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BEHAVIORAL AND BIOLOGICAL

INTERACTIONS WITH SMALL GROUPS

IN CONFINED MICROSOCIETIES

FINAL REPORT

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Program Overview and Research-Based Recommendations

The objectives of this research on small group performance in confined microsocieties have focused upon the development of principles and procedures relevant to the selection and training of space mission personnel, upon the investigation of behavioral programming, preventive monitoring and corrective procedures to enhance space mission performance effectiveness, and upon the evaluation of behavioral and physiological countermeasures to the potentially disruptive effects of unfamiliar and stressful environments. Initial research activities were directed toward the design and development of an experimental microsociety environment for continuous residence by small groups of human volunteers over extended time periods under conditions which provided for programmable performance and recreational opportunities within the context of a biologically and behaviorally supportive setting. Studies were then undertaken to analyze experimentally (1) conditions that sustain group cohesion and productivity and that prevent social fragmentation and individual performance deterioration, (2) motivational effects performance requirements, and (3) behavioral and physiological effects resulting from changes in group size and composition. The significance of these investigative endeavors is to be understood in terms of emergent motivational and social-interaction principles of practical relevance for the establishment and maintenance of operational mission performance effectiveness.

The results obtained from these small group studies clearly established the applicability and generality of behavioral technologies and methodologies to the experimental analysis of individual and group performance within the context of a human microsociety. The development of behavioral programming techniques was demonstrably effective in generating and maintaining such individual and group performance for monitoring and measurement with precision and regularity over extended time periods. Importantly, the application of fundamental contingency management principles and the technological guidelines that provided the basis for design and development of the programmed microsociety environment have been shown to sustain individual performance effectiveness and group cohesiveness without notable biological or behavioral disruption under conditions of spatial restriction, social separation, and enforced intimacy.

More specifically, the results of these studies have shown that both individual and group productivity can be enhanced under such confined microsociety conditions by the direct application of contingency management principles to designated high-value component tasks within the overall performance program. Similarly, group cohesiveness can be promoted and individual social isolation and/or alienation (i.e., group fragmentation) prevented by the application of contingency management principles to social interaction segments of the performance program. Measures of participation in group activities under confined microsociety conditions were shown to be related to the degree to which individual alienation or withdrawal occurs when circumstances require group "pairing" performances.

Conditions which have been found to result in the progressive deterioration of individual and group performance effectiveness include aversive programming contingencies, such as avoidance of criticism or punishing events. The by-products of aversive schedules that emerge under such circumstances were found to be detectable and quantifiable in measures of verbal performance (e.g., confrontation and intersubject ratings), work performance (e.g., diminished productivity), and group morale (e.g., irritability and dysphoric mood). Moreover, positive incentive contingency management was demonstrated to counteract effectively the disruptive consequence of such aversive programming contingencies while at the same time supporting high work productivity free from negative side-effects.

Related research results emphasized the prominent involvement of behavioral and biological processes that are functionally related to group adjustments when changes occurred in group membership composition and size. The experimental analysis of such "introduction" effects emphasized the critical importance of providing a structured transition in the form of orientation and training regimens for both novitiate and established group participants to minimize potentially disruptive performance effects of altering the interpersonal and social dynamics of a confined microsociety.

More recently, research on this project focused upon the problem of work productivity enhancement in a semi-autonomous confined microsociety. An operational setting was simulated in the specially designed live-in laboratory consisting of three individual rooms connected by a hallway to a large social area and a smaller work room or "duty station". The experimental environment was interfaced with a computer system which provided for continuous programming of access to laboratory facilities and resources as well as monitoring and recording of performance functions and behavioral interactions.

A workplace environment was simulated in this programmed human laboratory by following two strategies. First, a set of repetitive activities was arbitrarily established as the subjects' response repertoire. These activities resembled the kinds of things people do in a structured work environment (e.g., word-sorting, rug-hooking, digit symbol transposing, etc.). Second, the subjects were constrained to engage in this set of activities for an extended work period. Subjects spent part of each day working alone and another part interacting with two other people living under the same conditions. Volunteer participants lived continuously in this programmed residential environment for periods up to a month. All behavior was monitored through high-resolution color video cameras and recorded categorically by trained observers using a microcomputer program developed for observation of ordinary human behavior. In addition to the standard set of work-like activities available in the individual room, each subject also brought a set of individual hobby activities which were available only during the period when subjects could interact socially.

Experiments began with a baseline period (up to 7 days) during which the subjects were free to engage in any of the work-like activities provided but they had to engage in one them. The percentage of time devoted to the various activities during this period provided the basis for selecting one activity which occurred with high frequency (i.e., the "rewarding" activity) and one activity with a low frequency of occurrence (i.e., the "instrumental" activity). Performance of the low frequency instrumental activity was then required to gain access to the high frequency rewarding activity. To earn the amount of time devoted to the high frequency activity during baseline for example, the subject was required to double the amount of time devoted to the low frequency activity during baseline. The research then, was directed toward elucidating the conditions under which work performances can be enhanced in such a confined microsociety setting.

The results showed that required work activities are affected in the same way by the indicated contingency procedures as highly valued self-selected activities used in previous research. The amount of time devoted to the designated instrumental activities was greatly increased during the contingency periods. When such contingencies were placed on high-probability activities, there were consistent reductions in the time devoted to these performances and subjects rarely restored the restricted activity to baseline levels while the contingency remained in effect. Interestingly however, the subjects in these experiments consistently did more than the amount of instrumental activity required to restore access to the restricted activity in order to maintain a condition in which their "bank accounts", as it were, never went to zero.

