water deficit; (3) leg pain and cardiovascular embarrassment during acceleration is increased with hypohydration; (4) the progressive lessening of the leg pain with each succeeding run is partially attributable to muscular effort. Muscular effort increases subjective tolerance to acceleration, often restoring peripheral or central vision; and (5) subjective impressions of changes in tolerance only infrequently correspond to actual performance records.

INTRODUCTION

Although the four astronauts who made orbital flights in project Mercury had drinking water available ad libitum for the duration of their missions, they returned, without exception, with symptoms indicative of hypohydration (refs. 1-4). Hypohydration may be defined as a water deficit and normohydration as the subject's normal ad libitum water balance (ref. 5). Since hypohydration is often associated with periods of stress, such as athletic contests (ref. 6) or desert hikes (ref. 7), its appearance in the orbital flights of project Mercury is not surprising. The flights required substantial alertness for an extended time, and heat stress was frequently experienced. Although heat with accompanying hypohydration could be debilitating, there have been only two other studies (refs. 8 and 9) to our knowledge concerning the effects of hypohydration as it relates to physiological stress encountered during acceleration. The purpose of this paper was to assess the effects of acute and chronic hypohydration on subjective tolerance to $+G_Z$ acceleration.

PROCEDURE

The experiments were performed with the five-degree simulator at the Ames Research Center. Young male test pilots, laboratory personnel, and college athletes served as subjects. Only 4 of the 18 original subjects had previous centrifuge experience (table I). Each of the 13 subjects who completed the program underwent three experiments, N1, H2, and N3. On the test days each subject underwent four successive runs at an acceleration buildup of 3.7 G/min with a 1 to 1-1/2 min rest period between each run. Runs prior to July 22 terminated automatically once 6 G was attained. Runs after July 22 were maintained at 6 G until the subject lost central vision and terminated the run himself. Not all subjects retained central vision until the 6-G peak stress; some lost it at 5 G or less.

TABLE I.- INDEX OF SUBJECTS

Subject	Age	Occupation	Centrifuge experience	Hypohydration regimen
JB	36	Professor	None	Chronic
RD	25	Pilot	Much	None
DD	25	Student	None	Chronic
JG	31	Scientist	None	Chronic
FK	29	Teacher	None	Chronic
DL	22	Student	None	Chronic
WL	33	Engineer	Much	Acute
JL	22	Student	None	Chronic
MM	32	Pilot-Physician	Much	Acute
JM	25	Student	None	Acute
CO	22	Student	None	Chronic
MP	22	Student	None	Chronic
RP	32	Physician	Some	Acute
HV	27	Pilot	Some	Acute

The first and third experiments were completed while the subject was normohydrated; the second was the hypohydrated experiment. To attain chronic hypohydration the subjects were limited to Metrecal liquid and wafers, 2700 kcal and 1048 cc of liquid, for the 48 hours prior to the run. Acute hypohydration was obtained in a sauna bath (50° to 80° C for 3 to 4 hours). After leaving the sauna bath the subjects rested at least 1 hour before the ride. Eight subjects underwent chronic hypohydration and attained an average body weight loss of 3.8 percent. Five subjects used the sauna bath and attained a body weight loss of 3.4 percent. The physiological results of the study will be reported in a companion paper (ref. 10).

METHODS

Recording the impressions of the subjects was begun July 16 after 11 runs had been completed. Information gained from subjects had at that time already prompted modifications in the experimental procedure. For example, rolling the cab slowly rather than quickly to the upright position reduced nausea. Further, what one subject mentioned often became part of the briefing for another subject. Hence, from July 16 to the conclusion of the study on the 31, each subject underwent a period of interrogation following each run.

The impressions recorded during the debriefing after a run were grouped into numbered categories according to topic. The subjects would often describe their prerun condition and predict how it would affect their performance. These comments have been grouped under the heading "Prerun." Topic (1) contains general impressions dealing with a subject's overall feeling (nausea, cramps, pains, etc.). Topic (2) contains impressions of effects noticed during a given run compared to those in the preceding runs. Topic (3) concerns the effects and kinds of muscular contractions and resistive techniques used to counter the stress of acceleration. Topic (4) contains comments on visual sensations. Topic (5) groups together any complaints about experimental procedure and equipment or any effects the subject attributed to equipment and procedure. The impressions under the heading "Comments" were volunteered by the subjects.

The comments and impressions collected here were drawn from interviews following 32 of the 44 runs. Thirteen of the 14 subjects interviewed underwent a complete series of three runs (table I). This report contains material from 7 normohydrated (N1) runs, 13 of 14 hypohydrated (H2) runs, and 12 of 13 normohydrated (N3) runs. H2c refers to the chronic (48 hour) hypohydration group and H2a refers to the acute (sauna bath) group. Four subjects dropped out after the first run. Of the 11 runs which took place before the instigation of the interviews on July 16, 10 were N1. However, since many of the comments following later runs referred to earlier undocumented ones, this report also contains some information about runs prior to July 16.

An evaluation of the significance of many of the comments comprises the last portion of this report.

RESULTS

July 21, 1964

JB - H2c: 1.8-percent body weight loss.

Prerun:

> The subject scraped up enough energy to say he felt "blah" after 48-hour hypohydration. Like MP, he said he might have benefited from a good workout during his period of hypohydration. He noted a little nervousness,

but felt that the nervousness was overshadowed by a feeling of fatigue: "I'll go to sleep on this thing."

Subject rode from 1520 to 1529 hours.

Debriefing:

1. The subject said he actually felt better after the ride than before the ride. He experienced no headache. He reported that muscular contraction did not prevent "slight" pain, probably from pooling of blood in his legs. The pain was greatest during the first run, decreasing in the last three.

2. In comparison to the N1 experiment he noted that central vision (CV) disappeared completely.

3. The subject said that the flexing of the muscles in his legs and abdomen increased his tolerance, and "helped to wake him up." Although peripheral vision (PV) would come back once lost, he did not attribute this to increased flexing of the muscles, but to "concentration."

4. PV loss always preceded CV loss for the subject. CV disappeared completely this time; on the preceding normohydrated runs an "afterimage" had persisted. He reported that the central light became a core, like a glowing quarter, which began to "hop around" and finally disappeared. He noticed that the lights did not flicker near 6 G but appeared continuous. His opinion of the time between his PV mark and the loss of CV was about 30 seconds.

5. The subject thrived in the cockpit; the runs appeared to generate no discomfort.

Comments:

The subject stated that he would not drink until after he swam in order to test the effect of immersion in water on his thirst sensations. He anticipated a reduction in thirst while in the water and a resumption of it, equally as severe as before, when he emerged. The above attempt fulfilled his expectations. (Reported July 28, 1964)

July 28, 1964

JB - N3

Prerun:

The subject felt quite at ease.

Subject rode from 1515 to 1530 hours.

Debriefing:

1. The subject stated that he felt "woozy," especially after the run.

2. No comment.

3. No comment.

4. The subject noticed complete loss of CV. After the disappearance of central light he saw a "grid of light lines, no colors." He would lose PV "all at once," but would be unconscious of its disappearance were it not for the stimulus afforded by the resultant change in the CV. After the central light became a core of light, he noticed that the PV was lost. The total darkness which he noted after blackout when hypohydrated differed from the grid of lines which he noticed during this run.

5. No comment.

Comments:

The subject detected flicker fusion easily. He thought that it would not be too difficult to mark both loss and fusion for PV and CV.

July 22, 1964

RD - N1

Prerun:

Beginning with this experiment, the runs during future experiments did not terminate at the moment 6 G was reached. Acceleration was maintained at 6 G until the subject terminated the run. RD is a pilot, and seemed unconcerned about the run. Any experiment dated July 22 or later followed the above procedure for termination of a run.

Subject rode from 1030 to 1048 hours.

Debriefing:

1. The subject felt tired. At the end of the last three runs he felt as if he were lying on his back when the machine stopped. Also, he experienced some vertigo when he climbed from the cockpit at the termination of the fourth run.

2. No previous run.

3. The subject relaxed until after 4 G. To combat the effects of higher G stress he would "tuck" his chin and attempt to "stand on his feet." Muscular effort tired him out, and was ineffective in bringing PV back once it had vanished.

