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A LONG-TERM STUDY OF HUMAN PERFORMANCE IN A CONTINUOUSLY PROGRAMMED EXPERIMENTAL ENVIRONMENT

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ABSTRACT

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A volunteer adult male was confined to a three room experimental chamber for five months. A program of activities, controlled by automatic equipment, permitted the subject to engage in a particular sequence of activities. The terminal parts of the sequence allowed the subject to engage in more reinforcing activities and to choose among a greater selection of activities. Behavioral requirements in several activities were manipulated during the experiment. Performance changes were recorded in terms of frequency of selection of activities, duration of activities, and other quantitative and non-quantitative measures.

The effects of some of the short-term manipulations in the conditions of the environment were observed on behaviors both closely and distantly related to the behavior being manipulated.

The effects of prolonged social isolation and confinement resulted in the development of progressive behavior strain, which ultimately led to the termination of the experiment. These effects were described quantitatively in performance changes in many behaviors.

AUTHOR

INTRODUCTION

The experimental analysis of animal behavior has shown a rapid development during the past twenty-five years. This development has been based in large measure upon improvements in the techniques which permit more precise specification of behavior and its consequences. It has also been based upon the traditional freedom found in the animal laboratory to examine variables over a wide range, through a long time course, and under well controlled conditions. On the other hand, restrictive cultural traditions and the lack of appropriate techniques have long combined to limit the experimental control found in the human laboratory. Thus many important human behaviors have not yet been subject to experimental analysis, and frequently those behaviors which are brought under experimental control can be observed only for a brief period of time. A further common difficulty in the human area is the frequent necessity of examining one particular behavior without having control or adequate measurement of related behaviors. These general impediments to a richer experimental analysis of human behavior will not be overcome quickly or easily. In the recent past, however, a growing number of investigators have employed the principles and techniques generated in the animal laboratory for a renewed attack upon several long-standing problem areas in human behavior. Specific areas in which these techniques have been applied include the experimental analysis of emotionally disturbed adults (e.g. Lindsley, 1956; Issacs, Thomas, and Goldiamond, 1960; and Holz, Azrin, and Ayllon, 1963), and emotionally disturbed children (e.g. Ferster and DeMeyer, 1962; Wolf, Mees, and Risley, 1963), and also some more delimited problem areas such as stuttering behavior (Flanagan, Goldiamond, and Azrin, 1958). In addition, the principles developed in the animal laboratory have been employed in more basic research with normal adults and children (Long, 1959; Bijou, 1958; Weiner, 1962; Zimmerman and Baydan, 1963; Holland, 1958).

The present research is a continuation of this new laboratory approach with special emphasis placed upon the basic methodological problems of establishing and

maintaining continuous experimental control over the human subject. The particular problems of interest here were, first, to determine the feasibility of organizing a large number of contingencies which specify most of the behavioral repertoire of a human subject in a closed experimental environment; second, to explore the possibility of maintaining such experimental control for a sufficient period of time to permit the measurement of long-term changes in performance; and, finally, to determine the feasibility of obtaining functional relationships as a result of specific manipulations in the conditions of the environment.

A number of studies of man in special closed laboratory environments have already been reported in connection with simulated space flight and confinement problems (e.g. Grodsky, 1963; Burns, 1959; Burns and Gifford, 1961; Burns and Ziegler, 1960; Welch, 1961; Steinkamp et al, 1959; Hauty, 1958; Adams and Chiles, 1960 and 1961). These studies have generated important data with respect to effective work-rest cycles, loss of accuracy in time estimation, decrements in accuracy on monitoring tasks, internal cabin arrangements for stimulus displays and controls, and other variables related to special environment and performance problems.

However, some of the more general problems concerning the measurement, analysis, and control of human behavior have not been thoroughly explored in these studies because of their applied objectives, their relatively short duration, and the absence, in most cases, of precise specification and manipulation of the stimulus conditions under which behaviors may or may not occur, and the specific consequences of those behaviors. Indeed, the precise specification and manipulation of the contingencies between an organism's behavior and its consequences has perhaps been the key to the success of current basic research in the experimental analysis of behavior.

The work to be reported here also involved the use of a closed experimental environment. However, the objectives of this research were the exploration of more basic problems in the analysis, measurement, and control of human behavior. To achieve this objective, the principles and techniques developed in the animal laboratory were incorporated into the design of the experimental environment to be

described here. Specifically, the techniques developed by Skinner (1938) and many others, of automatically programming requirements or contingencies by which specified behaviors of the organism produce given changes in the environment, were of principle concern here. Another important technique of the animal laboratory that is closely related to the specification of contingencies is that of placing behavior under stimulus control. This is accomplished by a more complex use of contingencies so that particular behaviors will have given consequences, but only under specific stimulus conditions. Thus by the elaboration of contingencies and the use of appropriate stimulus control procedures, it has been possible to develop quite complex sequences of behavior in the animal laboratory. A further development of the animal laboratory of importance here is the use of 24 hour or continuous experimental environments (Skinner and Morse, 1958; Findley, 1959). These continuous environments allow for the measurement of many behaviors that would not be possible otherwise. With these procedures, performance changes in different behaviors, as well as their interactions, can be studied (Hanson and Witoslawski, 1959; Reynolds, 1961; Findley, 1962). In summary, then, the techniques of the animal laboratory, that is, the specification of contingencies, the stimulus control of behavior, the organization of complex sequences of behavior, and the use of the continuous experimental environment all combine to provide, in principle, most of the elements employed here for the design of an experimental environment for human research.

Building upon the techniques and principles of the animal laboratory, an experimental environment for human research was constructed, which provided for the maintenance of a single individual. Although the design of an environment for a single individual placed severe restrictions upon the quality of the environment in terms of the resulting social isolation, an attempt to design a research environment for two or more individuals without having first examined the problems of experimental control and measurement for one individual appeared premature.

The environment finally decided upon was similar in overall character to that of an efficiency apartment, but different in important respects. The environment differed fundamentally from a normal environment in that the opportunities for various

kinds of activities were available only as specifically provided for by the behavioral program. The apartment itself consisted of three rooms: a main room, a special work room, and a toilet. Access to the rooms and to the particular facilities in each was programmed in detail. Most of the important behaviors of normal living, ranging from toilet operations and exercise to creative work and other rewarding activities, were incorporated into the program. This program not only provided a specific organization to the activities that were available to the subject, but also brought these behaviors under stimulus control. For example, sleeping was brought under control by having the bed electrically locked against the wall until the opportunity for sleep became available in the program. Since all other activities were under similar stimulus control, they were not available during Sleep. The Sleep activity was terminated by the subject by replacing the bed in the locked position. This, then, made the opportunity for certain other behaviors available. Automatic equipment outside the experimental environment made possible the measurement of frequency, duration, and other properties of behavior associated with a given activity.

Upon completion of the design and instrumentation of this environment, an experiment of unscheduled duration was begun with a volunteer human subject, in order to examine the degree of experimental control and measurement made possible by the environment. After several weeks it was clear that the environment was quite livable in spite of the social isolation and confinement, and that the environment provided good control and measurement of behavior. The experiment was continued in an effort to document performance changes as a function of the duration of the experiment, and to examine the effects of certain short-term manipulations in the environment.

