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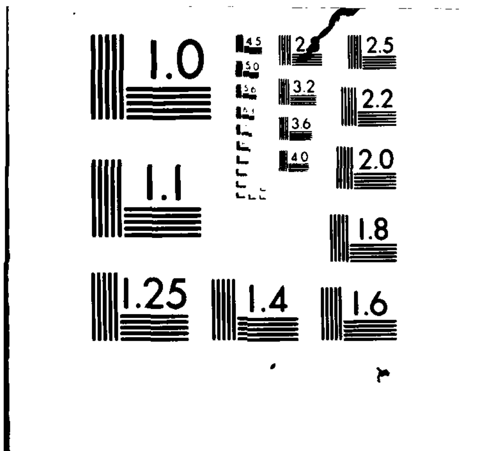

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This report presents a summary of the background, objectives, and methodological approach of an ongoing research project devoted to the analysis of individual and team performance effectiveness under conditions of isolation and confinement during extended residences in a continuously programmed environment. A more detailed description is provided of the results of a recent series of experiments designed and conducted to assess hormonal and behavioral effects of a change in team membership and size.

BEHAVIORAL AND BIOLOGICAL INTERACTIONS WITH CONFINED MICROSOCIETIES IN A PROGRAMMED ENVIRONMENT

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Abstract

This paper presents a summary of the background, objectives, and methodological approach of an ongoing research project devoted to the analysis of individual and small group performance effectiveness under conditions of isolation and confinement during extended residences in a continuously programmed environment. A more detailed description is provided of the results of a recent series of experiments designed and conducted to assess hormonal and behavioral effects of a change in group membership and size.

Introduction

Where sustained and effective human performance is essential to the success of group missions conducted within the unfamiliar and stressful circumstances of sea and/or space habitats, it is obviously necessary to determine the conditions under which (1) productive individual behavior and social interactions can be maintained and (2) performance decrements prevented or corrected. Accordingly, in response to the recognition of the practical importance of developing technological guidelines related to (1) the impact of the type of mission, (2) the characteristics of mission participants, and (3) the skill level of a novitiate participant as they affect the group's ability to accomplish mission objectives, a research project was undertaken to investigate performance effectiveness within the context of a programmed laboratory environment in which both interpersonal and work behaviors can be continuously monitored over extended time periods. A discursive rationale and preliminary model have been presented elsewhere for the application of continuously programmed environments in human research on the basis of extended experimental control, objective recording, and the maintenance of realistic and naturalistic incentive conditions for the assessment of a broad range of _individual_ behavioral processes.[1] A review of the very extensive literature involving the study of small groups[2] suggests that research on _group_ performance effectiveness would be equally advantaged by the development and application of an effective methodology for extended-duration analyses of both the functional and topographic aspects of social living and work situations which provide for operational performance assessment and evaluation. The present report describes the experimental methodology and results derived from studies of such human individual and social behaviors conducted at The Johns Hopkins University School of Medicine under residential laboratory conditions in a programmed environment.

Apparatus

All studies were conducted within a residential programmed laboratory represented in schematic form in _Figure 1_. Briefly, this

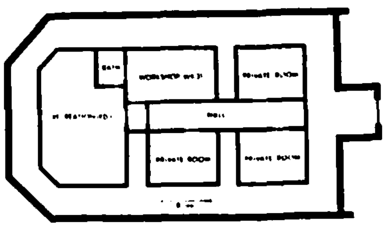

Figure 1

programmed environment, which has been previously described in detail,[3,4] is composed of three 2.6 by 3.4 by 2.4 m private rooms, a 4.3 by 6.7 by 2.7 m recreation room, a 2.6 by 4.1 by 2.7 m work station, and a 2.3 by 7.9 by 2.4 m hall joining the rooms. Remotely controlled solenoid locks on doors and storage compartments located throughout the environment provide for experimental programming of access to laboratory resources according to the rules of a behavioral program to be described below. Electromechanical control devices positioned throughout the environment are interfaced with computer systems located within adjoining laboratory support facilities which provide for monitoring, programming, recording, and data analysis. Audio and video equipment located, with the awareness of participants, within each of the residential chambers permits continuous monitoring during conduct of an experiment.

Subjects

In response to recruitment notices on college bulletin boards and in local newspapers, over 100 male and female subjects have been screened and accepted for participation in the research on the basis of psychological evaluation, educational background, and availability. Subjects are familiarized with the operational features of the laboratory, with the experimental methodology, and with performance tasks during several daily sessions preceding the experiment. Informed consent is obtained.

Behavioral Program

Figure 2 presents a diagrammatic

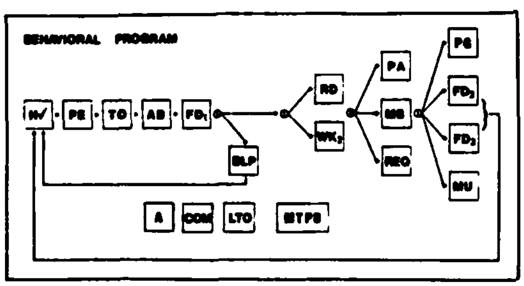

Figure 2

representation of a behavioral program exemplar governing, in general form, the sequential and contingent relationships of activities employed throughout the series of experiments. Each box within the diagram represents a distinct behavioral unit and response requirement. Subjects progress through the program sequentially from left to right. This progression involves program branches composed of a fixed activity sequence and optional activity sequences. Regardless of the sequence selected, the diagram indicates that all behavioral units are scheduled on a contingent basis such that access to a succeeding activity demands satisfaction of the requirements for the preceding unit.

Beginning at the far left, the fixed activity sequence is composed of all activities between and including Health Check (H√) and Food One (FD1). The Health Check activity requires the subject to determine his temperature, pulse, and weight, and to complete several subjective status questionnaires. He then completes the following activities in the order displayed: Physical Exercise (PE), requiring 500 correct responses on an automated exercise task; Toilet Operations (TO), providing access to the private room bathroom and drawers containing towels, toiletries, and a vacuum cleaner; Autogenic Behavior (AB), in which the subject follows taped relaxation instructions; and Food One (FD1), in which the subject is permitted to select two items from a presented list of 10 "light" foods such as coffee, tea, soup, cereal, etc.

When Food One is completed, the subject is eligible to select one of the following three activities: Reading (RD), providing at least 30 minutes' access to books contained within a drawer; Work Two (WK2), in which the subject completes in private various problems, experiments, or assembly projects presented in a drawer; and Sleep (SLP), providing access to the bed for an unlimited time period of at least 30 minutes. If the subject selects Sleep, he is required to return to the Health Check activity and the fixed activity sequence at the completion of Sleep. This minimum recycling sequence is designed to maintain and assess the subject's health if he were otherwise indisposed to engage in the broader selection of opportunities.