4. When PV was lost it disappeared from the left side first. CV and PV loss were two discrete events. He had no trouble discerning them.

5. The subject felt it would be easier to put on one's shoes without the harness for the EKG. He advised that shoes be replaced before fixing the harness.

Comments:

The subject looked at the lower, dimly illuminated numbered dial until he noticed the loss of PV. He then strained to look up to the central light.

This was the first and last experiment for this subject.

July 24, 1964

DD - H2c: 5.0-percent body weight loss.

Prerun:

The subject was apprehensive due to the effects of hypohydration and the memory of the discomforts experienced during his normohydration runs. Hypohydration broke the willpower of this subject. He reported that he "couldn't take it."

Subject rode from 1336 to 1345 hours.

Debriefing:

1. The subject experienced slight nausea on the first run "due to nervousness." He stated that he felt fine during the last three and actually enjoyed himself. Although his legs hurt most on the first trip, he felt that passive tilting under 1-G stress on a tilt table resulted in more pain. He became very tired after his all-out effort in the first run. Yet he seemed in excellent physical condition, to which he credited his increasing tolerance during the last three runs. He was tired during the second run, but felt better on the next two.

2. This experiment was entirely different from his preceding one. He thought that the fit of the helmet, which did not push on his head as it had previously, was the key to his comfort. It was apparent that he was elated with the successful completion of the four runs.

3. Although swelling in his legs persisted, the subject was able to reduce discomfort by muscular effort.

4. The subject felt no vagueness in the loss of PV and CV. He called his signals "definite markings of definite events." His CV loss ended in total blackness which was preceded by the disappearance of an "orange core." No coloration of the peripheral light accompanied his PV loss. He felt that flicker fusion occurred at a definite time, and would not be too difficult to mark. His visual loss of the central light occurred simultaneously with a switch from a white to an orange core of light. Flicker fusion of the central light became a white core.

5. The subject was grateful for the change in the fit of the helmet.

Comments:

The subject experienced dizziness when he stood to climb from the cab.

July 31, 1964

DD - N3

Prerun:

The subject said he felt very relaxed and comfortable but not lazy or bored.

Subject rode from 1315 to 1332 hours.

Debriefing:

1. The subject experienced no nausea after the first run. He felt considerable leg pain during the first run but none during the last three. He explained the situation by stating that the first run "gets everything stretched out for the last three."

2. The subject stated that he "felt the acceleration" more than he did when he was hypohydrated,

particularly on the first run. He also felt that the time lapse between the loss of PV and the loss of CV was shorter this day than it had been when he was hypohydrated.

3. He exerted muscular effort even after he terminated a run, saying this was necessary or "it will get you going down." His vision did not return with muscular effort, but remained blank until deceleration was in progress.

4. Vision losses were not clear this time. Although CV and PV losses were permanent, the exact instant of their occurrence was not distinct. PV and CV losses obscured one another for the subject because they occurred so close together.

5. DD felt cramped by the weight of the helmet on his head, and stated that it forced him to sit in an odd and awkward position. He considered it a severe problem.

Comments:

DD paid close attention during the experiment. He was a keen observer. He commented that each run introduced him to new experiences and to new observations. Subjectively, he felt that there was a great deal of variability between the runs.

July 16, 1964

JG - H2c: 4.3-percent body weight loss.

Prerun:

Subject appeared agitated, giddy. He said he "talked like a drunk." He was eager to "get it over with." Talking was difficult, and the subject was hoarse.

Subject rode from 1346 to 1405 hours.

Debriefing:

1. The subject's general feeling about the experiment was that it was "fine." There was no suggestion of nausea, although he experienced considerable leg pain on the first run.

2. In comparison with previous experiments this was "country club." He recalled, however, that his previous runs took place before modification of the fast

rollback of the cab. Further, additional cooling afforded by blowers added to his comfort.

3. To delay blackout as long as possible and to avoid pain in the calves of the legs, he "clamped" his leg muscles to 75-percent capacity under 3 G. Above 3 G he clamped his leg muscles to full capacity. He relaxed this clamping between runs, but did not try to relax and tighten up while under G stress. There was no "pumping" action.

4. The subject mentioned a clear-cut loss of CV; he felt this occurred earlier on his third run.

5. No complaints were made about discomfort in the cockpit due to equipment or procedure.

Comments:

The subject advised that keeping one's eyes closed between runs and before the 15-second warning helps one to relax and to avoid nausea.

In the half-hour after the run the subject consumed a liter of water in two drafts. He no longer felt thirsty.

July 23, 1964

JG - N3

Prerun:

The subject appeared tired. As he explained it, he was "wiped out from painting the garage." He waited 45 minutes in the cab for the changing of a meter. During that time he almost went to sleep. As might be supposed, the subject showed no nervousness or excitement.

Subject rode from 1038 to 1048 hours.

Debriefing:

1. The subject considered the maintained G stress at peak G responsible for increased fatigue. He said that endeavoring to hold out as long as possible on the first run would inhibit one's performance on succeeding runs. At the finish of a run he felt as if he were tumbling. This was a new feeling and produced no nausea.

2. Excessive perspiration followed the termination of the first run. This contrasted with the complete lack of sweating that was noted when the subject was hypohydrated.

3. Although he experienced muscular fatigue on the last runs as a result of his all-out effort during the first, the subject was not as conscious of black-out sensations on these runs. On the first run he stated that the disappearance of CV was marked with orange and yellow dots in the field of vision. He described them as "gold skews on black."

4. Vision losses also differed on the first run. With muscular effort the subject felt that he was able to regain peripheral vision and to lose it again almost at will. During the last three runs PV and CV losses were more definite and final.

5. The subject noted that his seat was at a different angle than it was on either of his first two experiments. He advised that the seat position be set to a person's liking on the first ride, and that all following rides be conducted with the seat in that same position.

Comments:

The subject commented on excessive phlegm in the throat. This was marked by a good deal of coughing in the cab.

July 21, 1964

FK - N1

Prerun:

The subject was briefed at 1220. He appeared calm and relaxed.

Subject rode from 1308 to 1324 hours.

Debriefing:

1. In retrospect the subject said he felt fine. He noticed neither fatigue nor nausea. He could feel a "pooling of blood in calves and feet." He would not term the sensation as one of "tingling," but described it as "a load dropped into the legs." The contraction of the legs alleviated any discomfort.

2. No previous experiment.

3. At blackout the subject felt there was an after-image. He was releasing the switch before losing the entire outline of the center light.

4. PV and CV losses were far apart; he felt that PV was lost much earlier than CV. Once he lost PV he could bring it back by increasing his muscular effort. The first loss of PV was clear-cut.

5. The subject complained about nothing. Although the helmet would push downward on his head, he was able to push it up again without undue discomfort.

Comments:

The subject did not notice the dimly illuminated lower dial, and had no trouble concentrating on the central light.

He noticed that his eyes watered for the last part of the second run.

Due to an oversight in the briefing, he had no idea that he was to make four runs. He was, in fact, surprised to learn that the experiment did not terminate at the end of his first run.

July 24, 1964

FK - H2c: 6.8-percent body weight loss.

Prerun:

The subject had to apologize for an argument with his switchboard operator. He was irritable and taciturn. He had waited about 2 hours in addition to his 48 before he was able to ride. He had a slight head and temple ache, and complained of a pain behind his eyes. The left eye was very bloodshot.

Subject rode from 1530 to 1543 hours.

Debriefing:

1. The subject stated that he was "good and tired" just previous to the third run. After the run he felt that he was more tired than he was following his normo-hydrated runs. He experienced no pain in his left leg, but complained that his back and right leg felt painful, particularly on the first run. He sweated more than he did when normohydrated.

2. Subjectively, FK did not feel that there was a significant decrement in his performance due to hypohydration (there was none - ref. 10). He felt that he had to work harder to achieve the same level of tolerance.

3. The subject noted that relaxing after releasing the switch could lead to blackout. He reported disappearance of a yellow dot afterimage of the central light immediately after relaxation while still under G stress. The yellow dot faded in again as the G stress lessened.

4. The subject described the loss of CV as a fading to gray followed by a disappearance of the core of light in a gray field. What remained was a gray and white "star effect." He noted that once the PV disappeared and the central light became a core, the core ceased to flicker and became a steady light.