METHOD

The general methodology presented here includes: a description of the experimental chamber, the details of the behavioral programs, the method of data recording and daily management of the experiment, a description of the experimental subject, the preliminary test, and the experiment proper.

The Experimental Chamber

The chamber was composed of three interconnected rooms, fabricated from commercially available sections normally used in the construction of large, walk-in refrigerators. The general arrangement provided for one large room 11' x 11' inside, and two smaller rooms 5' x 5' each. All three rooms were 8' in height. This chamber is illustrated in Figure 1, with a notation of the furnishings and facilities in each room. The rooms were separately air conditioned, with the temperature maintained at 75 degrees Fahrenheit, except in the Sleep activity, during which the temperature was maintained at 70 degrees. Fresh air input was obtained from outside the laboratory building within which the chamber was housed. Sound attenuation from the outside of the chamber to the inside provided for a reasonable sound reduction, except for unusually loud or high frequency laboratory noises. The inside of the chamber was constantly illuminated by fluorescent lighting, except during special parts of the behavioral program in which the lights were extinguished.

Although the inside walls of the chamber were lined with stainless steel, the use of a blue-green rug, some walnut accessories, and color highlights in appropriate places combined with the black Micarta control panels to achieve an interesting and decorative atmosphere. As shown in Figure 1, the center room served as the main living area, containing a collapsible bunk, a general purpose table and chairs, an automatic device for storing and dispensing hot and cold foods, and one comfortable lounge chair. Located on one wall were two recessed drawers, access to which was controlled by electrical locks. One drawer contained raw materials for hobby activities, and the other drawer contained fresh clothes and toilet supplies for use in conjunction with the toilet operations. A metal bar suspended from the center of the room was attached to a load cell and was used to obtain the subject's weight. Also located in the center room was an automatic record selection device (a modified commercial juke box) and its associated speaker. Equipment for programming two kinds of physical exercise, and several remotely controlled electrical outlets, which were made operative at specific times in the program, in addition to several appliances, such as an electric toaster-oven, vacuum cleaner, and immersion heater, were also provided in the chamber.

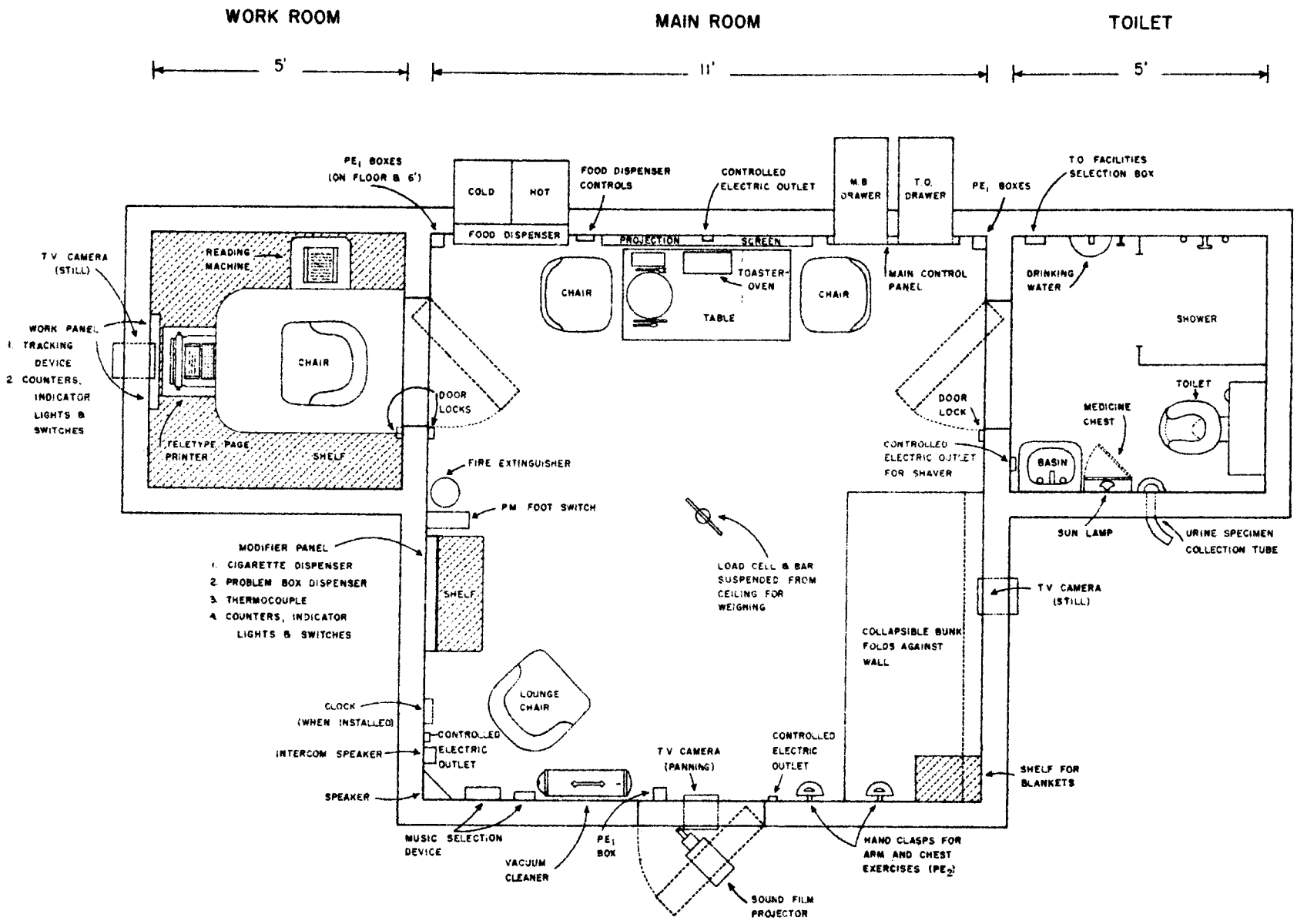

Fig 1. Diagram of experimental chamber showing furnishings and facilities in each room.

Above the two drawers a master control panel was mounted which contained lighted push buttons which served to inform the subject of the particular activities of the program which were available for selection at that time and which activities could be selected at a later time. Located on the wall opposite the bed was a second control panel (referred to as the auxiliary panel) that contained several devices and indicator lights which functioned in relation to specific activities in the program. For example, a thermocouple was attached to this panel, with a mouth probe by which the subject registered his body temperature. There was also a device mounted on this panel for dispensing cigarettes. Another device automatically delivered problem boxes, which were small cardboard boxes containing objects or written problems; other counters and indicators, such as standby lights, were also located on the auxiliary panel. Access to the two rooms adjoining the center room was normally prevented by the doors, which were kept closed and locked, and would permit admittance only during certain portions of the program. For example, entrance to the small work room could occur in conjunction with three different programmed activities. A teletype machine, a device for automatically exposing and advancing reading material, a control panel for a tracking device, several counters, and indicator lights were located inside this room.

The other small room contained a shower, commode, basin, sun lamp, electric shaver, drinking water source, and an activity selection box by means of which the subject could activate the various facilities within the room. Access to the drawer which contained toilet articles and access to the full use of the facilities within the toilet was limited to an activity termed TO (Toilet Operations). Another activity, termed LTO (Limited Toilet Operations) provided for access to the commode facility only.