The optional activity sequence begins with the choice of one of the following two activities: Reading (RD), providing at least 30 minutes' access to books, or Work Two (WK2), in which the subject completes various word games, experiments, or assembly projects. When the selected activity is completed, the subject is eligible to select one of the following three activities: Puzzle Assembly (PA), requiring the subject to assemble a jigsaw puzzle presented in a drawer; Manual Behavior (MB), providing at least 30 minutes' access to art supplies contained in a drawer; and Requisition (REQ), allowing the subject to press a lever to earn at least one but not more than 20 points exchangeable for treats, such as soft drinks and pastries. On completion of the selected activity, the subject is eligible to select one of the following four activities: Private Games (PG), allowing at least 30 minutes' access to an assortment of solitary games within a drawer; Food Two (FD2), requiring at least 30 minutes and providing the subject with a major meal to eat within his private room; Food Three (FD3), providing at least 30 minutes in the recreation room by one, two, or three subjects to eat a major meal and to play games; and Music (MU), allowing the subject to press a lever to earn a cassette tape that can be played at any time. Once a subject completes his choice among those four activities, he returns to Health Check and resumes the fixed activity sequence, indicated by the dotted line. The optional activity sequence allows the subject flexibility in the selection and arrangement of activities, both individual and social.

At the bottom of the diagram are four activities with more general rules. The Limited Toilet Operations (LTO) activity, which provides access to the bathroom, can be selected at any time. The Audit (A) activity can also be selected at any time, and it provides the subject with all subjects' work productivity during the current day. The Communication (COM) activity allows access to the intercom for intersubject communications. A subject is permitted to use the intercom to initiate or answer a communication only if he is between any two program activities. Although the Communication activity is available between any activities, an actual conversation requires at least two subjects' simultaneous presence within the Communication activity. Conversing subjects, however, whether in pairs or all three at once, can be located at different sequential positions within the behavioral program. For example, a Communication and conversation might occur when one subject is between Autogenic Behavior and Food One, and another subject is between Manual Behavior and the last column of activities, and so on. The Multiple Task Performance Battery (MTPB) activity, to be described below, provides access to the work station, and it can be selected between any two activities in the behavioral program.

A manual of instructions detailing the program and use of environmental resources is contained in each room of the environment. An example of a subject's instructional manual, health assessment questionnaires, and procedural details associated with the various activities has been previously described.[5]

Performance Task

A Multiple Task Performance Battery (MTPB) was used as the major performance assessment procedure throughout the research. Figure 3 presents a photograph of the MTPB

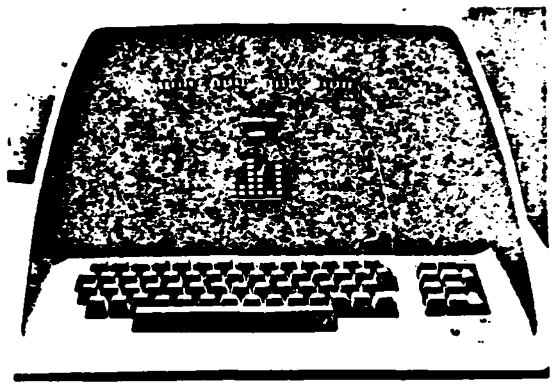

Figure 3

console on which the performance tasks were presented on a cathode ray tube (CRT) display terminal. The battery was composed of the following five task components which were presented concurrently to an operator: (1) blinking lights, providing a measure of watchkeeping, (2) warning lights, providing a measure of vigilance, (3) probability monitoring, providing a measure of attentive functions, (4) target identification, providing a measure of sensory-perceptual functions, and (5) arithmetic operations, providing a measure of computational functions. Accurate responses produced points which were presented on the screen as they were accumulated. The parameters associated with the tasks were chosen so that an operator with 5-10 hours of practice could accumulate 500-600 points per hour. The upper limit of performance was approximately 750 points per hour. A comprehensive description of the performance battery has been published by Emurian,[6] and a rationale for this "synthetic work" methodology has been provided by Morgan and Alluisi.[7]

Background Research Findings

Over the past three years, volunteer subjects have participated in a series of experimental group missions involving continuous residence for varying periods within the programmed laboratory environment. Early studies involved simply confinement and isolation of two-person groups for relatively brief 24-hour periods to demonstrate the adequacy of the hardware and to determine habitability under conditions which required only minimal, and basically biological, activity sequences, e.g., eating, sleeping, group interactions, etc. The major findings and conclusions were that the hardware was operational and the experimental setting capable of sustaining stress-free living conditions for at least these brief 24-hour periods. The second phase of the research involved extending the length of these studies from one to three, and then to ten days of continuous residence in the laboratory and introducing programmatic sequencing of performance activities. The major findings and conclusions were not only that such small groups could be maintained under stress-free living conditions for these more extended periods in the experimental environment, but also that the sequential contingency performance program was supportive of both individual and group behavioral productivity.[8]

Subsequent program parameter studies focused upon the temporal determinants of group productivity and effectiveness under conditions of performance schedule "pacing", i.e., imposed delays between activities, and of mission extensions of up to sixteen days of continuous residence in the laboratory. The major findings and conclusions emphasized the differential importance of selected components of the program, e.g., social activities, in maintaining individual and group performance effectiveness and the sensitivity of the behavioral program to reversible experimental manipulations, i.e., corrective countermeasures, in the course of extended residential missions. More recent studies have focused upon both differential program requirements for social cooperation in groups of three participants and effects on selected performance components of the mission activity schedule. The major findings and conclusions which emerged from a comparison of reversible cooperation and non-cooperation conditions emphasized the potentiating effects of such contingency management procedures upon group cooperative performance, on the one hand, and the group fragmentation which developed, i.e., subject pairing and individual social isolation, on the other. Perhaps most importantly, the results strongly suggested that cooperative programming contingencies can effectively prevent withdrawal or alienation of a potential social isolate from essential and productive group activities.[9]

Group performance cohesiveness studies were then undertaken to investigate variations in the number of group members, i.e., two of three or three of three, permitted to interact socially under different program conditions. Comparisons between these conditions revealed marked differences in the degree to which program synchrony could be maintained, with considerably more drift separating individual subject schedules under dyadic than triadic conditions. In addition, individual social distance measures derived from observations of triadic episodes were predictive of the degree to which a given member would become socially isolated under dyadic programming conditions which limited social interactions to only two members of the group. In general, low group cohesiveness appeared to increase vulnerability to social fragmentation in the absence of specifically programmed triadic cooperation contingencies.[10]

Performance program "chaining" sequence studies were then initiated to vary the degree to which the scheduling of activity components in the performance program was determined by the group participants or by a predetermined chaining sequence. The outcomes of these studies in terms of significant departures from the performance program and differential distributions of selected activities (e.g., social activities) under non-chaining conditions with limited sequential interdependencies among performance requirements emphasized the importance of participant - experimenter interactions. These observations provided the transition to a series of special mission studies undertaken to assess the effects of such interactions on individual and group performance.