5. The subject noted that he had tears in his eyes due to air blowing on his face.

Comments:

On July 31, when FK returned for his final normohydrated experiment, he commented about his hypohydration and its lasting effects. He said a "knot" the size of a walnut developed in his leg and persisted for three days after the run. He said that it took a week for his stool to become solid after hypohydration ended. He could not control his eye movements very well.

July 31, 1964

FK - N3

Prerun:

No comment.

Subject rode from 1445 to 1502 hours.

Debriefing:

1. Although the subject experienced slight sensations of nausea on his first run, he considered this day to be the best of the three experiments. He had felt no leg pain on the first run.

2. The subject stated that he never felt close to losing consciousness during this experiment. He had felt very close to losing it when he was hypohydrated.

3. No comment.

4. The subject detected definite PV and CV fusion. He felt that PV remained longer than it had on previous runs with the consequence that the time lapse between PV loss and CV loss was shortened. The subject described blackout as a static gray pattern with no stars, no sensations of motion, and no color.

5. No comment.

Comments:

The subject felt that the panel holding the central light always appeared to be rising. He said: "It's like you were at the bottom of a roller coaster dip and the car in front of you was on the way up - only it stays like that. You don't really go up; you just think the panel is rising."

At the end of his hypohydrated run, FK was given a beaker of cold water. It was interesting to note that he thanked Mrs. Douglas for it even though it was Dr. Greenleaf who had given him the beaker.

July 17, 1964

DL - N1

Prerun:

The subject received little briefing; most of it was done in the cockpit. He observed no run previous to his own. During the run his eyes would continuously swing peripherally. Instruction to keep his eyes straight ahead was given.

Subject rode from 1436 to 1458 hours.

Debriefing:

1. The subject experienced no nausea. Since he relaxed after the first run, runs two and three found him less able to tolerate G stress. At no time was CV loss definite; his legs and feet "tingled."

2. No previous experiment.

3. Subject consciously worked to delay blackout.

4. Only on the fourth run did he have a complete, clear-cut loss of PV. The mark for CV loss on the third run was accidental. When PV would begin to

disappear, it would begin earlier on the left side. The left side lost PV before the right.

5. The subject noticed no helmet pressure. He did not feel that equipment or procedure caused him discomfort.

Comments:

The subject noticed that near maximum acceleration it was somewhat easier for him to see the dimly illuminated number dial directly below the central light than it was to see the central light itself.

Again, because he did not relax between runs, the grip on the trigger tired his arm. Other than maintaining a grip on the switch, he made no muscular effort between runs.

July 22, 1964

DL - H2c: 3.8-percent body weight loss

Prerun:

No comments.

Subject rode from 1330 to 1350 hours.

Debriefing:

1. If the subject waited after sensing the rush of blood to the legs, he could not prevent pain in the legs by muscular contraction. It was necessary to begin contractions with the first notice of swelling in the calves.

2. The subject felt he worked harder during this ride than previously, and he was more tired. His PV loss was clearer than it had been during his normohydrated runs.

3. The subject found hyperventilation helped delay blackout. After the initial mark for PV loss, the subject could regain PV by contracting muscles in his legs. He felt that maintaining the acceleration at 6 G tired him out.

4. The subject would terminate the run just as CV began to fade - at the same point he terminated on the preceding run when normohydrated. He never completely blacked out. He felt that PV loss preceded CV loss by a long time.

5. No comment.

Comments:

The subject felt excessively fatigued beginning 1 hour after he had finished his H2 ride.

July 29, 1964

DL - N3

Prerun:

The subject explained that he was not "keyed up" for this run. He was relaxed, not preparing, but observing.

Subject rode from 1345 to 1400 hours.

Debriefing:

1. The subject stated that he was tired. He felt better when he was hypohydrated.

2. He maintained that after PV loss CV would fade out much sooner than it did during his hypohydrated run. During the latter run he could detect the central light as a bright core long after his PV had disappeared.

3. DL stated that he tired himself out on the first run. This left him with less endurance to continue muscular work during the last three.

4. He noted a short time lag between PV loss and CV loss. His CV loss was complete; PV loss was vague and preceded CV loss "by no more than 3 seconds."

5. No comment.

Comments:

The buildup of emotional tension before an experiment may have a great deal to do with one's performance. The subject's opinion was that because he was not "keyed up" his tolerance was lower.

July 20, 1964

WL - H2a: 4.0-percent body weight loss

Prerun:

The subject spent about 2 hours in the sauna bath.

Subject rode from 1525 to 1540 hours.

Debriefing:

1. Although the subject experienced no nausea, he stated that he felt "punk."

2. In comparison with his previous ride the subject said he had less tolerance than before: "I could tell." (He actually had more tolerance by 10 to 15 sec - ref. 10).

3. The blackout was complete. He described a "black background with gold, squiggly flashes."

4. The subject felt that there were about 15 sec between the loss of PV and the total, clear-cut loss of CV. He said that the CV loss occurred just as the machine terminated the first two runs, and that his tolerance on the last two runs dropped considerably, at least enough to make him feel that he and not the machine program terminated the run.

5. The helmet, pushing on his head, forced him to hold his head at an uncomfortable angle.

Comments:

The blackout sensation described above was not noticed during the subject's normohydrated run.

July 27, 1964

WL - N3

Prerun:

It appeared that the subject was quite accustomed to the procedure. He was not groggy or worried about the run.

Subject rode from 1105 to 1118 hours.

Debriefing:

1. On neither the last experiment (H2) nor on this one did the subject feel excessively fatigued.

2. In comparison to his last experiment the subject felt there was less "psychological change" between the feeling before the run and the feeling once the run was over. This third experience did not worry him as much beforehand nor was he especially relieved when it ended.

3. The subject thought that his visual tolerance was higher during this experiment than on both of the preceding trials. (That was the case - ref. 10.)

4. According to the subject, CV loss during N3 was much the same as in the original normohydrated condition (lower in N3 than N1 - ref. 10). Although the field of vision after blackout was "black with streaks of lightning" when the subject was hypohydrated, the flashes did not appear when he was normohydrated; everything was streaky gray.

5. No comment.

Comments:

The subject advised that experience had a great deal of effect on his attitude and on his opinion of his performance.

July 16, 1964

JL - N1

Prerun:

The subject seemed a little worried and frightened. He had no history of nausea. As a result of an earlier run today, he was told to save his energy until beyond 3 G. He was also instructed to disregard the peripheral lights.

Subject rode from 1514 to 1540 hours.

Debriefing:

1. The subject experienced nausea during the runs. He felt his stomach "coming up - right up the middle." He felt this sensation was due, in part, to prerun nervousness. He stated that the fourth run was his most comfortable and was marked by a complete absence of "stomach rise."

2. No previous experiment.

3. Thinking to delay blackout, the subject hyperventilated for the first three runs. Ceasing to do this he felt was "possibly the reason he felt better at the end of the fourth run."

4. The subject was uncertain about the loss of PV. He thought it may have been obscured by the CV loss that closely followed it. He estimated the time between the loss of PV and loss of CV to be about 2 sec. The actual interval was about 10 sec.

5. The subject noticed a downward pressure from the helmet. This pressure was uncomfortable and could not be alleviated by straightening his back and raising his head.

Comments:

The subject felt things would be different if he were more familiar with the controls, with the experimental procedure, and with the operation of the equipment.

Once in the cab the subject found it progressively easier to relax.

July 22, 1964

JL - H2c: 3.3-percent body weight loss

Prerun:

JL had undergone 48 hours of hypohydration. During this time he had consumed only 1 box of Metrecal cookies and 4 cans of Metrecal fluid. He was the third man to crave steak and potatoes; both LL and CO had expressed a similar preference for food instead of water. Unlike the others, he felt that the second day of hypohydration was the hardest. He had had 5 sticks of Juicy Fruit gum against our orders.

Subject rode from 1507 to 1525 hours.

Debriefing:

1. Although he expended "good muscle effort," the subject reported that he was less tired and felt better than he did the last time. He did not feel that each run was as long or as stressful as were those during his normohydrated run. (All were 10 to 20 sec longer in H2 compared with N1 - ref. 10.) He experienced vertigo climbing from the cab.

2. He had no sensation of nausea, and was convinced that his previous experience was the result of nervousness and naiveté, not mechanics.