The subject could be observed visually in the center room by means of two closed circuit TV cameras, and in the work room by means of a third camera. It was also possible to monitor the subject in the center room by means of an intercom system which picked up most noises and speech sounds that the subject might emit. Also located in the center room was a button connected to a large horn on the outside of the chamber,

which the subject could operate in case of emergency. The main room also contained a fire extinguisher.

The Behavioral Program

The general character of the behavioral program used in this experiment is that of a behavioral "chain" in which a sequence of activities is programmed in such a way that the consequence or reinforcement for the completion of one activity is the opportunity to engage in the following, usually more reinforcing activities in the "chain" (Findley, 1962). The special features of this program were that the various activities were performed one at a time, that is, they were mutually exclusive, and the subject proceeded through the total program at his own pace by satisfying the specific requirements associated with each activity. The activities were mutually exclusive because they were either physically impossible or impractical except when the occasion was provided for by the program. A visual display of these activities and their sequential arrangement were presented to the subject by means of the main control panel, as shown in Figure 2. Table I presents a list of the abbreviations, the full names, and a brief description of all the activities in the program. Each activity was associated with a specific illuminated push button which was normally green, indicating that the activity was currently in the program and would become available during the trip. Completion of a given activity, for example, Physical Exercise, switched the illumination from green to red on the next push button in the program sequence, the Food One (FD1) activity, indicating that selection of this activity was now possible. After FD1 was selected, all push buttons became green. When FD1 was completed, WK1 (Work Task One), SLP (Sleep), and WK2 (Work Task Two) were illuminated red, indicating that one of these activities could now be selected, and so on.

In the first five activities there was no choice in the selection of activities (unless the bypass switch was illuminated below the push button, permitting the subject to bypass that activity). When the subject reached the 6th, 7th, and 8th activity groups, a number of options were permitted. That is, selection of one activity was permitted out of three possible choices in the 6th and 7th Activity Groups. In the 8th Activity Group four selections were normally permitted from the eight activities.

Summing up, then, the completion of the first five activities permitted the selection of one of the three activities in the 6th Activity Group. The selection and

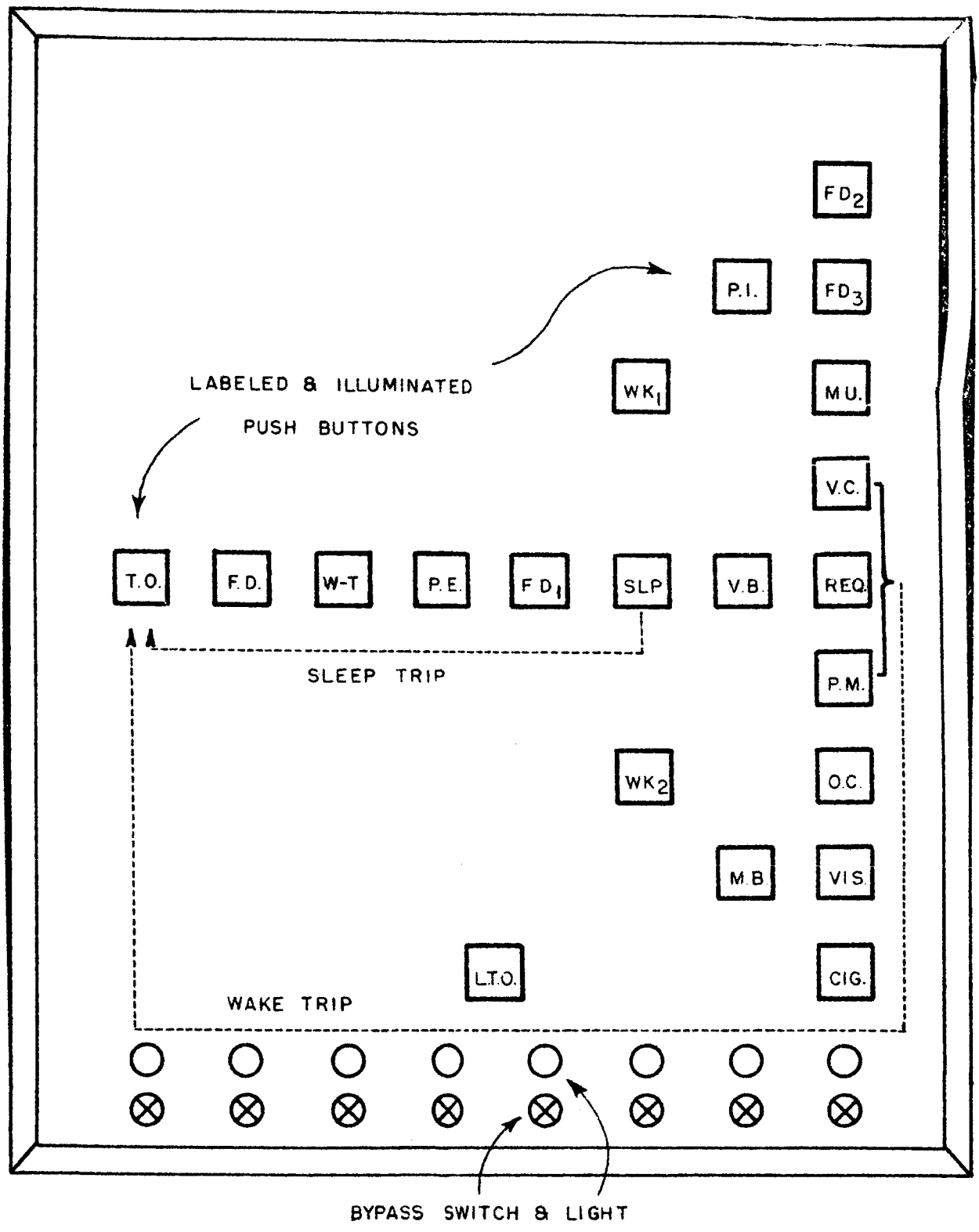

Fig 2. Main control panel containing push buttons that could be illuminated red or green. Each button is labeled with the abbreviation (table I) of the activity represented. Wake trips and Sleep trips are indicated by arrows.

TABLE I

Abbreviation of Activity	Full Name of Activity	Brief Description of Activity
L.T.O.	Limited Toilet Operations	Use of commode in toilet at any time
1. T.O.	Toilet Operations	Use of all facilities in toilet and T.O. drawer
2. F.D.	Flight Duration	Select flight-extend or flight-reduce
3. W-T	Weight-Temperature	Use of ceiling bar then mouth temperature probe
4. P.E.	Physical Exercise	Press buttons on lighted boxes, then pull weights
5. FD1	Food One (Light Snack)	Two selections from food dispenser
6. Activity Group		
WK1	Work Task One	Tracking task in work room
SLP	Sleep	Bunk unlocks from wall
WK2	Work Task Two	Problem box
7. Activity Group		
P.I.	Programmed Instruction	Use of reading machine in work room
V.B.	Verbal Behavior	Use of teletype machine in work room
M.B.	Manual Behavior	Use of art supplies, M.B. drawer
8. Activity Group		
FD2	Food Two (Dessert)	One selection from food dispenser
FD3	Food Three (Major Meal)	Three selections from food dispenser
MU.	Music	Earn record selections
V.C.	Variable Consequence	Earn delayed delivery of variable consequence
REQ.	Requisitions	Earn delayed delivery of requisitions
P.M.	Power Maintenance	Operate heavy foot switch
O.C.	Oral Communication	Earn delayed delivery of intercom conversation
VIS.	Visitors	Not in program
CIG.	Cigarettes	Earn cigarettes from dispenser

completion of Sleep in the 6th Activity Group returned the subject to the first activity. Alternatively, the selection and completion of either of the other two activities in the 6th Activity Group permitted the selection of one of the three activities in the 7th Activity Group, and the selection and completion of one of the activities in the 7th Activity Group permitted the selection of a fixed number of activities in the 8th Activity Group. After completion of the 8th Activity Group, the program automatically returned to the first activity. Progressing through the first five activities and then selecting the Sleep option in the 6th Activity Group was called a Sleep Trip, while working through the full program was called a Wake Trip. Sleep Trips and Wake Trips are shown in Figure 2 by the dotted lines.