Motivational and social-interaction principles derived from this research would appear to be relevant to the initial establishment and long-term maintenance of operational mission performance effectiveness. In particular, selection procedures for space mission participants should capitalize upon the benefits derived from pre-flight evaluations of individual performance effectiveness under continuously programmed environmental conditions. Group interaction assessments should also form an integral part of selection criteria under environmental programming conditions emphasizing social interaction contingencies. Moreover, training procedures for both individual and group performances should be undertaken within the context of the powerful "learning-performance" applications of contingency management principles in highly programmed environmental settings.

In-flight programming schedules should also be based upon detailed behavior analyses of performance-chaining sequences to insure that the opportunity to engage in "high strength" activities is contingently related to the prior occurrence of essential work tasks and that the performance of such work tasks occurs under positive incentive conditions. Finally, both pre-flight training and in-flight performance productivity can be enhanced by the application of appropriately programmed contingency management principles which minimize aversive control procedures and provide flexible work-rest cycles determined on the basis of performance effectiveness and individual and group program preferences.

Background of Research

Two basic approaches are generally used for studying behavior with observations being made under conditions of either (1) the natural habitat, or (2) in artificial, closely controlled environments. The benefits and disadvantages of each approach have been well-documented, with the naturalistic ethological monitoring of both current and long-term events lacking experimental rigor, and the controlled experimental environment setting demonstrating functional relations but often neglecting the analysis of progressive change in the degree of external control and the development of internal equilibrium. A promising recent development within the context of ecological methods and procedures attends to miniature social systems referred to as "behavior settings". The behavior setting is comprised of the physical aspects of a specific social situation and the people involved therein. Initial research in this field has focused upon the study of entire communities which include hundreds of behavior settings. The approach would certainly seem applicable to smaller social units as well, however, such as work groups and colonies in space.

One relevant issue receiving investigative attention within the context of "manning theory" is the extent to which the number of individuals in a behavior setting is sufficient to carry out necessary tasks. Considerations regarding performance and job satisfaction for example, have been found to be a function of whether tasks are under-, over-, or optimally manned, and deliberate interventions in behavior settings in order to improve their functioning and increase the satisfaction of the participants, have been proposed. The obvious need for an experimental method to concurrently manipulate independent variables and assess the effects of such manipulations over extended durations and on a multiplicity of behavioral interactions has of course, been broadly acknowledged. In the absence of such an effective methodology, serious proposals and recommendations for space occupancy designs have been limited to an "ecological systems" approach. <u>Without an experimentally derived data base from a functional analysis of human behavior, however, the overgenerality of these projections render them incapable of insuring the successful establishment of enduring space habitats.</u>

Developments over the past several decades in the joint disciplines of experimental and applied behavior analysis, that together have given detailed attention to the controlling relations between environment and behavioral interactions, provide an operational approach to solving many, if not all, of the methodological problems that have constrained previous studies in this critical domain. The inductively derived principles which have resulted provide a generalized operational account of the observable, manipulable, and measurable antecedent and consequent environmental events that bear functional relations to the behavior of both individuals and groups. Such controlling antecedent and consequent environmental relations are termed contingencies of reinforcement, and by their systematic manipulation, behavior can be demonstrated to change in orderly ways. Experimental analysis based upon these contingency management procedures has been shown to have widespread success in and reliability for, the control of behavior both across phyletic lines and within behavioral repertoires from the simple to the complex. While attempts are frequently made to distinguish between applied and basic research, such a differentiation is largely unwarranted in the present case since the methodology would involve highly controlled experimental procedures but the results of such analysis could well have immediate utility in the management of operational missions. Thus, the approach would be neither purely basic nor purely applied research, but partly both. Optimal control over important variables should be complemented with high accuracy of measurement under <u>human laboratory conditions</u> to pursue major research questions with widely varying goals using the species of primary interest <u>without sacrifice of methodological rigor</u>.

An extensive research literature developed in several interrelated areas of behavior analysis over the past two or three decades can be seen to have direct relevance to the conceptual and methodological requirements for investigations pertinent to extended space occupancy. This expanding data base makes contact with critical relations between the behavior of individuals and groups, with the analysis of contingencies of reinforcement, with behavioral economies, response distribution, and with the effects of behavioral programs and their relations to economic systems. Initial success in space ventures will depend largely on a precise knowledge of what behaviors are required and how to occasion and maintain them within individuals. A complete analysis of what produces and maintains the behavior of individuals could potentially be useful in generating accounts of social behavior, while the reverse is less likely to be true, at least for any group studies that do not account for variability in behavior within and between individuals. It is equally true of course, that a complete understanding of group contingencies may not be derivable from an analysis of those same contingencies applied to individuals. <u>But without an experimentally derived functional account of individual behavioral variability, a natural science of behavior cannot exist and without a natural</u>

science of behavior, the social sciences will necessarily remain in their current status as disciplines of less than optimal precision or utility.

The initial success enjoyed by behavior analysis research in providing functional accounts of the sources of individual variability has inevitably produced attempts to generalize the procedures to the research analysis of groups. There are a number of investigative approaches possible, but all fall into either a class of procedures that analyzes the effects of contingencies on a group's "behavior" (or a product of such collective behavior), or a class that analyzes the effects of contingencies on behavioral interactions within the group. Of the former, there are different ways to observe the behavior of a group. One approach is to measure a set of responses of some unspecified fraction of the members of an open, continuously changing population. And indeed, pilot studies have been conducted on human cumulative production rates between groups with changing populations in a laboratory environment.