3. After the first run, in which he experienced leg pain, the subject was told to contract his leg muscles. By the third run the subject was tired, but the leg pain had disappeared. His feet felt as if they were "asleep."

4. The subject experienced clear-cut CV loss. He said that the light turned yellow just before blackout. He noticed that the central light fused, but he did not mark it. He said that "a yellow cloud developed a black fringe and dulled out," then he would stop the run. It appeared to him that PV was better on the right. He experienced a clear-cut loss of PV.

5. He did not feel helmet discomfort during this experiment.

Comments:

None

July 29, 1964

JL - N3

Prerun:

No comment.

Subject rode from 1435 to 1448 hours.

Debriefing:

1. JL tired himself on the first run. He had no reserve strength to delay blackout for the last three runs.

2. He felt he did best on the normohydrated run today (run 1: H2 - 69.5 sec, N3 - 130.5 sec - ref. 10). He did not experience the complete lack of nervous tension and buildup which DL and CO mentioned.

3. No comment.

4. No comment.

5. No comment.

Comments:

None

July 23, 1964

MM - H2a: 3.6-percent body weight loss

Prerun:

The subject lost 1.6 kg in the sauna bath. He intended to mark every loss of PV in order to get a more definite impression of the effects of muscular techniques.

Subject rode from 1358 to 1417 hours.

Debriefing:

1. The subject noted marked leg pain especially on the first run. He terminated the run because of fatigue and pain, not because of CV loss. Although extremely tired after the effort expended for the first run, the subject thought his successive runs were not unduly affected since he was able to rest while a footboard was repaired in the cab after his first run (run times were 167.0, 113.0, 102.0, and 98.5 sec - ref. 10).

2. The subject marked flicker fusion in the CV light. He was not as thirsty as he was on the first hypohydrated experiment. He was not dizzy climbing from the cab.

3. After the first run, muscular effort reduced leg pain.

4. The subject felt that other subjects were premature in signaling the disappearance of CV. He experienced a complete disappearance of PV, but reported that the core of the central light persisted beyond his endurance to the physical strain of the first run. His PV was lost a long time before he considered his CV lost.

5. The first run resulted in an equipment failure; the support from under the left foot fell away.

Comments:

The subject described the approach of pain in the legs as a "tingling to the toes followed by pain."

July 30, 1964

MM - N3

Prerun:

MM admitted that he did not have the energy or interest to build up for this run.

Subject rode from 1016 to 1032 hours.

Debriefing:

1. The subject stated that his tolerance was lower than in previous runs (run times - 126.0, 116.0, 100.5, 85.0 sec - ref. 10) and the motions seemed harder to go through. He was tired; just before the last run he yawned phlegmatically. He seemed bored even in the cab. Leg pain was severe on the first run.

2. He was unable to develop the interest during this experiment which he had shown during his previous ones.

3. Muscular techniques could be employed to restore PV, CV, and flicker.

4. The subject's vision losses were not clear-cut. He could restore either PV or CV at will. Loss of CV was marked by a field of vision which contained no central light. The background was colored dark blue and green and covered with red spots.

5. No comment.

Comments:

The subject felt that "motivation was the key." He stated: "Daily physiology appears to have a lot to do with performance." Centrifugation tolerance tests which utilize PV and CV losses may test motivation and strength more effectively than G tolerance.

Flicker fusion also seemed to have arbitrary limits. There was no definite mark possible for the precise instant that flicker fusion occurred.

July 23, 1964

JM - N1

Prerun:

The subject was anxious; he thought his PV on the left side would disappear first since his left eye was weaker.

Subject rode from 1528 to 1541 hours.

Debriefing:

1. The subject experienced nausea during the first run. At the termination of the first two runs the subject experienced a sensation of being "on his back looking up." He felt no leg discomfort, he was not tired, and he noted no vertigo or nausea at the end of the experiment.

2. No previous experiment.

3. Muscular contraction would bring back both PV and CV. The subject felt that PV remained after CV was lost.

4. The PV and CV losses of the subject were confusing. He reported that he could see blue lights on each side after the disappearance of the central light. Even after the central light became dark, he reported that he could still see the dimmer numbered dial below it. He recalled that flicker fusion occurred during acceleration some time before the peak level was reached. At higher levels of stress he felt it more difficult to "raise the eyes" to the central light.

5. JM felt that the central light was set too high.

Comments:

It seems likely that the subject never lost CV. It is possible that the central light would disappear only because it would drift into the periphery of his vision as his eyes lowered to the numbered dial. The apparent persistence of the PV could again be explained by actual persistence of CV. The subject admitted that he could have been looking directly at the peripheral lights when checking whether or not he still had peripheral vision. Thus, if his CV remained, he would interpret his perception of the side lights as continued PV. His eyes were probably directed too low to observe the central light.

July 24, 1964

JM - H2a: 3.1-percent body weight loss

Prerun:

No comment.

Subject rode from 1442 to 1502 hours.

Debriefing:

1. The subject experienced no nausea, but felt extremely tired.

2. He felt that he worked harder during this run than he did when he was normohydrated. He was more tired than he had been previously.

3. The subject observed that during his final run, when he maintained muscular contraction throughout the ride, the vision losses were permanent. On other runs, when he contracted sporadically, his vision would return once or twice before finally going out.

4. The subject experienced a complete loss of vision. When he concentrated on raising his eyes, he saw only the white light, and was not troubled by the appearance of the dimly illuminated numbered dial. He felt that he would lose PV and CV simultaneously. He marked this with the marker button. When CV came back, which it did on all but his last ride, he would wait for its second disappearance before terminating the run. He concurred with DD that flicker fusion was more apparent on the peripheral lights. He almost blacked out on his last run while awaiting the return of CV. He was able to notice the flicker fusion of the central light, but did not feel he could mark the precise instant of its occurrence.

5. No comment.

Comments:

The subject commented that he was not tired the evening of the 24th. The stress of hypohydration and centrifugation affected him greatly. The following night he took a single puff on a cigar, became dizzy, and fell into a deep sleep.

The fact that by straining his eyes upward he could see the central light with no trouble indicated that the premature loss of CV which he noticed last time was probably the result of a displacement of the field of vision.

July 31, 1964

JM - N3

Prerun:

No comment.

Subject rode from 1352 to 1408 hours.

Debriefing:

1. The subject developed a headache after the third run. He experienced vertigo when climbing from the cab, a sensation which was "just as strong, but no stronger" than it was when he was hypohydrated.

2. The subject felt more tired after this day's runs than he did when he was hypohydrated.

3. On the first run the subject noticed that the calves of his legs "cramped." This was not noticed on the last three runs.

4. The sequence of the subject's visual sensations was as follows: First he noticed flicker fusion of PV; soon thereafter he lost PV while CV fusion occurred simultaneously. There was a short lapse of time between PV loss and CV loss. Just before CV loss the "core" turned a red color. During this period intensive muscular effort would reduce the degree of color and delay blackout. He described blackout as "staring through the windshield on a dark night during a severe rainstorm."

5. No comment.

Comments:

The subject apparently experienced disequilibrium at the approach of blackout. He stated that he felt close to complete unconsciousness; as if he "were going to turn all the way over and black out." This sensation of impending rotational motion affected him during deceleration while he looked away from the actual position of the light. He would look away thinking that he was actually staring at the exact position from which the light seemed to disappear at CV loss.

He noticed tears in his right eye even though the air blower was directed over his left shoulder.

July 17, 1964

CO - N1

Prerun:

The subject had an opportunity to watch another experiment before his own. During the period of observation he discussed much of the procedure and was quite at ease.

Subject rode from 1515 to 1534 hours.

Debriefing:

1. In general, the subject noticed fatigue. He experienced no nausea. His fatigue was general and not confined to one area which may have experienced great muscular stress.

2. No previous run.

3. The subject noticed that muscular work could postpone blackout. He would begin straining at low stress levels, however, and attributed his somewhat lower tolerance to tiredness near the end of the runs.

4. The subject had to strain to look upward at the central light. His CV loss was quick and definite. He estimated a very short time between PV loss and CV loss. He interpreted the disappearance of PV as a gradual one with no definite end point.

5. There was no helmet trouble.

Comments:

Constant gripping of the trigger on the "deadman" switch tired the subject's forearm.