The overall arrangement of the activities as illustrated in Figure 2 was such that the sequence of activities progressed from those which would probably not be maintained without explicit programmed consequences (exercises, weight and temperature recording, and work tasks) to those which provided more immediate or substantial reinforcements (reading, food, music). The first activity in the program, the TO (Toilet Operations) activity, was an exception to this design. In this activity a number of preparatory behaviors were permitted, such as showering, changing clothes, shaving, etc. The specific sequence of activities in the program with a detailed description of each is presented below.

T.O. (Toilet Operations)

Following either completion of a period of sleep or the fulfillment of the entire program, there was a four minute delay before the subject could enter TO. This permitted the technicians to perform any necessary actions, for example, data recording, checking the food supply, etc. The subject entered TO by depressing the TO button on the main selection panel. This action released the electrical lock on the door to the toilet, making all the facilities within available, and unlocked the TO drawer in the main room.

The facilities of the toilet included a shower, a basin, a separate fresh drinking water source, a sun lamp, and an electric shaver, all of which were activated by switches in the toilet. In addition, the toilet contained a commode and a urine specimen

collection tube.

The drawer in the main room contained fresh toilet articles, such as tooth paste, soap, towels, clean clothes, fresh linens, and cleaning supplies such as scouring powder, metal polish, garbage bags, etc., for the chamber. A vacuum cleaner in the main room could be used during TO. The subject's clothes consisted of shorts, tee shirts, slacks, socks, a sweater, and sneakers. The toilet articles and cleaning supplies were replaced as they were used. The clothes were replaced when the subject returned the soiled clothes via the TO drawer. There was a small note pad and pencil with which the subject could write "TO Requests" for such items as minor medical items, matches, and toilet articles which normally were not in the drawer. For these items the subject was not required to go through the formal requisition procedure (described below). This drawer was also used for the placement of small items into the chamber in connection with other aspects of the program. In addition, communications related to the feedback for the Verbal Behavior activity in the program were placed in sealed envelopes and sent in through this drawer.

To obtain a general measure of overall physical activity the subject wore two actometers, one on his wrist and one on his ankle. He was asked to record the readings from these during every TO and LTO, and to write all the readings for one trip on a card and send the card out during each TO. No minimum time requirement was specified for TO. The procedures to end this part of the program were the relocking of the bathroom door and the closing of the TO drawer. Data recorded for TO included the time spent in the activity, a list of the materials used from the drawer, and a notation of the facilities used in the bathroom and main room.

LTO (Limited Toilet Operations)

LTO was available to the subject at all times, whether he was in the main room or the work room. Depression of an LTO button in the work room unlocked the work room door. Depression of the LTO button on the main selection panel (Figure 2) unlocked the door to the toilet and extinguished the lights in the center room. Only the commode could be used by the subject at this time. To end the LTO and to resume an activity in the center room it was necessary only to relock the door to the

toilet. To resume an activity in the work room the subject returned to this room and relocked the door from the inside.

FD (Flight Duration)

After the completion of the TO activity the subject could enter the Flight Duration (FD) activity by depressing the FD push button on the main control panel. The subject was then required to indicate his current attitude to the environment by means of a forced choice response. Two indicators on the auxiliary panel were labeled "Reduce Flight" and "Extend Flight." The subject was required to depress one of the two push buttons associated with these indicators. His choice then registered on an add-subtract counter, which was located on the auxiliary panel. Prior to the beginning of the experiment, the subject had been instructed that the duration of the experiment would be under the control of the experimenters, but that the FD record would be considered along with other determining factors in the continuation or termination of the experiment.

W-T (Weight-Temperature)

Depression of the Weight-Temperature (W-T) button on the main selection panel activated an electronic weight recorder outside the chamber and turned on the "Weight" indicator light on the modifier panel. The subject was required to suspend his full weight from a bar near the ceiling for approximately 20 seconds, hanging as motionless as possible. The bar was connected to a load cell. After the weight had been properly recorded, the "Temperature" light on the modifier panel came on, indicating that the weighing activity was completed. The subject was then required to place a heat-sensitive probe (attached to the modifier panel) into his mouth for 20 seconds. The electrical changes in the probe were carried to an electronic thermometer and recorder. When the "Temperature" light on the modifier panel was extinguished, the subject was set up for the next activity.

PE (Physical Exercise)

At the completion of W-T, the subject could push the Physical Exercise (PE) button on the main selection panel, which activated the first of a two-part PE program. In the PE1 activity the subject was required to move rapidly about the room from one light and button to another. That is, the subject was required to push the button

corresponding to one of the five lights located around the room (see Figure 1) within maximum and minimum time intervals in order to extinguish the light "correctly." Errors resulted when the subject pushed a button too soon or too late. All responses extinguished the corresponding light and randomly activated one of the five lights. If a response was within the correct time interval the subject received a one-second buzzer. This process continued until the subject had produced a predetermined number of buzzers.

The completion of PE1 automatically moved the program into the second phase of the PE activity, PE2, which consisted of the use of a weight and cable device for chest and arm exercises. Inside the chamber there were two hand grips attached by cables to two fifteen pound weights outside the chamber. These grips had to be pulled to their upper limits and released to their lower limits a predetermined number of times. When the requirements had been met in both PE1 and PE2, the program automatically was set up for the next activity.

FD1 (Snacks)

After completing TO, FD, W-T, and PE, the subject was permitted his first option in the chain of activities, in the Food One (FD1) activity. That is, throughout the entire experiment the bypass switch was available for FD1 (Figure 2), and the subject could skip this activity by pressing the bypass switch. The standard diets for FD1, FD2, and FD3 are shown in Table II. After selecting FD1 the subject was permitted two selections from an automatic vending machine from compartments containing FD1 foods. The automatic vending machine was divided into hot and cold sections, and food was dispensed by operation of an associated push button. An electric oven and an immersion heater, operated from a controlled electric outlet, were available for the subject's use during the food programs. A cup and saucer, dinner plate, glass, silverware, and small glass coffee pot were also provided for him. When the subject pushed an "End FD" button he was automatically set up for the next activity.