An alternative group procedure is to hold membership constant and expose all members to the independent variables of interest, using within-subject repeated measures experimental designs, and assessing any behavior change on the basis of cumulative response measures taken from all members. This procedure has been used to determine the effects of reinforcement, and the same approach was employed in the analysis of a group living and worksharing system. Of considerable practical importance is the experimental literature on the application of group contingencies in business and industry. Experiments with group contingencies have been conducted with respect to increasing worker attendance, improving worker efficiency and performance, and increasing worker safety. Due to the operational nature of such procedures and their overall effectiveness, a behavior analytic approach to organizational behavior management is gaining widespread acceptance, and an economics proposal has suggested that a group of space colony workers eventually be rewarded with self-government dependent upon their prior fulfillment of prespecified production quotas. This is seen primarily as a way to avoid costly strikes and rebellions by spaceworkers.

Aside from analyzing the ways in which a group may collectively change the behavior of its members as a function of externally imposed contingencies of reinforcement, there is also available an experimental literature dealing with the acquisition of social and verbal interactions between members of a species at a variety of phylogenic levels. The conclusion suggested by this expanding data base is that the behavior of an individual organism in relation to that of another of the same species may be accounted for by appealing to the same fundamental learning principles which govern non-social behavior/environment interactions. The increased complexity in the analysis of such social situations arises from the changes which occur in individuals as a result of their interactions with one another, thus changing, in turn, the nature of the "environment" independently of explicitly programmed experimental conditions. Under such circumstances, a research analysis of controlling relations involving social interaction differs from single-subject study in a manner analogous to the difference between simple and compound interest where account must be taken continuously of ongoing changes. This is however, a problem attributable more to technical limitations imposed by the observation and measurement systems being used than by any inherent or fundamental difference in the behavior of organisms in social settings.

The experimental analysis of complex behavioral interactions received its first systematic laboratory treatment in the comprehensive review of reinforcement schedule effects published some three decades ago. This led to the elaboration of experimental procedures for producing and analyzing complex multi-response repertoires and resulted in the experimental analysis of "choice" behaviors. Closely related to these developments was the work that first demonstrated some of the relational aspects of a principle of reinforcement. Complex multi-response repertoires, matching and instrumental/contingent response interactions have been considered and integrated most recently within the context of a unified relational principle of reinforcement. Each of these developments has important implications for both the understanding of complex behavior and its management under conditions related to the occupancy of space environments.

The behavior of an organism may be defined as some portion of an organism's interaction with the environment that may result in both its detectable displacement in space over time and a measurable change in at least one aspect of the environment. Behavior is not specifiable in the absence of a relationship between a living organism and an environment, although in some cases the environment may be the organism itself, e.g., the behavior of interest may occur inside the skin. Behavior is considered detectable as a physical event in space and time, with both private observation and observation of private events treated as potentially legitimate scientific activities. Closely related and of equal importance, is the inclusion of verbal behavior within the definition of behavior, and evidence adduced to date demonstrates the utility of a behavioral account of both private events and verbal behavior.

The data base which provides the foundation for this extended analysis of complex behavioral repertoires derives its fundamental roots from a systematic laboratory study of the effects of various combinations of response requirements including the making of a reinforcing environmental event contingent upon a series of responses in a given sequence. This analysis has also been extended to the investigation of concurrent schedules of reinforcement, in which different behavioral responses may be emitted independently while each is provided with reinforcement on separate schedules. An analysis of the preference of organisms to engage in more or less responding of one such behavior than another led to a matching principle which holds that the relative strengths of responding should be proportionally matched to the density of reinforcement for each response. The matching law is closely related to the principle predicting that after producing a shift in relative response strengths, one could strengthen the lower probability response by making access to the higher probability response contingent upon it.

This general "Premack principle" stemming from the basic work of multi-response repertoires has had a profound influence upon virtually all aspects of behavior analysis in terms of experimentation, application, and theory since it simultaneously obviated several problems which had previously weakened behavioral accounts of reinforcement. An experimental procedure was provided which predicted changes in response probability while providing a non-circular definition of reinforcement. But perhaps most importantly, such a relational account showed that the reinforcing properties of a given environmental event were neither absolute nor intrinsic to that event, but that response strength is largely a function of given environmental conditions in relationship to the individual's recent past history of deprivation or satiation with respect to those environmental stimulus conditions.

Refinements in the predictive accuracy of the relational principles involved appear to be enhanced by an equilibrium approach which combines the assumptions of homeostasis from cybernetics with empirical analysis to account for reinforcement. The assumption, for example, that there exists a stable set of conditions that an individual will approach or maintain under circumstances that perturb or challenge these conditions provides the equilibrium approach to the relational principle of reinforcement with the significant advantage of making both predictions more precise and their assessment more accurate and valid. Indeed, the weight of available evidence would seem to favor this equilibrium refinement of the relational account of reinforcement with the further practical implication that under conditions of deprivation, lower-rate contingent behaviors may be used to reinforce higher rate instrumental behaviors, while under conditions of satiation, access to higher probability contingent responses may actually punish a low probability instrumental response.

There are, of course, a number of interrelated factors that need to be considered in qualifying the conditions under which matching and instrumental/contingent response predictions can be expected to obtain. At the molar level, for example, integration of the heuristic concepts supplied by basic economics theory may well serve to enhance the predictive power of a behavior analysis. One such ecological economics concept, that of closed versus open systems, would seem to be of direct relevance to the space-related applications of behavior analysis. In the typical laboratory study, the subject(s) occupies an experimental space for a limited period of time during which contingencies may be manipulated and changes in one or more instrumental responses observed. If the subject then leaves the experimental space (e.g., after a few hours) and returns to an environment where the contingency relationships under study do not obtain, the experiment may be seen to be "open" in the sense that the subject's demand for the relevant reinforcers is not in equilibrium with the reinforcement supply provided by the experimental situation. In a "closed" system, the amount of consumption of reinforcement by the subject is a direct function of an equilibrium between its demand on the environment and the environment's supply. Marked differences in behavior are observed depending on whether performances are occurring in closed or open systems.