He was apparently in competition with his friends and compared his tolerance to theirs. Also, there appeared to be a general feeling of support and friendship between the last three men - no doubt affecting the attitude with which they approached the experiments.

July 22, 1964

CO - H2c: 3.5-percent body weight loss

Prerun:

The subject felt lazy, lacked pep. "Felt like a 10-pound weight would be too much . . ." He had

excessive dryness around the lips, complained that his hunger and thirst went together. He wanted a juicy steak.

Subject rode from 1420 to 1442 hours.

Debriefing:

1. The subject reported that he was not as tired after the hypohydrated run as he was after the preceding normohydrated run. He stated that he felt better this time.

2. In comparison to the previous normohydrated run, CO felt the pooling of blood in his legs to be more uncomfortable during the normohydrated run than during this run. Further, he reported that under extensive G stress he felt that his ears were "plugged." Between runs this sensation would decrease slightly.

3. The subject could bring back CV if he waited for it to disappear before intensifying muscular contraction. He would wait until he was just beginning to lose CV, then he would resume muscular effort. He could then lose CV entirely for a short while (as he worked) after which it would return. When it had left the second time, he released the deadman switch.

4. The loss of PV was clear-cut, but CV, as reported above, was "gradual." He felt that the loss of vision, in general, occurred along a continuum with two sharp peaks denoting the losses of PV and CV, in that order.

5. No comment.

Comments:

The subject was very thirsty.

July 29, 1964

CO - N3

Prerun:

Subject claimed he was not nervous. He said there was "no nervousness left"; he felt no need to prepare himself.

Subject rode from 1403 to 1415 hours.

Debriefing:

1. The subject felt that each run affected him identically. He did not experience severe fatigue after the first run, and considered himself adequately rested and prepared for succeeding ones.

2. He felt less tired at the conclusion of the hypohydrated experiment than after this one.

3. No comment.

4. PV marks indicated the first time CO lost PV; these were not the only times. He felt he hit the PV marker button too soon on the last run.

5. No comment.

Comments:

Blackout sensations were different during this experiment than they were during hypohydration. The subject noticed complete absence of the central light and saw a completely black field. There were no colors and no sensations of motion on his visual field.

July 17, 1964

MP - N1

Prerun:

Subject appeared calm. He had no history of nausea, nor did he appear to care if he got sick. The subject was told that during hypohydration he was to refrain from aspirin, drugs, and chewing gum. He was not worried about the hypohydration. His briefing mentioned saving energy until 4 or 5 G. MM told MP that PV loss was not abrupt for some, but was definite for himself. Aside from slight moisture on his hands, the subject showed few signs of nervousness.

Subject rode from 1342 to 1400 hours.

Debriefing:

1. Although his heart rate was high during the run, the subject did not feel nervous. He noticed no "tingling" sensation in his feet or legs and felt no pain.

2. No previous experiment.

3. The subject made the usual abdominal and leg contractions to delay blackout. He said that he noticed a "natural compensation for the acceleration" in the intercostal muscles while accelerating.

4. Although he could bring back PV by muscle contractions, the subject marked the first loss of PV only. There was no loss of CV on the third run. On the last run, the only one on which he felt he might have lost CV, he felt there was a very short interval between PV loss and the doubtful CV loss.

5. He made no remarks about equipment.

Comments:

The subject's grip on the deadman switch tired by the fourth run because he did not relax his grip between runs. This probably caused his accidental termination of the fourth run.

July 21, 1964

MP - H2c: 1.8-percent body weight loss

Prerun:

Subject felt "tight," as if his skin were taut. He was not very agitated or nervous. He relished his sugar cocktail terminating his 48-hour hypohydration. During the run he seemed in high spirits. When asked if he was too tired to continue after the second run, he replied, "Put another quarter in."

Subject rode from 1345 to 1404 hours.

Debriefing:

1. Throughout the runs the subject retained a dull headache which had begun in the last day of hypohydration. He felt blood rushing to his buttocks and lower legs. The muscle flexing to counter this effect was, he felt, nearly involuntary and automatic.

2. He felt he may have worked harder during this experiment compared with the last, but was more at home in the cab.

3. Only on his final run was he close to blackout. He described his field of vision at this point as a

lightning effect on a backdrop of black. He did not notice this effect when normohydrated. Muscular techniques were used, and he could bring back PV once it was lost.

4. PV loss was clear-cut on all runs, but concentration and increased flexing of the muscles could bring it back. On the last run he maintained that he could still see the side lights even after he had marked CV loss.

5. No equipment or procedure complaints.

Comments:

Next to a drink of water, the first thing he wanted was a hamburger. He felt tense, a feeling which he attributed to hypohydration and not to the venipunctures.

July 28, 1964

MP - N3

Prerun:

The subject was anxious about his high heart rate during the preceding runs. He was also conversational about the effects of his hypohydration (cf. Comments below). He was worried about the runs.

Subject rode from 1415 to 1435 hours.

Debriefing:

1. The subject felt better after this experiment than after the first two. He was less fatigued.

2. During his preceding hypohydrated experiment, the subject found it easier to tell when PV loss occurred.

3. If he began muscular contraction before completely losing vision - before the appearance of a gold background with silver stars - he could regain CV. After noticing the gold and silver effect, no amount of effort could restore vision. As a result of prolonging the attempt to regain CV on run 3, the subject blacked out completely soon after releasing the switch to terminate the run.

4. The subject had difficulty in observing the precise time of PV loss.

5. No comment.

Comments:

After the previous experiment (H2) the subject looked pale. At home he felt exhausted and his heart beat remained rapid.

After the hypohydration runs, MP also noted that tight socks tended to leave abnormally large and deep impressions on the skin of his legs. His skin seemed paler to him.

July 20, 1964

RP - H2a: 3.8-percent body weight loss

Prerun:

No comment.

Subject rode from 1410 to 1428 hours.

Debriefing:

1. The subject's general reaction was one of fatigue. He felt he would strain against acceleration too early in the runs. He experienced a good amount of leg pain in his calves.

2. Subject felt tired, more so than during his N1 experiment.

3. The subject thought he could have delayed blackout more successfully had he waited longer before beginning muscular contractions.

4. Although the subject experienced clear loss of PV, he felt premature in signaling the disappearance of CV.

5. The subject complained again about the discomfort of the sauna bath hypohydration.

Comments:

The subject found the sauna bath so intolerably hot that between the 15- to 20-minute bath periods he would spend a good deal of time outside.

July 29, 1964

RP - N3

Prerun: No comment.

Subject rode from 1015 to 1030 hours.

Debriefing:

1. The subject experienced severe leg pain, particularly on the first run which he terminated because of pain.

2. The subject felt unusually fatigued which he attributed to his uncomfortable position. In comparison with previous runs, he waited until CV disappeared completely before terminating.

3. Constant contraction supplemented by intermittent, strong flexing of the legs was most effective in alleviating leg pain.

4. CV loss was marked by an appearance of the central light as a half-moon. With the vanishing of the half-moon a "spark effect" would emerge on a black background. PV loss was less distinct. Concentrating on PV only made the moment of loss less distinct and less definite. Flicker fusion of PV was easily detected, but the subject did not notice any fusion of the CV.

5. The subject complained of discomfort brought about by his seating position.

Comments:

None.

July 20, 1964

HV - H2a: 2.3-percent body weight loss

Prerun:

The subject retained a dull headache from the sauna bath.

Subject rode from 1248 to 1300 hours.

Debriefing:

1. The subject noticed no nausea or muscular pains, but complained of general fatigue.

2. In comparison with his normohydrated runs the subject was not nauseated, as he had been previously, but he felt he was more tired afterward.

3. Physical effort was expended to delay blackout.

4. PV loss occurred about the same time as CV loss except for the last run.

5. The subject did not complain about the centrifugation procedures, but he would have preferred a cooler sauna bath during hypohydration.

Comments:

Note that the subject rested between hypohydration and centrifugation to reduce possible heat effects.

There was no interrogation after HV's N3 run on July 27.

DISCUSSION

The subjects tended to comment on two broad areas: the experimental procedure and equipment, and the physiological effects of the experimental procedures. As a general rule the subjects were extremely conscious of what they were sensing and how they were feeling. They inspected their performance readily and were quite eager for outside opinion on how well they had done. Individual comments have not been collected in this section, though comments which aptly describe a generally observed phenomenon have been quoted.