WK1 (Work Task One)

After completion of FD1, the subject continued the program by selecting one of the three alternatives in Activity Group 6. If he selected WK1, the door to the work

TABLE II

STANDARD DIET AVAILABLE FROM FOOD DISPENSER

FD1 (Light Snacks)

Cold Side

1. Coffee and tea
2. Milk and butter
3. Cereal
4. Fresh Fruit

Hot Side

5. Soup
6. Ham and egg or bacon and egg casseroles
7. Waffles or bread (2 slices)

FD2 (Desserts)

Cold Side Only

1. Coke or fruit juice
2. Variety of desserts (pie, cake, or candy)

FD3 (Main Meal)

Cold Side

1. Salad
2. Milk
3. Cold sandwiches
4. Bread and butter (2 slices) or waffles
5. Coffee and tea
6. Eggs (2)

Hot Side

7. Soup 1 and crackers
8. Soup 2 and crackers
9. Tasty Tray
10. Casseroles
11. Hot sandwich
12. Canned meal

Note: Salt, pepper, sugar, Pream, crackers, mustard, ketchup, and mayonnaise were supplied with appropriate items in each compartment. Silverware and dishes were available at all times.

room was unlocked. The subject then locked the door from the inside to activate the tracking task activity. A display on the control panel contained a circle with a diameter of four inches, and a pointer which oscillated within a 56 degree arc. This pointer moved ten degrees per second. The depression of a push button reversed the direction of movement of the needle. The subject was required to keep the pointer centered within plus or minus one graduation on the dial of the tracking device for one second in order to obtain points on a cumulative counter. When the pointer was centered properly, a light was illuminated. When the subject had obtained 150 points and remained in the activity a minimum of 30 minutes, the task was completed and the subject could emerge from the work room and lock the door from the outside, thereby setting the occasion for the selection of one activity in Activity Group 7.

SLP (Sleep)

If the subject selected SLEEP rather than WK1 or WK2, he depressed the SLP button on the main selection panel. The bed was unlocked, the temperature of the chamber was lowered from 75 to 70 degrees, power was provided to an outlet near the bed for an electric blanket, and the overhead fluorescent lights were turned off ten minutes later. The subject was free to sleep as long as he desired, although a 30 minute minimum time in the Sleep activity was required. To end this activity the subject returned the bed to the locked position. When this occurred, the lights came on, and, after a four minute delay, the program was returned to the first activity (TO).

WK2 (Work Task Two)

If the subject selected Work Task Two as the desired alternative to WK1 or Sleep, he could then obtain a box containing a problem from a dispenser located on the auxiliary panel. Selecting WK2 also activated a 30 minute minimum timer. WK2 was designed to be a work task which required intellectual, clerical, and/or manual behaviors. Specific directions were furnished to the subject within each problem box, and he was instructed to follow these directions in completing the problem. The problem boxes were varied in content and required the use of a number of skills. The type of problems with which the subject was presented included the following: numerical and mathematical problems, mechanical problems, geometric design problems, and verbal problems (classifying words, defining scientific terms, etc.). Other problem areas

which were used included military history, political philosophy, economics, geography, astronomy, and chess. Although the problems involved in the WK2 activity were probably of some intellectual or instructional value, this activity was basically designed to provide a regular work activity which could be repeated several times per day. After the required minimum time had been satisfied and the problem box was returned to the dispenser in the auxiliary panel, the program was automatically set up for Activity Group 7.

PI (Programmed Instruction)

After selecting and completing one of the two work tasks in Activity Group 6, the subject could select one of three activities in Activity Group 7 -- Programmed Instruction, Verbal Behavior, or Manual Behavior. If the subject selected Programmed Instruction (PI), he was required to enter the work room and lock the door. He could then read material that had been pre-selected by the experimenters on a reading machine. The reading material was pasted on long rolls of paper. Each time the subject pushed an advance button, the paper was advanced one and one half inches. This material appeared before the subject in a 12 x 8 inch window in the reading machine. The material included a wide range of categories, varying from technical subjects such as electronics, astronomy, history, etc., to light reading such as novels and short stories. The subject was normally engaged in reading several kinds of material concurrently. The material was so arranged that a variety in content and interest level would usually be covered within a single PI selection. This activity was designed to be primarily educational in nature, and the subject could ask or answer questions pertaining to the reading material by using the teletype machine. Questions for the subject to answer and answers to his questions were programmed on the reading machine. PI was completed when the subject had remained in the activity for a minimum of 30 minutes, and when he had operated the advance button a predetermined number of times. When these requirements had been met, depression of an "End PI" button released the lock inside the work room and deactivated the reading and teletype machines. When the subject locked the work room door from the outside, he automatically set up Activity Group 8.

MB (Manual Behavior)

The second alternative in Activity Group 7 was Manual Behavior (MB). Manual Behavior was essentially a hobby activity, during which the subject was provided with a variety of raw materials. Depression of the MB button on the main selection panel unlocked the MB drawer, in which the following items were stored: crayons, modeling clay, X-acto cutting tools, oil paints, turpentine, linseed oil, clean rags, sheets of canvas paper for painting, sketch paper, colored chalk, an eraser, paper, pencil, and water for cleaning. He was allowed to keep completed projects in the chamber if he so desired. Depression of the MB selection button also activated a 30 minute minimum timer. MB was completed when the timer had timed out, and when the subject closed the MB drawer, thereby setting up Activity Group 8.

VB (Verbal Behavior)

The third alternative in Activity Group 7 was Verbal Behavior (VB). After selecting VB, the subject entered the work room and locked the door from the inside. He could then use the teletype machine located in the work room. He was free to type out any material he desired, and he could comment, for example, on the nature of the experiment, on his part in it, on his attitudes and feelings, his plans for the future, etc. The subject was required to remain in this activity a minimum of 30 minutes, and had to accumulate 20 points. Points were earned at variable intervals, but only if the subject was operating the teletype machine. A cumulative counter on the work room panel indicated the number of points accumulated. The subject could elect not to send the material to the teletype receiver outside the chamber by depressing a "privacy switch." Private or confidential material could be typed in this manner and left in an envelope in the TO drawer for the senior investigators. Some feedback was occasionally provided for this activity in the form of return messages in the TO drawer. When the subject had satisfied the 30 minute minimum required time and had accumulated the minimum number of points, he could end the activity by pushing an "End VB" button on the control panel. After locking the work room door from the outside he was automatically set up for Activity Group 8.

When the subject entered Activity Group 8 he was permitted to select several (usually four) activities from a choice of eight.

FD2 (Dessert)

In the FD2 program, the foods (see Table II) were dispensed from the automatic vending machine. The subject was permitted one food selection in the FD2 activity. After making his selection, he could press an "End FD" button, which automatically set up another choice in Activity Group 8 if he had not already selected the allotted four activities. If FD2 was his fourth selection, he would be automatically returned, after a four minute delay, to the beginning of the program, the TO activity. This sequence of events pertained to all activities in Activity Group 8.

FD3 (Major Meal)

In the Food Three (FD3) program several types of main meals were available (see Table II). Some changes in these foods occurred from time to time as the result of minor variations by the supplier. The subject could obtain these foods, as in the other two food programs, from either the hot or cold sides of the dispenser where the FD3 compartments were located. The subject was permitted three selections in FD3, after which he could press the "End FD" button to terminate the FD3 activity.