The two pairs of interrelated polar concepts of demand elasticity and inelasticity, and substitutability and complementarity may help to clarify the behavioral differences between closed and open systems. It has been convincingly demonstrated for example, that demand is not equivalent to response rate. Response rate is seen as being a function of demand where demand is equivalent to the product of the quantity of reinforcement obtained and the unit price. If demand for a given type of reinforcer is inelastic, then an increase in price (response requirement increment) will result in a commensurate or nearly commensurate increase in response rate in order to maintain prior levels of consumption. If consumption of a reinforcer decays rapidly as a function of price increases, then amount of responding levels off and/or decreases, and demand for the reinforcer in question is said to be elastic. In closed economies, demand for some reinforcers will be elastic, while other reinforcer demands will be inelastic. Whether they are one or the other type will probably depend largely on biological constraints. The availability of a substitute will increase elasticity; the inelastic nature of "survival reinforcers" results from the fact that other available reinforcers will not serve as substitutes, hence the reference to "essential", "required", or "primary" resources. In open economies any reinforcer may often be substituted elsewhere and, as a result, demand for most of the resources may be highly elastic.

Reinforcers may serve as substitutes and/or complements. By substitutability is meant the increase in responding for consumption of one reinforcer as the supply of another is reduced or becomes more expensive. For example, as requirements increase for a given instrumental response class, one sort of reinforcer availability is diminished. Consumption of that reinforcer may decrease while demand for another, more readily available, reinforcer may increase (we buy more chicken when beef is expensive or scarce). When different contingent responses may be substituted for another, this is presumably a reflection of the fact that the responses each produce reinforcers that may exert control over identical elicited responses. Reinforcers may also be complementary. Post-prandial drinking is a common behavioral phenomenon which illustrates complementarity. The contingent response of drinking water may complement the instrumental response of eating in the sense that it facilitates the consumption of dry food.

That a given reinforcer may serve as both a complement and substitute is readily illustrated by extending the example of drinking water to the consumption of various substances containing water. If the response requirements for access to water are raised sufficiently, behavior resulting in access to food substances containing water such as citrus fruits and so on, might be readily substituted. Conversely, increased supply or decreased price will decrease the demand for one reinforcer, and increase the demand for complements of that reinforcer. In the absence of access to substitutable substances however, the demand for water would be predictably inelastic (certainly at least, in closed economies) even though under baseline conditions it may not be preferred in choice tests over other reinforcers.

In the situation of restricted access to given responses, the resulting substitution might be predicted to produce a change in an organism's internal physiological and behavioral ecology along all remaining response dimensions to varying degrees. Purely rational, logical, or non-empirical attempts to predict multiple response distribution as a function of restrictions on access to given responses, however, will generally be unsuccessful. Without a functional, and preferably, empirical analysis, redistribution may not be accurately accounted for since not all behavioral repertoires are equally substitutable. Rather, behaviors will redistribute themselves selectively. Selective redistribution is the disproportionate reduction or increase in some response classes within the overall repertoire available to the organism, resulting from a change in the availability of some other activity. If a particular response increases in strength when another is restricted, such an increase is considered selective substitution. Conversely, if a response decreases in strength when some other response is restricted, such a decrease indicates a complementary relationship. As a result of such selective interactions, these responses increase or decrease to a greater extent than others. If they did not, all other non-contingent responding might be seen to increase slightly in equal amounts to fill in the excess time available, as the rational models predict.

Such redistribution is presumed to be selective, however, since only specific behaviors produce the same reinforcer-elicited responses as the restricted response. Knowledge of potentially substitutable responses is important since, if a restricted contingent response has a substitutable response available, it is possible for the contingency as implemented to fail to produce a change in instrumental responding. By selecting response classes (for both instrumental/contingent experiments and applications) in terms of their apparent reinforcer-elicited responses, it appears possible to minimize such problems. This may be done empirically by imposing a non-contingent restriction over a selected response during a baseline response period, and by then measuring the resulting proportional increases in the remaining unrestricted behaviors. Those which increase in strength in greater proportions than the others are, by definition, the selectively substituted responses for the restricted response.

There is, of course, an obvious and continuing need for the adoption of experimental approaches if the predictive accuracy of economics is to be improved. One pertinent area of evident relevance to the management of experimental settings for human behavior and space applications research focuses upon the relationship between "token economies" and direct behavioral contingency systems. In functional terms, spending time engaged in instrumental responding in return for access to a choice of reinforcing activities may be equivalent in many respects to earning tokens at a job and exchanging them for reinforcing activities. In actuality, tokens permit savings and therefore a more flexible distribution of work and consumption. In addition, the intermittent collection of tokens during a large response requirement can probably sustain more enduring performances in high strength compared to the collection of all the same tokens at the end. On the other hand, it may be argued that mechanical token exchange may be dispensed with, either by replacing it with a token credit card system, by providing a wide variety of appetitive contingent activity options to all members in the group, or by providing fewer options of higher value on an individualized basis for each participant. The respective relative efficiency of these alternatives in terms of the control of individual and collective behavior and simultaneous management of life-support systems, work requirements, and reinforcer and resource allocation is, of course, an empirical question.