The first of these special mission studies focused upon the rule conditions under which MTPB and other work assignments were consequated.[11] Under "positive" incentive rule conditions, completion of work assignments by individual crew participants produced corresponding increments to a group account which determined remuneration for participation. Throughout other successive days of such a mission, completion of identical work assignments no longer produced increments to the group account, but were required to avoid reductions of similar magnitude. Comparable performances of identical value to the group were required, with the difference between the two conditions being the motivational valence (positive or negative) of the performance consequences imposed by the experimental program (i.e., "mission control").

The results showed that a distinguishable and stable pattern of work performances and social interactions emerged during the appetitively-programmed days of such "missions". Typically, the completion of several work periods under the positive condition was followed by a social episode which usually included a common meal. Additional brief work periods then generally occurred interspersed with individual or social recreational interludes before sleep. In contrast, the segments of the "mission" with work performances aversively maintained by avoidance of group monetary reduction were characterized by notable change in the relatively stable work/rest patterns and by progressive deterioration of group cohesiveness. Low-productivity participants were subjected to interpersonal unpleasantries and were sometimes isolated from the group. Concomitantly, crew members reported dysphoric mood, and they became openly hostile and vehemently expressive of their displeasure with the program monitors and the experimenters ("mission control").

An example of one of the more extreme effects of avoidance incentive conditions was reflected in the performance data of the last experiment conducted in that series. After two initial days under appetitive incentive conditions, the three-person group was assigned an MTPB avoidance criterion of 12,000 points to accomplish on each of Days 3-5. Mission members informally agreed to distribute the criterion evenly among themselves. At the conclusion of Day 4, however, Subject 3 fell behind in his share of work, and he caused the criterion to be missed by 56 points. Unlike a high-productivity participant's tolerance of variation in work output during the appetitive condition, one of the other group members (Subject 1) became openly hostile at this relatively trivial shortcoming, and he reprimanded Subject 3 during an intercom conversation at the end of Day 4. Significantly, Subject 1 also refused to perform any further work during the aversive condition, and on Day 5 the group lost heavily in potential earnings as a result, at least in part, of insufficient personnel to operate the performance battery on a sustained basis. Of at least equal importance was the fact that Subject 1's emotional outburst and his refusal to work was, in part, paralleled by Subject 2 who showed a markedly diminished output of work on Day 5. Neither Subject 2 nor Subject 3 showed a compensatory increase in work productivity on Day 5 that may have otherwise satisfied the criterion which was missed on that day by 6495 points. When the appetitive condition was reintroduced on Day 6, however, Subjects 1 and 2 again contributed to work output, and, indeed, all subjects showed the greatest daily point accumulations on that final day of the experiment.

The behavioral effects observed in this last experiment were related to hormonal levels obtained from analyses of total urine volumes collected throughout the course of the experiment. Figure 4, for example, shows a strong overall relationship for these three subjects between individual MTPB productivity and mean daily cortisol levels determined by radioimmunoassay.[12]

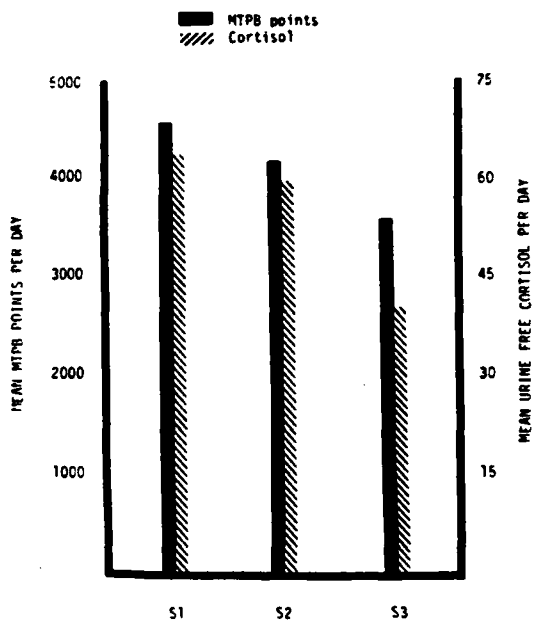

Figure 4

A direct relationship is evident between mean MTPB points per day and mean cortisol per day with the crew member showing the highest average MTPB productivity (Subject 1, omitting Day 5) also showing the highest average cortisol level. Conversely, the crew member showing the lowest average MTPB productivity (Subject 3) also showed the lowest average cortisol level. Significantly, Subject 1 was the high-productivity participant who refused to work on Day 5 of the mission, and Subject 3 was the low-productivity participant who failed to reach the criterion on Day 4 of the mission. These observations together suggest that sustained high productivity along with prolonged performance accuracy on a demanding task may render an individual vulnerable to disruptive emotional reactions such as those provoked by the avoidance phase of the study. Most importantly perhaps, these results emphasize the contributions of a multi-dimensional analysis of individual and group performance effectiveness, and they clearly demonstrate the utility of programmed environment methods and procedures in assessing the broad range of dependent measures which encompass such an analysis.

Current Research Results

These foregoing investigations clearly establish social variables as fundamental contributors to the overall status of a confined microsociety, and they emphasize the sensitivity of such variables to a range of experimental manipulations having operational significance. Throughout such studies, mission participants were observed to seek social interaction under one set of conditions (e.g., cooperation contingencies and appetitive performance outcomes) and to withdraw from such interaction under other conditions (e.g., pairing contingencies and avoidance performance outcomes). Thus, the joining and leaving of a group by mission participants under circumstances encompassing more than a single environmental condition would appear to generate social effects reflecting important dynamic processes requiring systematic experimental analysis.