MU (Music)

When the subject selected Music by depressing the MU button in the 8th Activity Group, he was then required to complete a predetermined number of responses for each record on a push button located on the auxiliary panel. Associated with the button was an indicator panel showing the number of records the subject had currently accumulated. This number was set at a maximum of five. Completing the required number of responses earned an additional record. Making a selection from one of the 100 possible record choices reduced the number accumulated by one. Earned records could be played either during the Music activity or during any other activity in the center room. The available music selections varied from country music to classical music. Typically the number of earned records required was five, with a response cost of 25 responses per record. After five records were earned, the activity was automatically terminated.

Delayed Reinforcements

Three delayed reinforcement activities were provided for the subject. When a delayed reinforcement activity was selected, the subject was required to emit a fixed

number of responses on the auxiliary panel. A particular delayed reinforcement was earned when the activity was selected a fixed number of times. After the subject had earned the delayed reinforcement, an indicator light was automatically illuminated. Following a delay of perhaps several days, the earned consequence would be delivered after the completion of the 7th Activity Group. The delayed reinforcements were divided into three broad categories: Requisitions, Oral Communications, and Variable Consequences. These are described below. In none of these categories did the subject know precisely what the reinforcement would be.

VC (Variable Consequences)

Variable Consequences (VC) was designed to provide the subject with an unknown consequence, the nature of which was controlled entirely by the experimenters. The consequence could be one which was either positively reinforcing, e.g., the delivery of a tape recorder; or the consequence could be aversive, e.g., the restriction of food to banana flavored food pellets, milk, and oranges for several days. Some VC's could not be described as being either clearly positively or negatively reinforcing, e.g., the introduction of a clock into the chamber. In addition, the duration of the VC was not revealed to the subject.

OC (Oral Communications)

Oral Communications (OC) was a reward which was accomplished by allowing the subject to talk, via the intercom system, with individuals selected by the experimenters, for a period of approximately 30 to 40 minutes. Delivery of this reinforcement was, of course, dependent upon the subject earning an Oral Communication by selecting OC the required number of times. Conversations during OC were structured away from dates, current events, or any content which would disturb the progress of the experiment.

VIS (Visitors)

This activity was normally not available for selection by the subject. It was made available for a few hours near the end of the experiment, but was never selected.

PM (Power Maintenance)

This activity was an avoidance response in which the subject was required to operate a heavy foot switch in order to prevent a power failure within the chamber.

A cumulative counter on the modifier panel advanced one count each time the program entered Activity Group 8. When the counter reached 25, the power failure occurred. The subject had to reset this counter before it reached 25 to prevent the power failure, which consisted of the extinguishing of the lights in the center room, and a suspension of all activities for a five hour period. The selection of PM and the operation of the foot switch for a total of fifty responses completed the PM activity and reset the cumulative counter.

CIG (Cigarettes)

After selecting the Cigarette (CIG) activity the subject was required to operate a push button on the auxiliary panel a predetermined number of times for each cigarette. In addition, a predetermined number of cigarettes had to be earned with each selection of the Cigarette activity. Cigarettes were automatically delivered individually as they were earned. Typically, the number of responses required per cigarette was 25 and the number of cigarettes required per selection of the activity was ten. Various brands of cigarettes were delivered to provide some variety for the subject.

Data Recording and Daily Management

Frequency, duration, and other performance measures for each activity were obtained from event counters, cumulative time counters, cumulative event recorders, multiple event recorders, weight recorders, and other automatic devices in addition to the intercom and closed circuit TV systems located outside the chamber. The programming of events within the chamber, including the working of all electrical-mechanical devices, illumination levels, door locks, electrical outlets, etc., was controlled by programming circuits built around relays, timers, predetermining counters, and special purpose devices. During the course of the experiment, technicians worked eight hour shifts around the clock. Only one technician was necessary per shift, and the technician recorded the data and performed all the other operations necessary for the maintenance of the experiment. The technicians were also responsible for the management of the food supplies, restocking the TO drawer, preparation of materials for delayed reinforcements (for example, the projection of movies), as well as the description of any special events. The day to day conduct of the experiment, therefore, was readily handled by only one technician. Manipulations in experimental conditions, the preparation of PI and VB materials, the selection of the specific delayed reinforcers, etc., were pre-arranged by the experimenters. The automatic recording of results and the continuous monitoring of the subject by visual displays, the TV cameras, and the intercom system permitted very close contact with the subject's moment to moment performance.

Experimental Subject

The subject in the present experiment was Whilden P. Breen, Jr., age 34 years. Mr. Breen joined the laboratory staff approximately one year before the beginning of the experiment. His initial interests were in serving as an experimental subject and/or as a research assistant with the project. Following a period of assistance in the construction and preparation of the experimental chamber, Mr. Breen was selected to be a test subject on the basis of preliminary physical, psychological and psychiatric examinations, and his desire to contribute to behavioral science in this particular way.

Mr. Breen was born on December 11, 1927, in Birmingham, Alabama. He received his A.B. degree in History from the University of Alabama in 1955, and completed a year of post-graduate work in History toward an M.A. degree in 1961. Mr. Breen is married, has served as an officer in the U.S. Army, has taught Social Studies and Physical Education in the Alabama Public School system, and has had a variety of employment experiences in the business world.

Preliminary Training

Mr. Breen entered the experimental chamber for a preliminary training period of three days to acquaint him further with the behavioral program and the living conditions of the chamber. This preliminary training period also was employed to test and refine procedural techniques for the experimenters and assistants, and also to assist the experimenters in making some decisions concerning the response and minimum time requirements for several activities to be used in the experiment proper. The preliminary test of the environment indicated the feasibility of proceeding with the experiment. Following a two week period of further preparation, Mr. Breen entered the chamber for an indefinite period.

The Experiment Proper

In the experiment proper, the initial behavioral requirements for each activity were determined partly by the results of the preliminary training session and partly on the basis of intuitive judgments as well as by some practical considerations. Thus the minimum time requirements for the weight and temperature activities were determined by the characteristics of the recording devices. The minimum time and response requirements associated with WK1, WK2, and PI, VB, and MB were arranged to produce work periods of approximately one hour for each activity. The number of selections possible in Activity Group 8 was set at a value of four as a best estimate in order to permit access to food, cigarettes, music, and a delayed reinforcement in each Wake Trip without permitting excessive accumulation of any of these reinforcements. In the case of the delayed reinforcements, practical considerations required that these activities be maintained at low frequency levels, and therefore the response requirements were set relatively high. The number of responses required per selection for VC, OC, and REQ was set at 200, 200, and 50 respectively, and the number of selections required for delayed delivery of the reinforcements was set at 15, 5, and 5 respectively. The initial settings on the PE activity (not included in the preliminary training) were arbitrary. During the course of the first few trips, several values were explored before selecting a value which produced a vigorous and sufficiently sustained exercise period.

During the five months, or 152 days, in which Mr. Breen remained in the chamber, a number of procedural manipulations were made by the experimenters. The subject's behavior also resulted in some changes in the form of the introduction of new materials and special events. In addition, a few temporary apparatus difficulties occurred during the experiment. Performance changes were related to the duration of the social isolation and confinement conditions of the experiment and to the effects of the specific environmental changes referred to here. The details of these environmental changes and manipulations will be presented in the Results and Discussion section as the performance in each activity is described individually.