In an experimental setting of the sort most relevant to space applications, of course, instrumental/contingent relations may be specified and mechanically arranged so that subject interactions with experimenters are minimized. Thus precision, control, and simplicity are all increased with the use of a direct behavior program. In the closed environment of a space research and applications setting similar considerations may very well prevail, at least in the early phases, and token payments for scientist, crew members and construction workers, will probably be delivered as credit deposits in banks on Earth. Obviously, the similarity of tokens or credits to money make this option appealing to humans. But in early extraterrestrial sojourns, space habitat personnel shall presumably be expected to perform tasks related to ecosystem construction and maintenance, or research and industrial manufacturing, with few token or tangible rewards. Social and activity reinforcers will, however, be both available and subject to relatively easily controlled contingent delivery. As a result they are probably the reinforcers of choice!

Quite apart from the immediate efficiency of using token, credit, or other symbolic instrumental/contingent management methods, their ultimate contribution, if any, to the survival of the culture should be carefully scrutinized. A culture may easily evolve to dispense tokens for behavior which is apparently counter-productive to the welfare of many of its members. This is likely to weaken the entire culture. Tokens, like verbal behavior, may be adaptive insofar as their use permits us to bridge the temporal gap between behavior and its deferred consequences, but there is little guarantee that this will always occur in ways conducive to cultural adaptation. History is replete with examples of token and verbal behavior being prostitute to the interests of a few self-serving and self-appointed custodians of wealth and traditional "knowledge". To the degree that this reduces potential opportunities for individuals to acquire diverse or intelligent repertoires, its adaptive significance may well be questioned. Token exchange economics are, of course, ultimately a means of maintaining internal stability within a society and will only survive as a system if a large segment of the society is "reinforced" by the system. It remains to be seen whether the maintenance of mutual reinforcement, either natural or contrived is sufficient for biological survival. One might suspect that any system which seriously threatens survival will ultimately be abandoned. That it might be abandoned too late is to worry!

Whatever the resolution of these methodological/technological research issues, a functional analysis of human performances as observable interactions between the environment and the individual is essential, and should provide an operational account of behavior change in a manner similar to the way in which Darwin's theory of natural selection accounted for the evolution of phylogenic lines (i.e., in descriptive, non teleological terms). Similarly, as Darwin's account has been subsequently shown to be consonant with information obtained at the cellular level, so too should behavior principles ultimately prove to be in accord with an account of ontogenic adaptation at a biochemical level. The preliminary outline of such an account has been proposed in general terms and suggests that there are common behavioral and environmental processes underlying both the active and reactive interactions between organisms and their environments and that these processes constitute the fundamental features of ontogenic behavioral selection at a functional level of analysis. The common critical feature that exists prior to learning is the elicitation process, a reflexive response following contiguously upon presentation of an eliciting stimulus. But two other features are also necessary to provide a sufficient account of learning. One of those features is the antecedent contiguity of the environmental-behavioral event in relation to the elicitation process. The other necessary feature is that a discrepancy must exist between the initial response and the elicited response, or, to put it differently, in order for learning to occur the response to the eliciting stimulus must be at variance with the strength of responding to the antecedent stimuli.

The unifying relational principle here suggests that the environment acquires control over whatever responses occur in a favorable spatio-temporal relationship to a homogeneous discrepancy (i.e., a discrepancy confined to the response systems activated by the reinforcer). In such a view, a heterogeneous instrumental behavior that is discrepant concurrently with a homogeneously discrepant response will change in strength purely as a function of its correlation with the homogeneous discrepancy. A wide range of behavioral phenomena, including what are generally regarded as anomalous findings, such as deviations from matching, and biological constraints on learning are accounted for within the framework of the relational principle. While still tentative and in need of further research to assess the entire range of its applicability, it currently appears to offer one of the more comprehensive and parsimonious accounts of behavior and its maintenance by reinforcement. This account is molecular, rather than molar, and as such suggests that moment to moment environmental/behavioral interactions determine the molar aspects of behavior. Molar accounts such as the equilibrium and economic approach are useful in applied settings since they refer to easily observed and measured units of behavior. Evidence exists however, that such molar accounts are often inadequate to the task of accurately predicting behavior change. In principle, of course, "economic" accounts of behavior, at least, need not be molar and a wide variety of proposals for how equilibrium comes about are currently being entertained and experimented upon within the field. A unified relational analysis of the principles involved, however, would seem to provide a theoretically consistent and empirically useful account of any discrepancies obtained between predicted and observed data.

It is, of course, obvious that the most productive conceptual and methodological approaches to long-term research investments focused upon human behavior in space environments will require multidisciplinary inputs from such wide-ranging fields as molecular biology, environmental physiology, behavioral biology, architecture, sociology, and political science, among others. The extent to which these several areas of scientific and professional expertise can be meaningfully integrated in the interest of developing a productive space research agenda, however, will depend critically upon the available knowledge base defining fundamental behavioral interactions of the individual organism. This core subject matter will, of necessity, provide the critical links which extend the ties between many diverse disciplines that must provide the essential foundations of a research agenda on human behavior in space environments.

Research Accomplishments

For well over a decade, the work on this project has been directed toward the development and application of an experimental methodology for the study of human individual and small group productivity under semi-autonomous confined microsociety conditions. A discursive rationale and preliminary model have been provided for the application of continuously programmed environments in such 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 behavioral and biological processes. In addition, an effective methodology has been developed for the experimental control, manipulation, and measurement of relevant individual and group performance factors in such human behavioral research. To date, over 200 male and female volunteers have participated in a series of studies for extended periods of continuous residence in the programmed confined microsociety environment

Initial studies were designed to evaluate and optimize the temporal, sequential, and contingent relationships that enhance habitability and performance productivity with groups of two and three individuals over extended intervals. That baseline individual and social behaviors observed within the confined microsociety environment are sensitive to changes in behavioral contingencies was convincingly demonstrated in a series of 10- to 15-day three-person studies. The results of these initial experiments confirmed the practical feasibility of contingency management and isolated groups. The relationships between individual performance productivity and social interactions were emphasized by the observed deterioration of individual productivity under conditions of group fragmentation. Explicitly programmed social contingencies were demonstrably effective however, in maintaining group cohesion and preventing performance deterioration.