Accordingly, group performance effectiveness studies were initiated to assess the effects on individual and group behavior of a novitiate participant's introduction into and withdrawal from a previously established and stable two-person social system. The objective of the first two such studies was to focus upon (1) the social mechanisms and temporal properties associated with the integration of such a participant into an established group, and upon (2) sources of group disruption and/or cohesiveness fostered by his presence. In addition, measures of hormonal levels based upon the collection of total urine volumes throughout the course of the studies focused upon changes in the androgen testosterone as an endocrinological index of demonstrated sensitivity to social interaction effects in both animals[13,14] and humans.[15] Such a behavioral biological analysis was implemented to provide a more valid and reliable assessment of the individual and social impact generated by introduction and withdrawal of new members with an established group.[16]

Urinary testosterone levels were determined by radioimmunoassay. Following a 72-hr hydrolysis with beta glucuronidase, the samples were extracted with methylene chloride. The methylene chloride layer was washed with water and dilute sodium chloride and then evaporated. The extracts were purified on LH-20 Sephadex columns. Recoveries through the procedure were monitored by the addition of a small amount of titrated testosterone added to each sample prior to extraction. The Sephadex column eluates were evaporated and taken up in Ria buffer. Aliquots were incubated overnight at $4^{\circ}C$ with a testosterone antibody produced in rabbits. Free and antibody-bound hormones were separated using Somogyi reagents. Radioactivity measurements were made in a Beckman LS-250 counter. Samples were assayed in duplicate and corrected for recovery.

Groups 1 and 2: Introduction and Withdrawal of a Novitiate

In the first two ten-day experiments, an initial baseline was established by having two mission participants follow a behavioral program while residing in the programmed laboratory environment for several successive days. Remuneration was a function of performance productivity on the MTPB. Accurate individual operation of the MTPB produced points which were deposited in a joint account to be divided evenly between the two participants at the conclusion of the experiment. A daily ceiling of ten thousand accuracy points, representing approximately 12-16 hours of total work, was in effect for Group 1, whereas no such ceiling was imposed for Group 2. After three successive days under such dyadic conditions, the third (i.e., novitiate) participant was introduced into the programmed environment. For Group 1, the third participant was permitted to contribute to the other participants' MTPB accumulations, but he was remunerated on a per diem basis without regard to his performance productivity. For Group 2, however, when the third participant was introduced as a group member, the contingency protocol stipulated that only two of the three mission members could work on a given day, and the other (i.e., resting) participant would be remunerated based upon the average MTPB productivity of the two working participants. After four successive days under such triadic conditions in both groups, the novitiate participant was withdrawn from the programmed environment, and the mission continued for three additional days with the original two-person group.

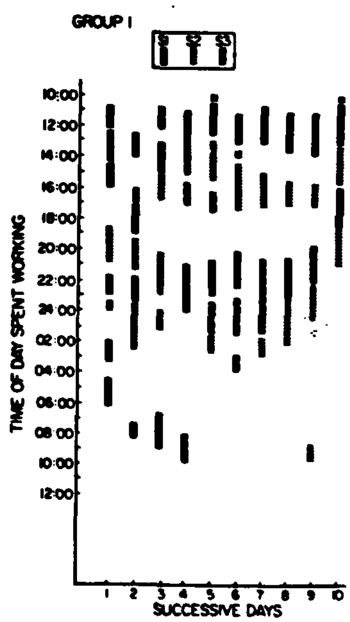

Figure 5

In both groups, the novitiate member showed a gradual, rather than an abrupt, integration into the established work schedule which was left free to vary according to the participants' dispositions. As shown in Figure 5, the novitiate participant (i.e., Subject 3) in Group 1 progressively contributed to the daily performance ceiling until his terminal productivity on Day 7 was equivalent to the other two mission participants. Similarly, as shown in Figure 6, the two ten-day members

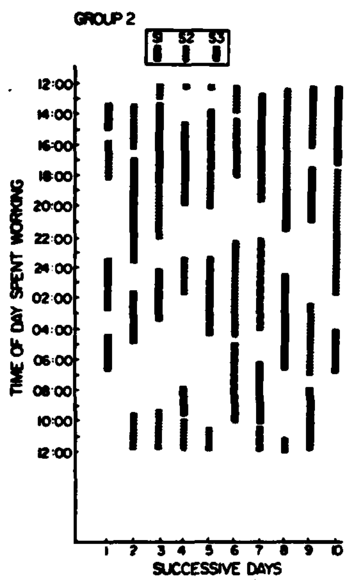

Figure 6

in Group 2 refused to allow the novitiate participant to work on Day 4, the first triadic day of the mission, despite that participant's repeated exhortations to be granted permission to work. When the novitiate participant was allowed to work on Days 5-7, he demonstrated daily work productivity not notably different from the two ten-day participants. Taken together, these observations show a significant resistance by an ongoing group to change an established and proven pattern of work even when such a change would have provided relief from operating a demanding task (i.e., the MTPB).

An analysis of testosterone levels obtained from 24-hour total urine volumes collected during both experiments showed striking, though predictably inverse relationships to the experimental manipulation of changing the size and composition of a group. As shown in Figure 7, in Group 1 the testos-

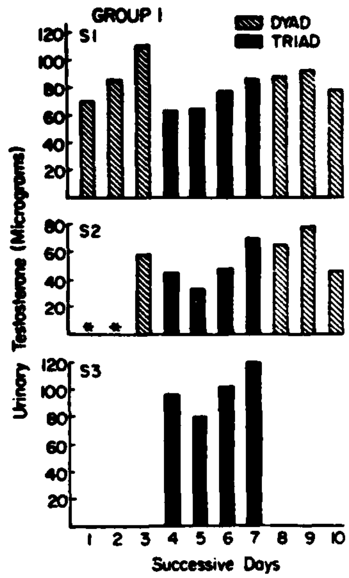

Figure 7

terone levels of the established two-person group members dropped when the novitiate member was introduced, and they recovered to baseline levels when he was withdrawn. Significantly, the novitiate member's testosterone levels were consistently elevated in comparison to his teammates, and he also showed corresponding elevations on "Dominance" factors associated with the pre-mission screening battery. As shown in Figure 8, in Group 2 the novitiate team

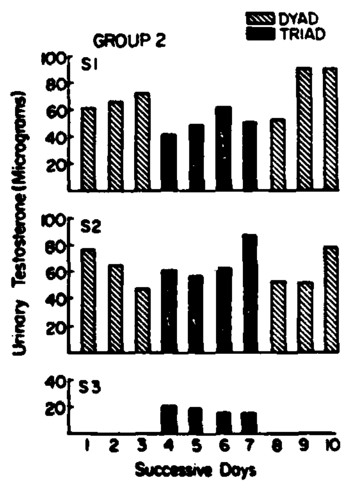

Figure 8

*Samples were missed on Days 1 and 2.

member showed clinically low testosterone levels, and he also showed the lowest value on the pre-mission "Dominance" scores. These observations show the influence of personal history (i.e., individual difference variables) and role differentiation as assessed from behavioral, endocrine, and psychometric perspectives on the potential personal readjustments and interpersonal challenges that a group must manage successfully when a change in membership occurs. Finally, the elevated testosterone observed in the novitiate in Group 1 and the low testosterone observed in the novitiate in Group 2 may reflect active processes associated with joining the respective established groups, but the absence of baseline levels precludes such an interpretation.