Equipment and Procedure

Helmet.- Of the 14 subjects interrogated, 4 (HV, DD, JL, and WL) stated that the helmet caused them discomfort, forced them into awkward posture, and affected their tolerance. DD terminated N1 after only 2 runs because of the helmet. After his N3 experiment he was surprised and angry that the "helmet problem" had not been corrected. He said his H2 experiment was his best, although it may have been only the effect of the helmet that convinced him. Results from 5 of the 32 runs were influenced by the malfunctioning of the helmet.

Deadman switch.- The deadman switch evidently had a counterforce which was strong enough to tire a subject's hand and arm. DD and CO experienced local fatigue in the wrist because they held the switch closed between each N1 run. MP accidently terminated his last N1 run because his wrist was too tired. It is recommended that naive subjects be instructed to relax their grips between runs.

Height of central light.- Six of the 14 subjects had difficulty "lifting" their eyes to the central light. Most of these subjects found it easier to concentrate on a dimly illuminated dial below the central light. It seems possible that visual stress attributed solely to acceleration was compounded

by the stress due to the apparent height of the central light. JM's visual sensations in his N1 run differed considerably from the standard pattern. Since he was able to see the dial even after he had signaled the disappearance of CV, it is probable that he had difficulty in seeing the light for some reason other than the lack of CV. He mentioned afterward that it took some straining to continue watching the central light. It seemed to him that it was necessary to lift his eyes to the central light.

Sauna bath.- All 5 men who hypohydrated in the sauna bath thought that the temperature was unnecessarily high. Although it varied between 50° to 80° C, it was a good deal hotter for the first 3 subjects than for the last 2. This would have been an important consideration had there not been a waiting period when the heat effects could abate before the run. Such effects were noticed in particular by the first subject (HV) who did not avail himself of long rest periods between spans in the hot room.

Seat position.- RP and JG complained that the position of the seat changed in successive experiments, causing them to feel off balance, etc. Thus, for 2 subjects another possible variable besides hypohydration was present. JG recommended that succeeding experiments either employ the same seat shape and position for all subjects or fit the seat to the subjects liking the first time, resetting it at the same position during successive runs.

Physiological Effects

Leg pain.- In 16 runs, 11 subjects commented on what appeared to be pooling of blood in the legs and feet. Often this pooling was accompanied by severe pain. For 11 of the 16 experiments, the subjects mentioned that the leg pain was greatest during the first run. After the first run, leg pain progressively abated and the subject would often be unaware of it on the third and fourth runs. The progressive abatement of pain appeared to be a general pattern since those subjects who did not mention it either experienced very slight sensations in the first place or did not specifically deny that such a decrease was experienced.

The mechanism for this progressive decrease in pain is obscure. However, the venous constriction reflex during acceleration described by Leverett, Bondurant, and Riley (ref. 11) is a possibility. They noted that the initial constriction of the veins in response to 3 G positive acceleration required from 1 to 10 seconds, reaching a peak after 10 to 30 seconds. This span agrees well with the length of time the subjects felt the most intense leg pain, even though such pain did not appear until nearly maximal acceleration.

Generally, muscular effort appeared to mitigate the pain although some subjects noted that the pain during the first run was very strong. JB (H2) could not prevent the onset of "slight" pain in his first run despite muscular effort. Seven other subjects (FK - N1, and DD, DL, JL, MM, RP, and JG - H2) stated that they were conscious of the mitigating effects of muscular contraction.

That muscular effort helps prevent pain was further indicated by those subjects who underwent passive tilting on a tilt table. DD (H2) felt that tilting caused him more pain than 6 G during the first run on the centrifuge when muscular effort was permitted. Taliaferro, Wempen, and White (ref. 9) observed a significant (20 percent) decrement in visual tolerance in passive hypohydrated subjects. Since our decrements were of similar magnitude (ref. 10), it seems that muscular activity does not appreciably alter tolerance in hypohydrated subjects. However, subjects claimed that acute muscular exercise would often restore vision once it had been lost.

Hypohydration appears to intensify leg pain. Of the 16 runs in which pain occurred, 10 were H2 runs. Thus, in all but 3 of the H2 runs there is recorded commentary concerning pain. Only FK and CO complained of "slight" leg pain in their N1 runs. DD, MM, and RP experienced "severe" leg pain on their N3 runs, but were also among the 10 subjects who experienced leg pain during H2. Only one subject (JM) observed slight "cramping" during his N3 runs without mentioning similar or more severe sensations during H2. RD did not notice leg pain at all, but had no H2 experiment. WL and HV (H2a) were the only subjects who did not mention sensations of pain in the legs during any experiment. JB, JG, DL, and MP felt such pain only during their H2 runs. All 5 subjects had undergone 48 hours of water deprivation.

The subjective indication that orthostasis and leg pain under $+G_Z$ acceleration were brought about or intensified by hypohydration agreed with the results of Beetham and Buskirk (ref. 12). They found that hypohydration augmented the normal decrease in pulse pressure with orthostasis. The rise in diastolic blood pressure which occurred on standing was also greater in hypohydrated subjects. Pulse-rate rise with orthostasis was both greater and more quickly achieved in hypohydrated subjects (refs. 12 and 13). Beetham and Buskirk attributed increased cardiovascular embarrassment under gravitational load to a decreased blood volume, although they did not measure the blood volume of their subjects.

The observations of Beetham and Buskirk agree well with certain other physiological parameters measured during this study. Notably, the average supine pulse rate for our normohydrated subjects was 63 beats per minute, only 2 beats per minute below the average pulse rate for the hypohydrated subjects. Standing pulse rates for all normohydrated subjects averaged 72; however, the H2a subjects averaged 94 and the H2c, 88 (ref. 10). Similar pulse alterations during orthostasis in subjects with decreased blood volumes were observed by Gullbring et al. (ref. 14).

Alterations in cardiovascular fitness were observed in astronauts after the orbital flights of Project Mercury. Some orthostatic hypotension was noted in all 4, although Cooper and Carpenter were the most hypohydrated. Engorgement of the veins on standing and other "symptoms" of hypohydration were observed. Faintness and vertigo were particularly evident in Cooper. The aeromedical reports of the 4 orbital flights (refs. 1, 2, 3, and 4) indicated that no astronaut exceeded a weight loss greater than about 5 percent of the preflight weight: Glenn - 3.1 percent (156 g/hr), Carpenter - 3.9 percent

(180 g/hr), Schirra - 3.1 percent (132 g/hr), and Cooper - 5.3 percent (102 g/hr). No significant subjective or objective decrement in pilot function was reported.

Fatigue.- Centrifugation with muscular resistance permitted is extremely tiring. In other work, exploring tolerance to acceleration in a variety of positions, Smedal, Creer, and Wingrove (ref. 15) found that even in a restraint suit 6 minutes at 6 G was sufficient to produce extreme fatigue in pilots. Except for one blackout, restrained subjects all terminated because of fatigue.

Statements concerning fatigue were perhaps the most subjective of the recorded comments. Inquiries were made about the general impressions of fatigue. Usually the subjects volunteered relative information which compared the run to other previous runs or to previous sensations of tiredness. No standard test for quantitizing such fatigue was used. General subjective indications revealed that the subjects usually felt "worse" when they were hypohydrated. Nine subjects said they were tired during and after their H2 run. Others looked tired, but did not say so. However, of the 9 subjects who noticed fatigue during their H2 run, only 4 (DD, FK, DL, and HV) stated that the hypohydration run left them more tired than normohydration runs. CO and DD thought that H2 was their "best experiment," though not necessarily the least fatiguing. Helmet and seat position troubles sometimes complicated statements of preferences. The general opinion was that the resistive efforts "required more work" when hypohydrated, but that the overall level of performance was similar, that is, they had to work harder to achieve the same result. This shows a separation between reality and subjective indications since the hypohydration tolerances were actually 14 to 20 percent of the normohydration tolerances (ref. 10).