The robust effects of such social contingencies upon the behavior of small groups in isolated and confined microsocieties provided the basis for an experimental analysis of motivational factors as determinants of performance effectiveness and morale. The results of these studies showed that with groups of subjects under aversive control (i.e., an avoidance schedule), work performance changed and idiosyncratic expressions of displeasure and aggression emerged. Appetitive schedule conditions were, for the most part, free from such deleterious by-products even when extremely high work outputs were observed. Furthermore, strong overall relationships were revealed between individual performance productivity and mean daily cortisol levels.

These early investigations clearly established social variables as fundamental contributors to the overall status of a confined microsociety. Group participants were observed to seek social interaction under one set of conditions (e.g., cooperation contingencies and appetitive performance schedules), and withdraw from such interaction under other conditions (e.g., pairing contingencies and avoidance performance schedules). Accordingly, group performance effectiveness studies were initiated to assess the effects on individual and group productivity of a novitiate participant's <u>introduction</u> into and withdrawal from a previously established and stable two-person social system. Two performance tasks were incorporated into the behavioral program and measures of urinary androgens were obtained. The sensitivity of testosterone levels to changes in group composition, for example, was most evident in groups whose 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 performance work schedule least disruptive of established wake-sleep routines when changes in group composition occurred was generally accompanied by elevations in testosterone levels. Conversely, decreases in testosterone levels were associated with changes in group composition that occasioned shifts to less than optimal work and/or sleep schedules. These findings emphasized the importance of a multidimensional analysis of the behavioral and biological interactions which determine the adaptations and adjustments of small groups in confined microsocieties.

Subsequent extensions of these studies involved a series of experiments undertaken to determine how the <u>replacement</u> of a member of an established group affected the individual and group performances of a functional unit. Total urinary testosterone was determined for all subjects across successive days of these experiments, with changes in such hormonal levels being observed in relationship to shifts in work and sleep times. This latter effect confirmed the outcomes observed in the introduction studies, and demonstrated, by systematic replication, the generality of the behavioral-biological processes governing such effects. In addition, autocorrelational analyses were conducted for mean vocal utterances per minute for all possible subject pairs as observed during group performances. These analyses revealed an alteration in communication patterns when replacement occurred, and they suggest that intermember speech patterns may provide "early warning signs" of a group's difficulty in forming an effective operational unit.

The clear focus on motivational processes in accounting for the experimental outcomes emerging from these studies led to the development of a new set of procedures emphasizing analysis of such factors in the maintenance of productivity and social habitability in progressively autonomous confined microsocieties. Conceptually, the key element in this approach to human productivity is the appeal to a person's own natural behavioral dispositions as a basic determinant of motivation. Previous experimental studies of human motivation have generally emphasized the "extrinsically" defined rewards like food or money. Under the special conditions of extended isolation in confined microsocieties likely to be characteristic of future space operations, however, more refined procedures will doubtless be required to maintain highly motivated human participants. In this latter regard, the thrust of current laboratory initiatives directs attention to those "intrinsically" valuable activities that characterize the ordinary human repertoire with a view to structuring or patterning these activities to optimize autonomous individual productivity and cooperative group interactions.

It is, of course, commonplace to observe that individuals and groups will work long and hard to engage in selected activities generally judged to be pleasant. From an experimental perspective, a set of such pleasurable activities can be identified in advance of their being used as rewards by assessing the relative value of the activities in a behavioral hierarchy. Under conditions of unrestricted access to a wide range of activities, those on which the most time is spent will function as reinforcers (i.e., rewards) when access to them is made available only after a specified amount of time is spent in a lesser valued activity. Generalization of these relationships to work environments has presented recurrent problems however, because the reported studies with humans have invariably used activities chosen by the subjects themselves (e.g., preferred hobbies, reading materials, etc.). The kind of tasks found in most work settings are not as inherently valuable however, and it has not been clear that these general motivational principles apply to sets of assigned or required activities. It has been our objective then, during these extensions of this behavioral technology to assess the functional properties of the kind of performance tasks typical of a work environment (e.g., space station) within this motivational context.

The general procedure developed for assessing the effects on work productivity of such motivational interventions has involved groups of three subjects each living continuously in a residential laboratory and engaging in a variety of activities over extended periods up to 3 and 4 weeks. Each day is divided into a required work period and a social access choice period. During the work period each subject remains alone in his individual room and engages in four designated and required work activities including two computer terminal monitoring tasks, a routine sorting task, and repetitive manual operation. It is left to the subject to decide in which of the four tasks to engage, but one or another of these activities must be in progress at all times during the work period hours. During the choice period each day, subjects have access to individual activities of their own choosing (e.g., reading material, games, music, etc.) as well as access to group activities and interactions in the common social areas of the residential laboratory. Thus, comparisons can be made of the motivational effects upon productivity under conditions which involve both work and non-work activities.

A series of studies has been completed with groups of male subjects recruited and screened in accordance with procedures previously described and published in detail. They lived continuously in the programmed residential environment for periods up to a month. Each subject was alone in his individual room for 6 hrs per day, and for 9 hrs each day each also had access to a common social area that all subjects could use simultaneously. All behavior was monitored thru high-resolution color video cameras and was categorized and recorded by trained observers using a microcomputer program developed for observation of ordinary human behavior.

All communication with subjects was done using microcomputer terminals with both standard messages and open-ended interactions. In most cases, reference was made to previously explained procedures, but the system also allowed for answering questions and responding to requests for food or supplies. Control of access to the activities involved in contingencies was signaled using a red indicator light near the computer keyboard; when the indicator was on, a previously designated activity was not available.