RESULTS AND DISCUSSION

The data will be discussed as they are presented. First, an overall view of some of the major changes throughout the five month course of the experiment, as expressed in the distribution of percent times the subject spent in the different groups of activities, will be given. Following this broad overview, a more detailed analysis of performance changes within individual activities will be presented. In addition, the effects of specific manipulations in the program as they affected one or more activities will also be presented. At the end of the section describing performance changes within the individual activities, additional data will be presented that was gathered from behaviors that were not a formal part of the program, for example, dancing, requests for medical needs, various complaints, and general observations.

Figure 3 presents a group of curves summarizing the percent times that the subject spent in each main section of the program, plotted for the entire experiment. This figure shows some of the general findings of the experiment. Many of the fluctuations in these curves are related to special effects that will be described as the activities are treated individually.

Examination of the percent time spent in Sleep (Figure 3-A) reveals very little, if any, systematic change in the percent time measure, indicating that the subject suffered no undue sleep loss nor did he sleep excessively, on the average, throughout the experiment. However, measures of duration and frequency of sleep showed certain systematic changes, and these will be presented subsequently. The sharp drop in percent sleep time at Point A (the period between days 35 and 45), represents a period in which wide fluctuation in wake-sleep cycles occurred. This drop suggests considerable loss of sleep during this period. It was during this time, however, that the subject took a number of unauthorized "naps," particularly during the TO activity, and this partially offset the loss of sleep suggested in the percent sleep curve. In general, then, the subject spent approximately one third of his time in the Sleep activity over the course of the experiment.

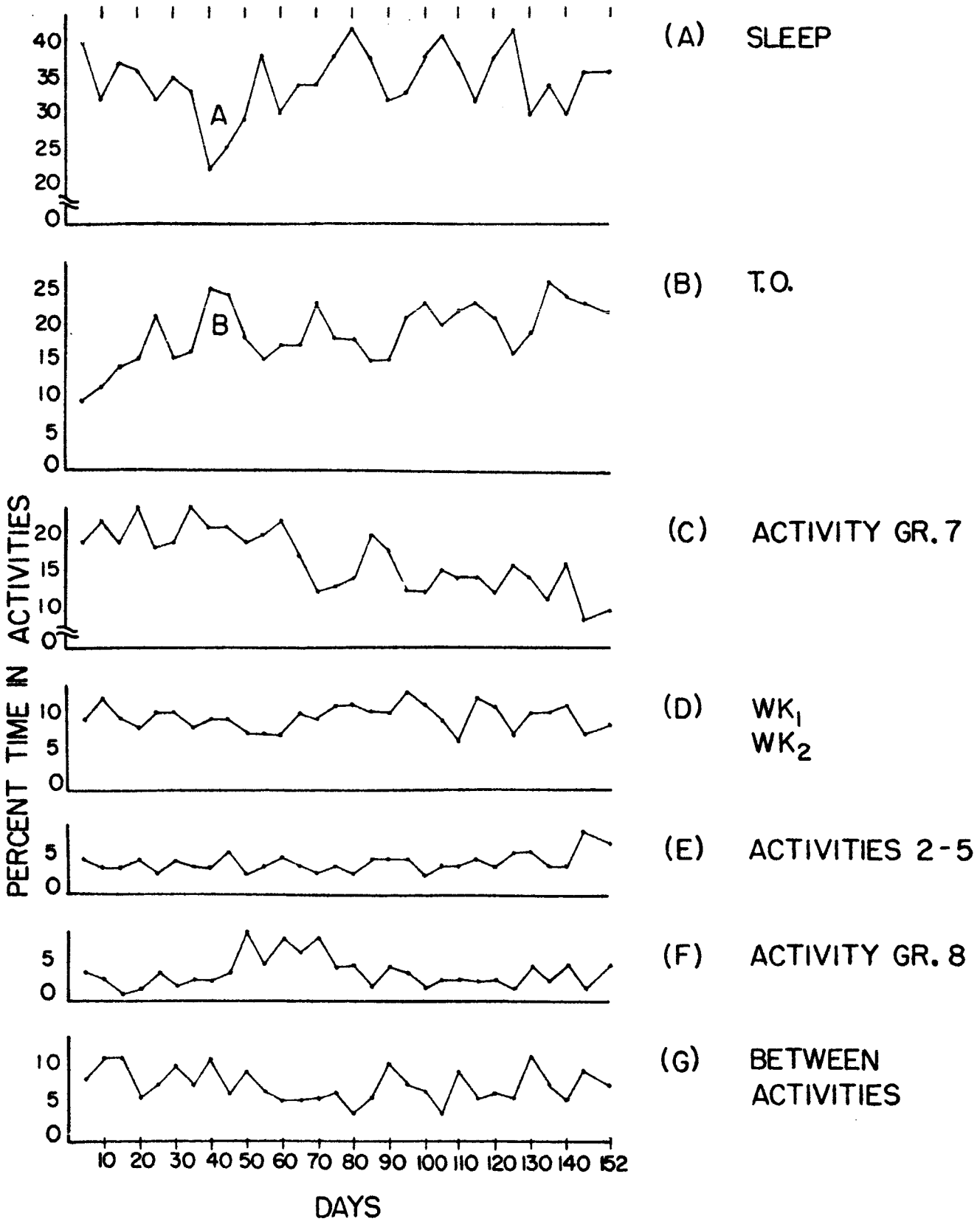

Fig 3. Distribution of percent times the subject spent in some of the activities and groups of activities for the duration of the experiment.

Figure 3-B presents the percent time the subject spent in the TO (Toilet Operations) activity. One of the major effects of the experiment is described by this curve. The percent time that the subject spent in this activity gradually rose from an initial value of approximately 10 percent to a final value of approximately 25 percent. This rise in percent time in TO is not related to any increase in the time spent sleeping in TO, with the exception of Point B in this figure, which is closely related to Point A in the percent sleep curve. The general trend of a systematic rise in percent time in TO was not compensated for by a general fall in percent time spent in the Sleep activity. The increase in the amount of time that the subject spent in the TO activity, the first member in the chain of activities, strongly suggests an effect related to behavioral "strain" observed in other experimental procedures (Ferster and Skinner, 1957). The significance of this effect in the present experiment is not related only to the absolute rise in time in TO, but is, in addition, related to the particular compensatory shifts in percent time in other parts of the program. More specifically, this rise in percent time in TO was most closely related to a systematic decrement in percent time in the 7th Activity Group, that is, Programmed Instruction, Verbal Behavior and Manual Behavior, as shown in Figure 3-C. No other group of activities showed a systematic fall in percent time in compensation for the rise in percent time in TO. In general, the 7th Activity Group represented intellectual and creative activities, while those of TO reflected preparatory behaviors and bodily maintenance activities prior to entering the program. This finding of the rise in TO time and the decline in time spent in Activity Group 7, will be amplified as the activities are treated individually.

The percent time that the subject spent in Work Tasks 1 and 2 combined is shown in Figure 3-D. The percent time in the two activities combined remained relatively stable throughout the experiment, although certain systematic fluctuations between these two activities did occur which will be shown in the results for the individual activities.

The percent time spent in activities 2 through 5 (Flight Duration, Weight-Temperature, Physical Exercise, and FD1) is combined in Figure 3-E. The percent

time spent in these combined activities remained relatively low and stable during the experiment except for a final rise attributed to the FD1 activity.