Opinions on fatigue varied considerably. Three subjects (JL, MP, and FK) stated that N3 was their best experiment. Three others (JG, MM, and RP) indicated that it was the most fatiguing and found them at their lowest tolerance. Yet it was apparent that hypohydrated subjects felt below par during the prerun physical tests. That by increased effort they were able, in their opinion, to compensate for any physiological decrement in tolerance due to hypohydration shows perhaps these things: First, that in the opinion of the subjects such a decrement was not too great. They felt able to tolerate and to fight against acceleration. In fact, they often indicated that they felt better able to do so when they were hypohydrated. Second, fatigue due to increased exertion was more likely during a hypohydrated run. Hypohydrated subjects were often more susceptible to fatigue. Third, it shows that the subjects were motivated to prevent blackout for as long as possible. They were not individuals who would signal CV loss at the first sign of pain; they were more likely to attempt delay of CV loss to the limit of their capacity. Thus, the general level of fatigue seemed to influence the tolerance to $+G_z$ stress since such tolerance demanded physical effort. It was noted that hypohydration increased the likelihood of subjective fatigue. This increased susceptibility was also observed by Greenleaf and Sargent (ref. 16) and Lee and Mulder (ref. 17) who found that hypohydrated subjects appeared tired and listless, feelings which increased with progressive hypohydration.

Headache.- Four subjects (FK, MP, HV, and JM) mentioned headache during or preceding runs. Three of them were hypohydrated. The only hypohydrated subject who stated that he had no headache was JB. Subjects who had experienced 48-hour hypohydration had only slight or dull headaches. Subject HV (H2a) had a severe headache immediately after leaving the sauna bath and a dull one by the time he began his run. The three hypohydrated subjects had headaches before the run. Subject JM (N3) developed his headache during the third run.

Nausea.- Five subjects complained of nausea in 6 experiments. Only JB (N3) felt nauseated after the experiment. The others (JL and JM - N1; DD and FK - N3; and DD - H2) felt progressively less nauseated as the experiments continued. JL and DD credit this abatement to a lessening of "nervousness." They felt they worked out the tension during the first run, leaving themselves relaxed and no longer nauseated for the next three runs.

Disorientation.- At the end of the runs 3 subjects (RD and JM - N1; JG and JM - N3) felt disoriented. Sensations varied. JM and RD felt as if they were on their backs looking up and JG felt as though he were tumbling. JM and RD sensed impending tumbling during their runs. All sensations of disorientation occurred with normohydrated subjects. JM did not feel disoriented when hypohydrated, but mentioned such feelings on both normohydrated experiments.

Vertigo on exit.- Four subjects (RD, DD, JL, and MM) experienced vertigo when they climbed from the cab. Dizziness was often strong enough to warrant some physical support of the subject as he walked to the medical room. Two of the subjects (DD and JL) experienced vertigo on exit only when they were hypohydrated. JM noticed vertigo during both H2 and N3; RD noticed it in his N1 runs, but had no other runs.

Tears.- Two subjects (FK and JM) noted tearing during their centrifugation. At first it was hypothesized that tearing resulted from air pressure due to the blowers. However, JM (N3) observed tears when the blower was directed away from his eyes. The cab was closed so the tearing could not have been caused by the wind. FK experienced tearing during both normohydrated experiments, but did not mention it after H2. The subjects volunteered no cause for the phenomenon.

Flicker fusion.- The peripheral and central lights flickered consistently on a constant frequency throughout the runs. All the subjects could detect the flickering of both lights before beginning a run. Previous work (ref. 18) indicated that frequency of flicker fusion for a central light was altered very little up to 4.8 G. Although fusion of the central light was noticed 9 times and that of the peripheral lights only 6, DD and MM felt that fusion of PV was easiest to detect. Those who noticed when CV fused thought that the event was simultaneous with PV loss. Only MM attempted to mark flicker fusion although DD and JB felt that their impressions of fusion were distinct enough to mark. On the N3 runs MM found that the point of flicker fusion was vague. Other subjects also noticed that between runs flicker fusion would vary in discreteness and sharpness. If flicker fusion was mentioned in the subject's briefing before the run, he would generally look for it during the run.

Inquiries made afterward suggested that flicker fusion was a general phenomenon. Subjects who were not looking for it during the run would often recall during the interview that it had occurred.

General visual sensations.- The general pattern for the progressive loss of vision with increased stress was as follows: the first visual alteration noticed by the subjects was usually the flicker fusion of PV. This generally occurred at about 3 G. The loss of PV occurred next. Subjects noticed a narrowing of their field of vision, often followed by a color change of the central light. The subjects reported they were no longer conscious of a halo around the central light, but that the light appeared as a white or orange core. When it was noticed, flicker fusion of CV occurred practically simultaneously with the loss of PV. The central light became a steady source of light with no fringe. The loss of CV was the next event to occur. The span between the loss of PV and the loss of CV varied. Some subjects thought that the two events were so close together they obscured one another. Others felt that the central core remained for as long as a minute after the loss of PV. The length of the interval appeared to depend, to some extent, on the kind of muscular contraction used to delay blackout. Eight subjects mentioned that PV returned once it had been marked as lost. With more muscular effort CV also would return. Four subjects in 5 experiments reported that by acute muscular effort they could lose and regain CV at will. CO (N3) and other subjects stated they developed a sense of how close they were to losing CV and could expend just enough muscular effort to stay ahead of blackout. Others apparently could or did not do this, and would contract maximally early in the runs. Loss of vision in these cases was not susceptible to restoration through muscular effort. Further, these subjects would end a run in an extremely tired state.

Visual sensations varied. Blackout patterns were described by 10 subjects (JB, DD, JG, FK, WL, MM, JM, CO, MP, and RP). They varied from black or gray homogenous fields to wild bouncing lights of many colors. Often subjects described lightning-like flashes on a black background. There was no apparent relation between the degree of hydration and the kind of blackout sensation described.

RECAPITULATION

The impressions of the subjects indicated that a number of important variables influenced their tolerance to $+G_z$ acceleration. Hypohydration was only one of them. Others, such as helmet cramping and variation in seat position, could be easily modified in future experiments. Still other variables appeared to be inherent in the procedure. Since muscular work can be performed which will delay blackout, the overall fatigue of the subject was an important consideration - especially in an experiment which measured tolerance in terms of time as well as the degree of stress resisted. Although hypohydration certainly influenced the subjects' sensations of fatigue, there were many other possible influences which were not adequately controlled. The subjects were advised to sleep well the night before their H2 run, but this proved difficult for those undergoing chronic hypohydration. Sometimes such subjects

were unable to sleep at all. This influence of hypohydration on sleep has been observed by King (ref. 19) under much greater degrees of hypohydration.

Attitude, nervousness, and competitive feelings apparently affected the measurement of tolerance by influencing the degree of muscular force exerted by the subject. A lazy subject might consistently display low tolerance even though he had sufficient reserve strength to counter the detrimental effects of hypohydration. Or a highly motivated subject might decide to relax and to take it easy. This relaxation was observed in several subjects who experienced a letdown of their N3 experiment. The letdown was typified by remarks about the difficulty in sensing emotional buildup prior to the run. No release of tension and a decreased sense of accomplishment were often described as the characteristic emotional state at the completion of the third experiment. Several felt that it was their least impressive showing. Although the policy of using athletes and other highly motivated individuals as subjects probably tended to prevent premature termination and half-hearted efforts, some allowance must be made for a variation in such intangibles as motivation and daily attitude. Furthermore, it happened frequently that the subject's sensation of decreased performance or increased tolerance was in direct contrast to the actual change as recorded objectively.

Learning was also important. Some subjects mentioned that consistent contraction and peak muscular work during an entire run increase fatigue and led to loss of vision which could not be regained by additional muscular contraction. Familiarized subjects reported that they could restore PV and CV almost at will by exerting the appropriate degree of muscular effort. With learning, the subjects increased their control over the marking of visual end points. The importance of adequate briefing and of having selected subjects with the same degree of motivation increased as the subjects gained more voluntary control over end points and tolerance indications. Empirical uniformity became more difficult to achieve.

Further variation entered into the experiment on July 22 when the procedure was altered. Since several subjects could sustain an entire run to 6 G without CV loss, it was decided to maintain the 6-G stress until the subject terminated the run. This policy altered the responses of subjects by increasing their fatigue. During the first run the subjects would strain to their limits, becoming exhausted before the final run.