Groups 3 and 4: Novitiate Baseline Control Levels

The third ten-day experiment was designed and conducted to assess further the effects on individual and social behavior of a third participant's introduction into and withdrawal from a previously established and relatively stable two-person social system. This systematic replication of the two previous missions focused upon the social and performance effects associated with the integration of such a participant into the established group and upon sources of group disruption and/or cohesiveness fostered by his presence. Particular experimental attention was also directed to participants' hormonal (i.e., testosterone) levels in relationship to the programmed changes in group membership. The replication involved procedural innovations intended (1) to extend the previous analyses to a somewhat different set of experimental conditions with novitiate participants, (2) to potentiate the outgroup status of the third participant who joined the ongoing two-person group, (3) to demonstrate the reliability and generality of previous results, and most importantly, (4) to provide baseline hormonal levels for the novitiate before and after his participation as a group member.

The two-person group resided for ten successive days within the continuously programmed environment. Participants followed a behavioral program of contingently scheduled activities which determined individual and social behaviors, the latter being available on a non-cooperative basis throughout the study. Separate from the behavioral program was access to the work station containing a multiple task performance battery (MTPB) and a serial learning (SL) task. Accurate operation of the MTPB and SL tasks produced "accuracy points" which were deposited in a joint account to be divided evenly between the two ten-day participants at the conclusion of the experiment and which determined remuneration for participation.

After four successive days under such dyadic conditions, the third participant was introduced as a member of the group. For three preceding days, this third participant had resided in a private chamber, but his behavioral program lacked communication, social, and work opportunities. This three-day period provided a hormonal baseline against which to evaluate the effects of joining the group. During the next four three-person group days, the novitiate participant was required to operate the MTPB and SL tasks for his individual remuneration, whereas he was paid a fixed per diem on baseline "alone" days. At the conclusion of this four-day period, the third participant left the group for a final two-day baseline period within his private chamber while the established group returned to its status as a two-person team.

The results showed that the novitiate participant intruded himself into the established work schedule on the first triadic day of the mission (i.e., Day 5). As shown in Figure 9, the novitiate, Subject 3,

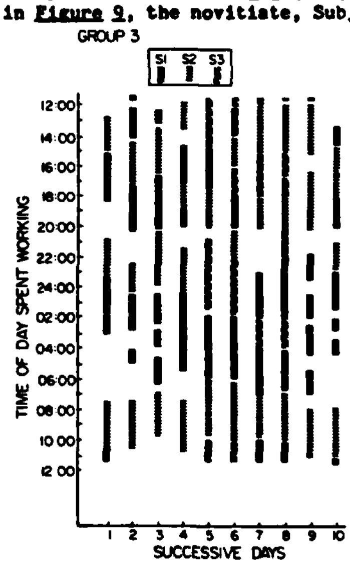

Figure 9

commenced working at 1200 hours on Day 5 which marked the change of day, without communicating his intentions to other mission participants. Subsequently on the same day, he initiated two additional work periods. As a result of reactions of the two ten-day participants to this intrusion, the novitiate participant was required to shift his work episodes to successively later periods of the day across Days 5-8. Finally, the accommodation of the novitiate into the work schedule by the two ten-day participants is suggested by the more frequent sustained work periods exhibited by participants while the novitiate was a member of the group.

A more striking effect of the impact of the novitiate on the status of the social system is revealed by the changes in wake-sleep cycles which occurred when the novitiate joined the group. As shown in Figure 10, time of day spent sleeping during

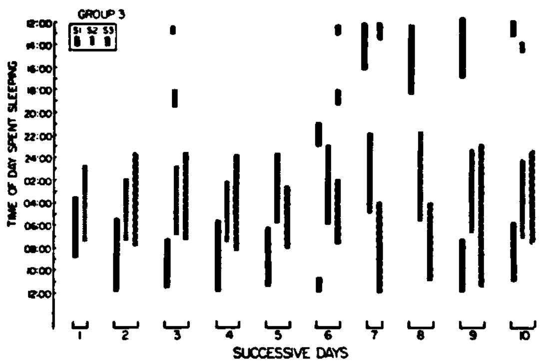

Figure 10

triadic Days 5-8 changed precipitously for Subjects 1 and 3, and remained comparatively undisturbed for Subject 2.

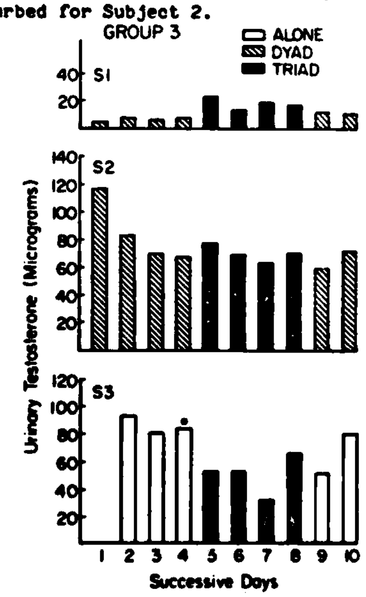

Figure 11

*Because of a missed 8-hr collection on Day 4 for Subject 3, that 8-hr interval was assigned the average value of the preceding eight 8-hr intervals in determining a total value for Day 4.

An analysis of testosterone levels obtained from 24-hour total urine volumes collected during the experiment showed changes by two of the mission participants as a function of the two-person and three-person conditions. As shown in Figure 11, Subject 1, a ten-day group participant whose basal testosterone values were low in comparison to reported normal male levels, showed increases in testosterone when the novitiate was introduced into the group, and his values declined during the final two two-person days of the mission. Significantly, this participant was the only group member expressing irritation with the novitiate member as determined from interpersonal ratings obtained during the Health Assessment activity. The novitiate participant, Subject 3, who was introduced into the group on Day 5, showed a marked suppression of testosterone across the four three-person days, with a recovery to baseline levels during the last two solitary days of the experiment. Testosterone produced by Subject 2 was stable after a decline across the first two days of the mission. Significantly, Subject 2 showed the least change in his established wake-sleep patterns whereas Subjects 1 and 3 showed pronounced changes. These data suggest that the organization of a social system and its subsequent reorganization under the specified rule conditions impacted upon endocrine system activity as revealed by corresponding changes in testosterone output among mission participants.