Each subject's repertoire of activities was categorized and defined using a combined criterion of manual contact and/or head orientation. The categoritization was discussed with each subject to be certain that the boundaries corresponded to the subjects' perceptions of their activities and were clearly understood for purpose of later verbal identification. There was a standard set of work-like activities available in the individual room during the period each subject was alone. Two tasks were performed at a computer keyboard with a video screen. One involved vigilance of a string of numbers to detect skipped entries in a series (VIGI), and the other required substituting digits for asterisks in simple decoding procedure using a 3 x 3 matrix (DSST). There was also a manual task that required hooking pieces of wool into holes in a piece of nylon backing (RUG). The last task required alphabetizing pieces of paper on which randomly generated nonsense words were printed (WORDS). Each subject also brought a set of individual hobby activities, and these were normally available only during the period when subjects could gather in the common area.

The experiment began with a baseline period (up to 7 days) during which there was only one restriction on how subjects spent their time. They were free to engage in any of the work-like activities provided, but they had to engage in one of them. They were not allowed to sit and do nothing. This baseline was intended to be the functional equivalent of an operational mission in which individual crew members and/or payload specialists are required to engage in activities designated by mission control. The percentage of time devoted to the activities during the initial baseline was used to select the responses for the first contingency condition. Each experimental manipulation was also followed by a baseline period. This work-alone baseline was also compared with a baseline during the private session which included both the work activities and the preferred activities brought into the laboratory by each subject. This comparison provided a check of the assumption that the work-activities were without significant inherent value. Indeed, under such conditions, the subjects were observed to spend little or no time on the artificial or synthetic work activities, though the level of performance of the work activities increased dramatically once the competing self-selected activities were no longer available.

Data from the work-activities-alone baseline condition immediately preceding each contingency were used to select two activities for which there was a relatively stable preference order. An activity with a high probability (percent time in baseline) was selected as the contingent response ("reward"), and an activity with a lower probability was selected as the instrumental response. Performance of the instrumental response was required to gain access to the contingent response.

The amount of time available for the contingent response was a constant proportion of the time devoted to the designated instrumental response, and the size of the proportion was learned from experience with the contingency, not from instructions. A brief, minimum amount of instrumental performance was required to turn off the red restriction light and gain access to the contingent response. Access to the contingent response did not have to be used immediately or all at one time (no "limited hold"), so the subjects could engage in the response at several different times for short durations or use the time all at once. There was no limit on the amount of time that could be accumulated for the contingent response. As long as the total time on the contingent response did not exceed the credit accumulated by instrumental performance, each subject could alternate between the two responses in any pattern. When the earned time was used, the red light was turned on and the minimum instrumental performance was again required to remove the restriction.

At the beginning of each contingency condition each subject read a description of the contingency condition. Subjects were told the activities involved, and they were reminded that they were <u>not</u>

required to remove the restriction or engage in either of the activities in the contingency. Other optional activities were available at all times.

A response deprivation formulation was used to calculate the amount of contingent credit earned for each unit of instrumental performance. To earn the amount of time devoted to the contingent response during baseline, a subject was required to increase the time devoted to the instrumental response above its baseline level. Consider a subject with an instrumental response that occupied 25% of baseline and a contingent response that occupied 40%. A proportional contingency might require doubling that instrumental performance to maintain the contingent response, so each 5 units of instrumental time would yield credit for 4 units of contingent access time. Such a subject could continue to perform the contingent activity 40% of his time as long as he engaged in the instrumental activities during 50% of the work period.

Before the beginning of the experiment all subjects spent time in the laboratory receiving a full orientation to the living situation and the experimental procedures. Instructions were given explaining communication with the experimenters, use of the micro-computer terminals, the daily schedule, the food schedule, and all of the experimental procedures to be used. A written protocol was provided for each subject to keep for reference during the experiment. There was no deception in the experiment, so subjects were aware of all procedures in advance; they were not told the exact order or duration of the conditions however, nor were they told how previous subjects in the study had performed.

Subjects were awakened at 09:00 by a signal tone and allowed 45 minutes to shower, dress and eat. The interval from 09:45 to 16:00 was the individual activity period during which time subjects were free to take a 30-minute lunch break. From 16:00 to until 23:00 subjects could spent time in the social area engaging in group activities with other subjects. Each group prepared and ate a meal sometime during the social period. At 23:00 subjects returned to their private area to prepare for sleep, and the lab was darkened at 24:00. Subjects remained in bed in their darkened private room until the 09:00 wake-up signal.

The results of these studies showed that the effect of the reinforcement contingencies was straightforward and consistent. Both the designated work activities (instrumental responses) and the rewarding activities (contingent response) were affected in the same way as highly valued activities used in previous research. The amount of time devoted to the designated instrumental responses was greatly increased during the contingency periods. Such increases were observed in 43 of 47 transitions between a baseline and contingency condition with over half the contingencies producing instrumental performances more than double the baseline level.

The results of these studies also demonstrated that the effects of such experimental manipulations upon the contingent or rewarding work activity were similar to those which have been reported with inherently valuable, preferred, or at least self-selected activities. When contingencies were placed on the high-probability work activity, there were consistent reductions in the time devoted to these activities, and subjects rarely restored the restricted activity to its baseline level. There would appear to be a degree of deprivation of the high-probability work activity that is sufficiently acceptable such that subjects are willing to at least tolerate it rather than eliminate it. By the same token, the subjects in these experiments consistently did more than the amount of the instrumental work activity required to restore access to the restricted work activity, thus always maintaining a condition in which their "bank accounts" never went to zero.