The existence of such sources of variation as differential muscular effort, fatigue, attitude, and motivation brings one to question the reliability of visual end points as a measure of tolerance to $+G_z$ acceleration. Too much voluntary control exists. With many input variables potentially affecting the time of PV and CV loss it would seem impossible to assign a variation in tolerance to any one of them. Hypohydration may have depressed tolerance. The mechanism of its action on tolerance, however, includes many secondary effects. Hypohydration appeared to modify a subject's will to work and to alter his "outlook." It increased irritability and impatience. Yet its effects were mild enough that other events, for example, the absence of helmet trouble, often completely reversed the subjective opinion of the H2 runs - perhaps by acting on the same secondary input as hypohydration, for example, the will to work. (DD's is a good case in point.) Although hypohydration

would generally produce a feeling of listlessness, even a minor change in the comfort of the subject was sometimes more than enough to compensate. The effect of hypohydration on tolerance to acceleration appeared to be a composite of its effects on whatever other psychological and physiological parameters were involved with resistance to that stress. In this experiment these secondary parameters were probably influenced by hypohydration and by other variables. Any decrement in tolerance due to hypohydration was often, in the opinions of the subjects, compensated by increased effort, learning, and a reduction in nervousness.

Considering the importance of learning and attitude, more control would be gained if the information given to each subject before his run were identical. Seasoned subjects, well acquainted with the experimental protocol, should be used. During the postrun interviews a complete and standard debriefing should be devised and adopted, and it should explore impressions on fatigue, leg pain, flicker fusion, and blackout.

Fatigue and susceptibility to cardiovascular embarrassment are of concern to the astronaut as long as excessive acceleration remains during lift off and reentry. If voluntary hypohydration remains a consequence of an extended space mission, the results of this preliminary study indicate a need to explore further the cardiovascular implications such water deficits might have upon reentry into a gravitational field. It is essential to know the degree to which the bodily systems are impaired by quantitative levels of hypohydration. Further, since hypohydrated subjects appeared more susceptible to nervousness and ire due, in part, to the heat and hunger, adequate hydration during extended space flights might help promote compatibility. Longer space voyages are needed to determine if voluntary hypohydration is influenced by extended weightlessness. It is likely, on the basis of the above subjective opinions, that an astronaut would be able to compensate for decrements in function, provided his level of hypohydration did not exceed 5-percent body weight loss.

CONCLUSIONS

The following conclusions appear justified on the basis of the subjects' opinions:

1. Moderate hypohydration, both chronic and acute, is associated with decrements in tolerance to $+G_z$ acceleration. By appropriate physical efforts such decrements can be compensated for with hypohydration levels less than 5-percent body weight loss.

2. The decreased tolerance is traceable, in part, to increased fatigue brought about by the water deficit.

3. Leg pain and cardiovascular embarrassment during acceleration is increased with hypohydration.

4. The progressive lessening of the leg pain with each succeeding run is partially attributable to muscular effort. Further, acute muscular effort can increase visual tolerance to acceleration in experienced subjects.

5. Subjective impressions of changes in tolerance only infrequently correspond to actual performance records.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., Mar. 28, 1966

REFERENCES

1. Berry, Charles A.; Minners, Howard A.; McCutcheon, Ernest P.; and Pollard, Richard A.: Aeromedical Analysis. Ch. 3 of Results of the Third United States Manned Orbital Space Flight, Oct. 3, 1962. NASA SP-12, 1962, pp. 23-36.

2. Catterson, A. D.; McCutcheon, E. P.; Minners, E. P.; and Pollard, R. A.: Aeromedical Observations. Ch. 18 of Mercury Project Summary Including Results of the Fourth Manned Orbital Flight, May 15 and 16, 1963. NASA SP-45, 1963, pp. 299-326.

3. Minners, Howard A.; Douglas, William K.; Knoblock, Edward C.; Graybiel, Ashton; and Hawkins, Willard R.: Aeromedical Preparation and Results of Postflight Medical Examinations. Ch. 8 of Results of the First United States Manned Orbital Space Flight, Feb. 20, 1962, pp. 83-92.

4. Minners, Howard A.; White, Stanley C.; Douglas, William K.; Knoblock, Edward C.; and Graybiel, Ashton: Aeromedical Studies. A. Clinical Aeromedical Observations. Ch. 5 of Results of the Second United States Manned Orbital Space Flight, May 24, 1962. NASA SP-6, 1962, pp. 43-53.

5. Johnson, Robert E.: Human Nutritional Requirements for Water in Long Space Flights. In: Conf. on Nutrition in Space and Related Waste Problems. Univ. of South Florida, Tampa, Fla, Apr. 27-30, 1964. NASA SP-70, 1964, pp. 159-169.

6. Buskirk, E. R.; and Beetham, W. P., Jr.: Dehydration and Body Temperature as a Result of Marathon Running. Medicina Sportiva, vol. 14, no. 9, Sept. 1960, pp. 493-506.

7. Adolph, E. F.; and Associates: Physiology of Man in the Desert. Interscience Publishers, Inc., N. Y., 1947.

8. Greenleaf, J. E.; Matter, M., Jr.; Bosco, J. S.; Douglas, L. G.; and Averkin, E. G.: Effects of Hypohydration on Work Performance and Tolerance to $+G_z$ Acceleration in Man. Aerospace Med., vol. 37, no. 1, Jan. 1966, pp. 34-39.

9. Taliaferro, E. H.; Wempen, R. R.; and White, W. J.: The Effects of Minimal Dehydration Upon Human Tolerance to Positive Acceleration. Douglas Aircraft Co., Inc., Paper 3114, Oct. 1964.

10. Greenleaf, John E.; Matter, M., Jr.; Douglas, L. G.; Raymond, S. A.; Bosco, J. S.; Averkin, E. G.; and St. John, R. H., Jr.: Effects of Acute and Chronic Hypohydration on Tolerance to $+G_z$ Acceleration in Man: I. Physiological Results. NASA TM X-1285, 1966.

11. Leverett, Sidney D.; Bondurant, Stuart; and Riley, Mitchell B.: Venous Constriction in Man During Exposure to Positive G Force. Federation Proc., vol. 16, no. 1, March 1957, p. 80.

12. Beetham, W. P., Jr.; and Buskirk, E. R.: Effects of Dehydration, Physical Conditioning, and Heat Acclimatization on the Response to Passive Tilting. J. Appl. Physiol., vol. 13, no. 3, Nov. 1958, pp. 465-468.

13. DeGiovanni, C., Jr.; and Birkhead, N. C.: Effect of Minimal Dehydration on Orthostatic Tolerance Following Short-Term Bed Rest. Aerospace Med., vol. 35, no. 3, March 1964, pp. 225-228.

14. Gullbring, B.; Holmgren, A.; Sjöstrand, T.; and Standell, T.: The Effect of Blood Volume Variations on the Pulse Rate in Supine and Upright Positions and During Exercise. Acta Physiol. Scand., vol. 50, 1960, pp. 62-71.

15. Smedal, Harald A.; Creer, Brent Y.; and Wingrove, Rodney C.: Physiological Effects of Acceleration Observed During a Centrifuge Study of Pilot Performance. NASA TN D-345, 1960.

16. Greenleaf, John E.; and Sargent, Frederick, II: Voluntary Dehydration in Man. J. Appl. Physiol., vol. 20, no. 4, July 1965, pp. 719-724.

17. Lee, D. H. K.; and Mulder, A. G.: Some Immediate Effects of Reduced Cooling Powers Upon the Water Balance and Related Effects in the Human Subject. J. Physiol., vol. 84, July 1935, pp. 410-432.

18. Keighley, Geoffrey; Clark, William G.; and Drury, D. R.: Flicker Fusion Frequency Measurements on Man Subjected to Positive Acceleration on a Human Centrifuge. J. Appl. Physiol., vol. 4, no. 2, Aug. 1951, pp. 57-62.

19. King, J. H.: Brief Account of the Sufferings of a Detachment of United States Cavalry, From Deprivation of Water, During a Period of Eighty-Six Hours, While Scouting on the "Llano Estacado" or "Staked Plains," Texas. Am. J. Med. Sci., vol. 75, Art. XI, April 1878, pp. 405-408.

NASA-Langley, 1966 A-2207