In Group 3, the magnitude of the drop in testosterone exhibited by the novitiate in comparison to such values observed during baseline days suggested an active process associated with the joining of the group and emphasized the importance of baseline observations on all mission participants. Accordingly, a fourth experiment was designed and conducted to incorporate procedural changes intended to provide basal hormonal levels prior to both dyadic and triadic group formation.

In addition to dyadic and triadic social conditions to be described, the ten-day experiment was composed of baseline and work days. On baseline days, mission participants followed a behavioral program in their individual rooms, but without having access to work, intercom communications, or social activities. During such baseline days, subjects received a per diem allowance. On work days, participants also followed a behavioral program which included social activities and intercom communications, and they were additionally required to operate the MTPB for their earnings.

The two-person group participants resided for ten successive days within the continuously programmed environment. Days

1-3 were solitary baseline days with no work opportunities, and on Day 4, hese participants formed a two-person team with competitive work opportunities. That is, a participant's MTPB accuracy-point earnings were deposited within his individual account which was awarded to him at the conclusion of the experiment. This two-person work condition was in effect from Days 4-6. Also on Day 4, the novitiate participant began his baseline days within his private quarters, remaining under such conditions from Days 4-6. On Day 7, the novitiate participant joined the previously established two-person group. Days 7-10, then, were triadic days with all three participants operating the performance battery on a competitive basis. In summary, the design of this experiment allowed assessment of androgen productivity and behavioral factors under baseline conditions which preceded dyadic team formation and triadic team reorganization.

As shown in Figure 12, the two-person group developed an orderly and alternating sequencing of work intervals throughout dyadic Days 4-6. When the novitiate joined the group on Day 7, this sequencing persisted, but, importantly, the novitiate participant assumed the most preferred work interval (i.e., 1200-2000 hours). In contrast, Subject 1 worked from 2000 to 0400 hours, and Subject 2 worked during the least preferred time of day (i.e., 0400-1200 hours). Finally, when the novitiate was a

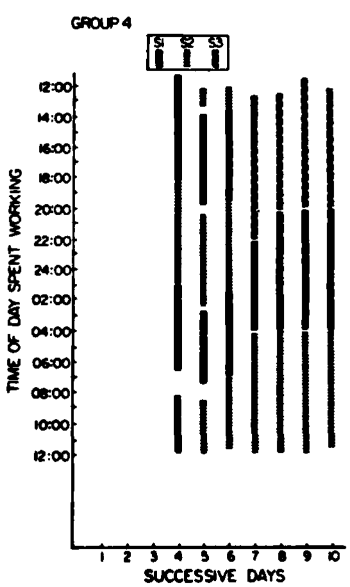

Figure 12

group member during Days 7-10, the work intervals of the two ten-day participants were longer and uninterrupted in contrast to the more frequent and comparatively briefer intervals observed throughout Days 4-6. Thus, the novitiate participant exerted a pronounced effect on the routine previously established by the two-person group.

Wake-sleep cycles were altered among solitary baseline, dyadic, and triadic days. As shown in Figure 13, sleep periods for the

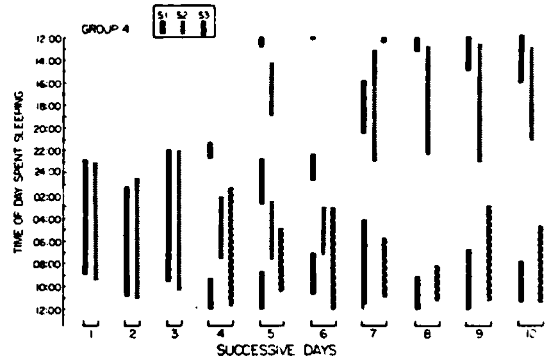

Figure 13

two ten-day participants during Days 1-3 were synchronous with a typical day-night orientation, uninterrupted, and at least 8 hours in duration. During dyadic Days 4-6, however, some disruption in sleep patterns by the dyadic group is evident in response to those members' adaptation to the performance tasks. The most striking change occurred, however, when the novitiate joined the group on Day 7. Throughout Days 7-10, Subject 2 showed a pronounced and consistent shift in his sleep period, Subject 1 showed a moderate adjustment which extended into the early hours of an experimental day (which commenced at 1200 hours), and most importantly, Subject 3 showed no such major alterations in sleep patterns in comparison to his baseline wake-sleep cycles established during Days 4-6.

An analysis of testosterone levels obtained from 24-hour total urine volumes collected during the experiment showed orderly relationships to the observed changes in wake-sleep cycles and work time. As shown in Figure 14, Subjects 1 and 2, the two ten-day participants, showed intermediate testosterone levels across the baseline and dyadic days of the experiment with some indication of a response by Subject 2 to formation of the dyad. These levels are comparable to those exhibited by the novitiate, Subject 3, throughout his baseline Days 4-6. When the novitiate participant joined the group on Day 7, his testosterone

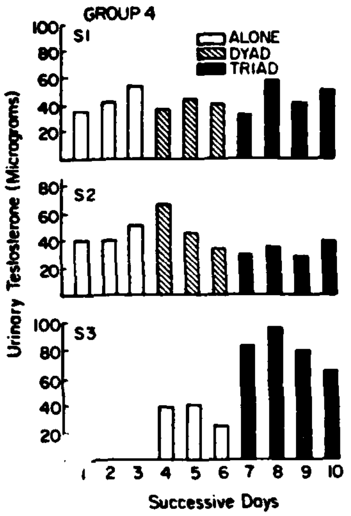

Figure 14

levels at least doubled, and these substantially elevated levels persisted throughout the remaining triadic days of the experiment. In contrast, testosterone levels of the two ten-day participants dropped when the novitiate joined the group, with some recovery to those levels observed throughout the six preceding days toward the end of the experiment.

In summary, then, the participant (Subject 2) who showed the greatest shift in his wake-sleep cycles when the novitiate joined the group also showed a reduction in testosterone throughout the four triadic days of the mission. Conversely, the novitiate participant (Subject 3) who showed the least such shift also showed consistent elevations in testosterone throughout the four triadic mission days.

Group 5: Sleep Period Control

Because of the consistent relationships observed between changes in testosterone and changes in wake-sleep cycles when the novitiate entered the group in Groups 3 and 4, a fifth experiment was designed and conducted to assess the effects of introducing a novitiate participant into an established group when the program schedule held the sleep period constant for all subjects.

The experimental design plan for Group 5 was almost identical to that for Group 4 with no work opportunities on Days 1-3 and with the following constraint in effect throughout dyadic and triadic days. Throughout such work days, access to the work station, intercom, and social room was prohibited between 2400 hours and 0800 hours of each day. This restriction was imposed so that mission participants would likely orient their sleeping to those particular hours, although they always had the opportunity to engage in the many remaining individual activities within the behavioral program. Finally, in contrast to Group 4, the novitiate participant entered the environment on Day 3 for *four* solitary baseline days prior to his entrance into the group on Day 7.