The results of these experiments show clearly that a time-based model of value applies equally well to both work-like performances and self-selected or preferred recreational activities. Even when the activities have no apparent inherent value, an assessment of the time devoted to them in a constrained baseline yields orderly predictions of redistribution under a contingency. These results generally confirm the potential for application of the model to workplace settings like Space Station. These results also support the position that a baseline estimate is a relative rather than an absolute measure of the value of a performance. Forcing all of the activities above their normal level of performance did not alter the utility of the hierarchy for making predictions about contingencies. As long as relative preference can be described quantitatively, a response deprivation calculation can make an accurate prediction about the outcome of a contingency.

It is possible that the instrumental increases observed could have resulted from other factors in addition to deprivation of the baseline level of the contingent response. A restriction of one response makes time available for others, and in the present experiment there was a requirement that subjects engage in one of the active response categories. It is in fact the case however, that the instrumental performance which showed such dramatic increases in response to the contingency requirement was selected because it was the lowest probability activity in the array of work options for each individual subject. Other higher probability performances remained available without significant change in the time devoted to them under contingency conditions.

Significance of the Research

In extended duration operational mission settings like Space Station characterized by a range of behavioral requirements, major human factor concerns focus upon productivity and quality performance under conditions devoid of many of the usual consequences that maintain effective output in the workplace. In addition, the increasing autonomy generated by such circumstances will require an augmented focus on maintaining interpersonal harmony among the group participants to achieve mission objectives without supervision or external constraint. Research designed to confirm and expand generalizable knowledge relevant to the motivational factors that maintain and enhance both individual and group performance effectiveness in isolated and confined microsocieties is essential to the development of the fundamental and applied data base in this critical life science domain.

The nature and extent of long-term space initiatives are obviously problematic issues which involve important political, fiscal, and scientific/engineering considerations. Since specific requirements and time schedules are difficult to determine under such circumstances, the emergent imperatives of human behavior research in support of long-term space occupancy would seem best served by the development of conceptual and methodological approaches which are heuristic and productive of investigative innovation. Despite uncertainties associated with the behavioral requirements of space laboratories, work stations, interplanetary probes, and settlements beyond the Earth's atmosphere, a common feature of these diverse endeavors will be extended time intervals involving confinement of human participants in extraterrestrial habitats. A primary focus of conceptual and methodological concerns must then be upon the development of research-based technological, organizational, and sociological support of the human behavioral repertoire under such circumstances.

Beyond the somewhat narrower considerations of space craft design and specific scheduling of human performance and leisure requirements the interactive physical and behavioral features of the environment must provide for configuration of the sociopolitical organization of space-dwelling groups. The solution to this problem will doubtless depend upon input from many scientific disciplines and upon several levels of conceptual and methodological analysis. The present, somewhat primitive, state of knowledge in this area is probably limited to the information base of those public agencies which serve as the storehouse for the provisioning of expeditionary forces of various kinds (e.g., space crews, military teams, labor groups, etc.). Initial expeditionary efforts have always been characterized by authoritarian structure because of serious environmental hazards, uncertainties, and minimum provisioning found in such under takings. So it will also be for the forseeable future with space exploration.

The frequent sequalae of such expeditions, however, are the establishment of extended or permanent settlements and the eventual evolution of independence. This evolution develops because, though originally the "senders" are exclusively responsible for the reinforcing consequences of the activity, pay explicit fees, and demand absolute control over the rewarded performances, gradually as larger numbers of individuals are transported to established settlements, the needs and aspirations (reinforcers) of the "sent" take on progressively larger influence relative to the reinforcers of the "senders". This evolving relationship in the reinforcement matrix between the "senders" and "sent" is the fountainhead for the evolution of social structure and government policy as it exists in empire, colony and emergent independent states. The process has filled history books with a major portion of human activity and suffering throughout time. Formal programs of investigation to understand this evolution and the dynamics of social organization, as influenced by internal and external group contingencies, must be a major subject matter requiring extended research.

The complexities of such research initiatives which must take into account a wide variety of possible space settlements, are obviously imposing. The conceptual and methodological problems associated with designing, establishing, and maintaining such functional human and ecological systems would seem to require, in the first instance, an approach at the most fundamental scientific level, with subsequent work moving toward more complex situations on the basis of accumulated data. While such an approach will ultimately benefit the larger society by supplying an analysis of procedures for effectively promoting social and ecological stability, the immediate results are far more likely to be useful in the management of small, semi-permanent, isolated groups such as those involved in operational missions or space research. What must ultimately be determined is how to maintain a synthetic behavioral ecosystem. This requires at a minimum a specification of how individuals' social and non-social environments influence behavior. Once specified, this can be used to synthesize an environment which will reliably produce and maintain appropriate repertoires with respect to other members of the social environment, life support systems, and work activities.

The need for such analysis and synthesis may be greater than one might initially suspect. Between the Soviet and U.S. manned space programs, people have now spent well over 3000 days in space without ill effects, although only relatively small groups have been involved under continuous control by ground command. It has been suggested that this may generate superstitious overconfidence, with a failure to recognize the need for technological developments in human group maintenance of a satisfactory environment with more extended numbers of individuals under stressful and potentially adverse conditions in order to augment the probability of successful space occupancy. The development of such a technology would be facilitated by a research methodology that provided for simulation of expected environmental conditions and the systematic experimental analysis of behavioral interactions over extended time periods. The conceptual framework and methodological approach to the management of behavioral ecology developed in the course of the research project described in this report is analytic and synthetic in orientation, explicitly experimental in nature, dictated by both scientific and pragmatic considerations, and closely approximates procedures of established effectiveness in other areas of natural science.

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