As shown in Figure 15, when the dyad was formed on Day 4 of the experiment, the two participants (*i.e.*, Subjects 1 and 2) developed an orderly sequential pattern of work with each alternating work period lasting approximately 2-4 hours. This pattern persisted throughout dyadic work Days 4-6. When the novitiate entered the group on Day 7, his integration into the group involved his willing adoption of the previously established work pattern. Throughout Days 7-10, the three participants alternated access to the work station with each work period lasting approximately 2 hours and changing at about the same time of day throughout triadic work Days 7-10. Thus, this particular novitiate participant was not observed to cause a major disruption in the style of working which developed preceding his entrance into the group, nor did Subject 1 or 2 try to prevent his recurrent access to the work station.

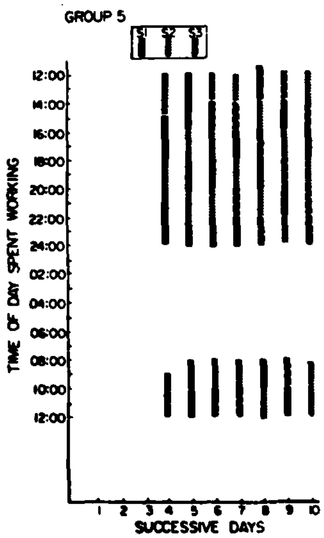

Figure 15

As shown in Figure 16, wake-sleep cycles were stable for all subjects across successive experimental days. The time of day spent sleeping roughly corresponded to the interval when the activity restrictions were in effect. The only exceptions were observed on Days 5 and 6 when Subject 3 was removed from the behavioral program because of a minor stomach upset, but he remained in the programmed environment and napped during the day hours. These data, then, are in striking contrast to the shifts in wake-sleep cycles produced in the previous experiments when the novitiate became a group member.

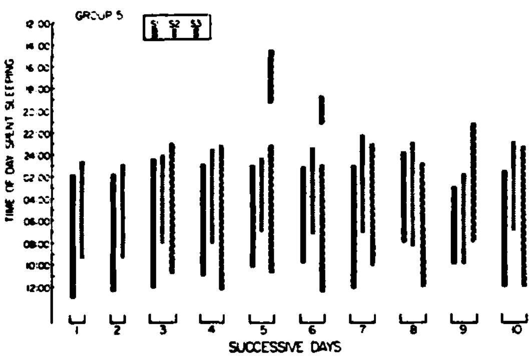

Figure 16

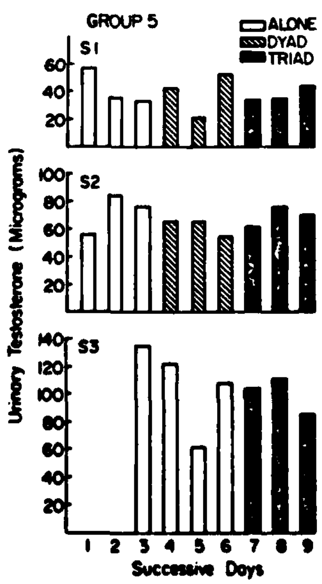

Figure 17

The uneventful entrance of the novitiate participant and the absence of resistance by the established dyad were paralleled by the lack of notable changes in urinary testosterone across successive experimental days. As shown in Figure 17, no subject showed a consistent and large-magnitude change in testosterone as a function of the dyadic and triadic conditions. (Sampling error prevented Day 10 determinations.) Subject 1's values were low to intermediate, Subject 2's values were intermediate, and Subject 3's values were high. These data then, suggest that irrespective of the variance among participants' baseline testosterone levels, the accommodating and cooperative character exhibited by members of this particular group was sufficient to inhibit confrontations which in previous groups were related to behavioral and hormonal readjustments.

Group 6: Mixed Gender Effects

The five previous experiments were undertaken with all-male groups because of the importance of eliminating major sources of intersubject variability during the early phase of a research program. With the completion of Group 5, however, the data base appeared sufficiently robust to warrant an extension of the observed behavioral-biological interactions to a situation involving a mixed-sex group. Accordingly, the sixth experiment within this series, and the last study to be reported in this paper, involved the introduction of a female novitiate participant into an established two-person male group.

The design plan of this sixth experiment was similar to the one used for Group 3. The two-person male group operated the MTPB for ten successive days, and each participant's accuracy points were deposited within a joint account evenly divided at the conclusion of the experiment. After four successive days under dyadic conditions, the novitiate female participant was introduced as a member of the group. For the four preceding days, this participant had resided in her private room under solitary baseline conditions. After four successive days under triadic work conditions, the novitiate was removed from the group for two final baseline days while the remaining participants again worked as a two-person team. Finally, unlike all previous experiments, the two male participants had previously participated in an earlier study: Subject 1 was a dyadic group member and Subject 2 was the novitiate in Group 4.

As shown in Figure 18, during Days 1-4, Subject 1 worked during the early hours of an experimental day which began at 1200 hours. This is similar to the hours during which he worked in Group 4 on Days 4-6. Importantly, Subject 2 in the present experiment, who was the novitiate in Group 4, was not observed to

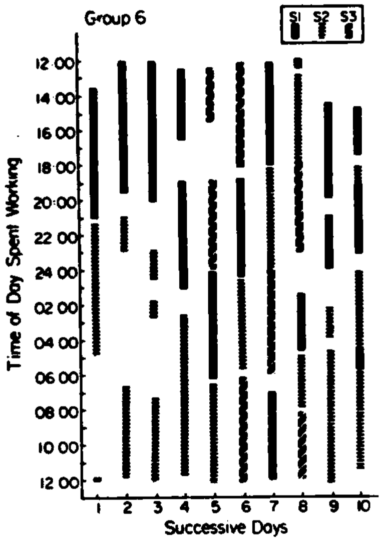

Figure 18

work during the preferred hours as he had in Group 4 on triadic Days 7-10. On Days 1-4 in Group 6, the work period alternations were perhaps not so regular as they were on Days 4-6 in Group 4. When the novitiate participant entered the group on Day 5, she alone worked during the first 12 hours of that day, with Subjects 1 and 2 working during subsequent 6-hour intervals, respectively. Thereafter on triadic Days 6-8, subjects alternated access to the work station, but no stable patterns of such alternation developed, and for all subjects, work periods occurred sporadically throughout the day, rather than being oriented to a specific time of day across successive days of the triadic condition. Finally, when the novitiate left the group at the end of Day 8, the work sequences for Subjects 1 and 2 roughly corresponded to those observed during dyadic Days 1-4.

As shown in Figure 19, no subject maintained consistent wake-sleep cycles across successive days of the experiment. Although such cycles were comparatively regular during Days 1-4 when Subjects 1 and 2 worked as a dyad and Subject 3 lived alone under baseline, when the novitiate entered the group on Day 5, wake-sleep cycles were thereafter erratic on triadic Days 5-8. When the novitiate left the group at the end of Day 8, wake-sleep cycles did not show an abrupt return to a typical day-night orientation. Importantly, Subject 2, the novitiate in Group 4, did not successfully maintain his wake-sleep cycles over successive experimental conditions as he was observed to do when he was a member of Group 4.

An analysis of testosterone obtained from total urine volumes collected throughout the experiment was notable for the absence of large-magnitude changes across successive experimental conditions. As shown in Figure 20, Subject 1 shows values consistently intermediate across successive experimental days. Importantly, these values are similar to those observed when he was a participant in Group 4 (see Figure 14). Subject 2, the novitiate in Group 4 who showed marked elevations in testosterone when he joined the group, failed to show comparable elevations when the female novitiate joined the group on Day 5. Significantly, in the present experiment, Subject 2 did not maintain his established wake-sleep cycles as he was observed to do when he was a member of Group 4. Subject 3, the female novitiate, showed a slight drop in testosterone across Days 5-8 in comparison to values observed during baseline Days 3-4. Finally, given the turbulent character of subjects' work intervals and wake-sleep cycles which contrast with the relative constancy of the *hormonal measures*, these data suggest that this particular group failed to resolve issues of leader-follower relationships which might have otherwise been reflected in the endocrine domain.

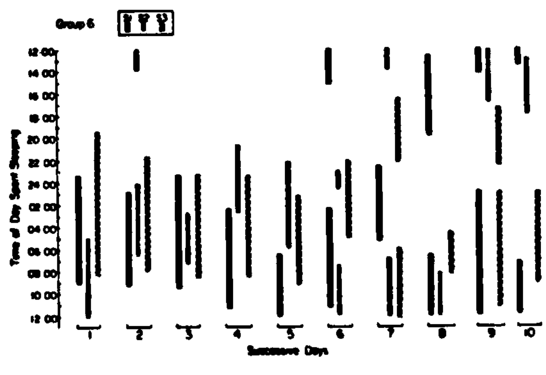

Figure 19

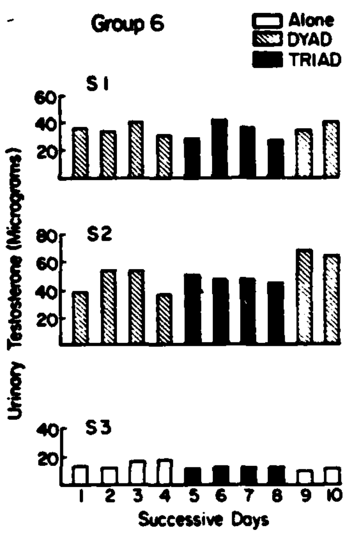

Figure 20

Discussion

The results of these experiments show clearly that interactive behavioral and biological processes are prominently involved in the individual performance adjustments and social adaptations of small groups in a confined microsociety. Of particular interest in this regard are the findings which implicate the programmed environmental and behavioral interactions in at least those aspects of endocrine regulation reflected in the cortisol and testosterone measurements. While the positive relationship between corticosteroid levels and individual work productivity is generally consistent with the "catabolic" influence presumed to be exerted by these hormones on energy metabolism,[17] the interactions between androgen levels and both individual and group performance dynamics present a more complex interpretive problem.

In this latter regard, for example, the sensitivity of testosterone levels to changes in group composition was most evident in those groups in which work routines and/or wake-sleep schedules were disrupted for some members but remained stable for others. More specifically, success in gaining or maintaining access to a work schedule least disruptive of established wake-sleep routines was generally accompanied by elevations in testosterone levels occasioned by changes in the group composition (e.g., S2, Group 3; S3, Group 4). Conversely, decreases in testosterone levels were associated with changes in group composition that occasioned shifts to less than optimal work and/or sleep schedules (e.g., S3, Group 3; S2, Group 4). Significantly, the participants in Groups 5 and 6 showed little or no androgen response to the programmed changes in group composition. For Group 5, this outcome was consistent with the orderly transition in work routines and the absence of changes in wake-sleep cycles which accompanied the introduction of a new member into this group. In Group 6, however, no member emerged who clearly and persistently provided direction in structuring the transition between a two-person and three-person group, and the members' wake-sleep cycles were erratic.

The suggested interaction between broadly defined "dominance-submission" relationships and testosterone levels in the present series of studies conforms well with the observations reported on changes in group composition and organization in lower primates. Under conditions which involved the introduction of a new rhesus monkey into an existing group, changes in testosterone levels among high-ranking males were observed to be functionally related to an animal's success (or failure) in defending his status in the primate social order. Victorious animals showed significant increases in testosterone levels[18] while monkeys defeated by the group were reported to show marked androgen level decreases.[19] These general relationships between the "dominance-submission" hierarchy and testosterone levels in subhuman primates were further confirmed in experiments which involved the merging of two established groups, with defeated alpha males showing a decrease and victorious alpha males an increase in androgen levels.[14] It must be emphasized, of course, that these studies with laboratory monkeys occurred under conditions which involved intense and enduring aggressive confrontations unlike anything observed in the much more benign exchanges among the humans participating in the present group interaction experiments. The general conformity in environmental-endocrinological relationships described under these two somewhat disparate investigative circumstances, however, suggests a continuity across species of these fundamental behavioral biological interaction processes.

It is, of course, both premature and hazardous to speculate on the implications of the present findings for the analysis of group performance effectiveness under confined microsociety conditions. With regard to the relevance of the interactive endocrinological relationships observed under such conditions, however, it seems reasonable to suggest that the adaptive significance of any hormonal response can best be understood in terms of the consequences of that response at the metabolic level. Although metabolic research on the androgens has been largely confined to reproductive functions, it is well established that testosterone has potent "anabolic" properties, promoting protein synthesis in muscle and many other tissues[20,21] and potentiating some effects of insulin on carbohydrate metabolism.[22] Whether these "anabolic" effects of testosterone and the androgenic metabolites play any appreciable part in general organic or energy metabolism must, of course, await clarification by further investigative analysis. But at the very least, the present series of experiments emphasize the importance of a multidimensional analysis of the behavioral and biological interactions which determine the adaptations and adjustments of small groups in confined microsocieties.

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