Figure 3-F shows the percent time spent in all the activities in Activity Group 8 combined. These activities were the terminal members of the behavioral chain, and provided important reinforcements for the subject. The percent time spent in Activity Group 8 remained low and stable throughout the entire experiment, except for the period from approximately days 45 to 85. It was during this period that a cigarette experiment, which will be described later, was in effect, and the rise in percent time is accounted for by the large response requirements and the resulting pausing behavior, particularly during the Cigarette activity. Changes in performance in earlier members of the behavior program were not reflected as changes in percent time in the reinforcing activities at the end of the program.

Figure 3-G presents the percent time spent in the period of time between the end of one activity and the beginning of the next. These are labeled as the percent time "between activities." The percent time spent in these parts of the program showed no systematic trends. The high value for this curve may be accounted for by the high frequency of its occurrence. That is, before and after every activity, some time will accumulate for this measure, and this curve does not, therefore, reflect undue pausing between activities. As the experiment progressed and the subject showed progressive strain, decrements in performance were revealed not by increasing latencies before entering into activities, but these decrements were revealed in performance changes within activities, some of which have already been shown in the TO activity and in Activity Group 7.

TO (Toilet Operations)

The Toilet Operations (TO) activity was the first activity in the program, that is, the first activity in any trip. A trip was terminated when the subject left the Sleep activity and returned to the TO activity, or, alternatively, when the subject completed the entire program through Activity Group 8, and then returned to the beginning of the program. Therefore, the TO activity followed either the completion of Sleep or the completion of the full program. Figure 3-A showed the gradual increase in the percent

time spent in the TO activity, and Figure 4 now divides the time in TO into its component parts, that is, the TO's that preceded the selection of sleep versus the TO's that preceded the completion of the full program. The ordinate presents the amount of time spent in TO by hours. The upper curve presents the rising total time spent in TO for wake trips and sleep trips combined, the middle curve for wake trips only, and the lower curve for sleep trips only. A clear separation in functions is apparent. The sleep curve failed to change systematically during the experiment.

The behavior of the subject was normally under good stimulus control in that activities which could occur outside their prescribed location in the program generally did not occur elsewhere in the program. However, the subject did sleep on the floor of the chamber during the TO activity at various times during the experiment. The cumulative frequency with which the subject was observed sleeping on the floor in other activities (predominantly in TO) is shown in Figure 5. This behavior occurred principally in the period between days 35 and 45.

In Figure 4 the early rise in total TO time at Area A is accounted for by the rise in TO time for wake trips only, which, in turn, is related to a temporary breakdown in stimulus control, with the subject sleeping frequently in this activity at this time. Taking this effect into consideration, the total time in TO can be seen to rise gradually throughout the entire experiment and is almost entirely the result of a parallel rise in TO time in those trips in which the subject subsequently proceeded into the full program, that is, the Wake Trips. The increasing TO time for Wake Trips is perhaps best accounted for in terms of the consequences of entering the full program. That is, a decline in the reinforcing properties of the full program or its parts would generate the kind of pausing or strain seen here. This kind of effect has already been reported in the research literature at lower animal levels (Findley, 1962).

The rise in TO time was not related to changes in behavior concerned with the maintenance of bodily needs or care of the chamber. This was shown by an examination of the frequency with which the subject used the various facilities available during TO (Figures 6, 7, 8, and 9). No progressive effects of any kind were noted with respect to the use of the shower facility, which was used approximately once per day, nor with

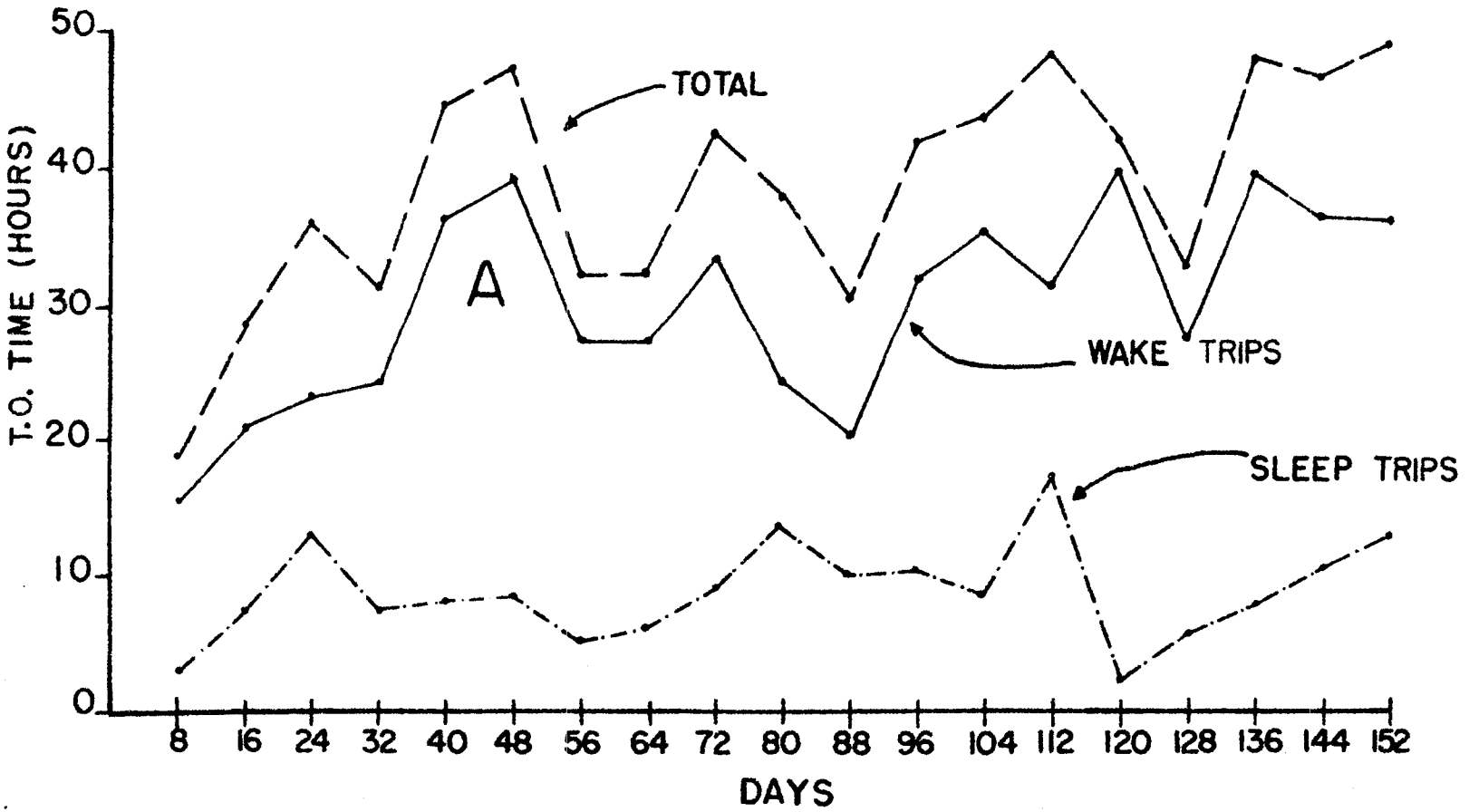

Fig 4. Total time in the Toilet Operations activity and the two components of this curve, T.O. time in Sleep trips and Wake trips.

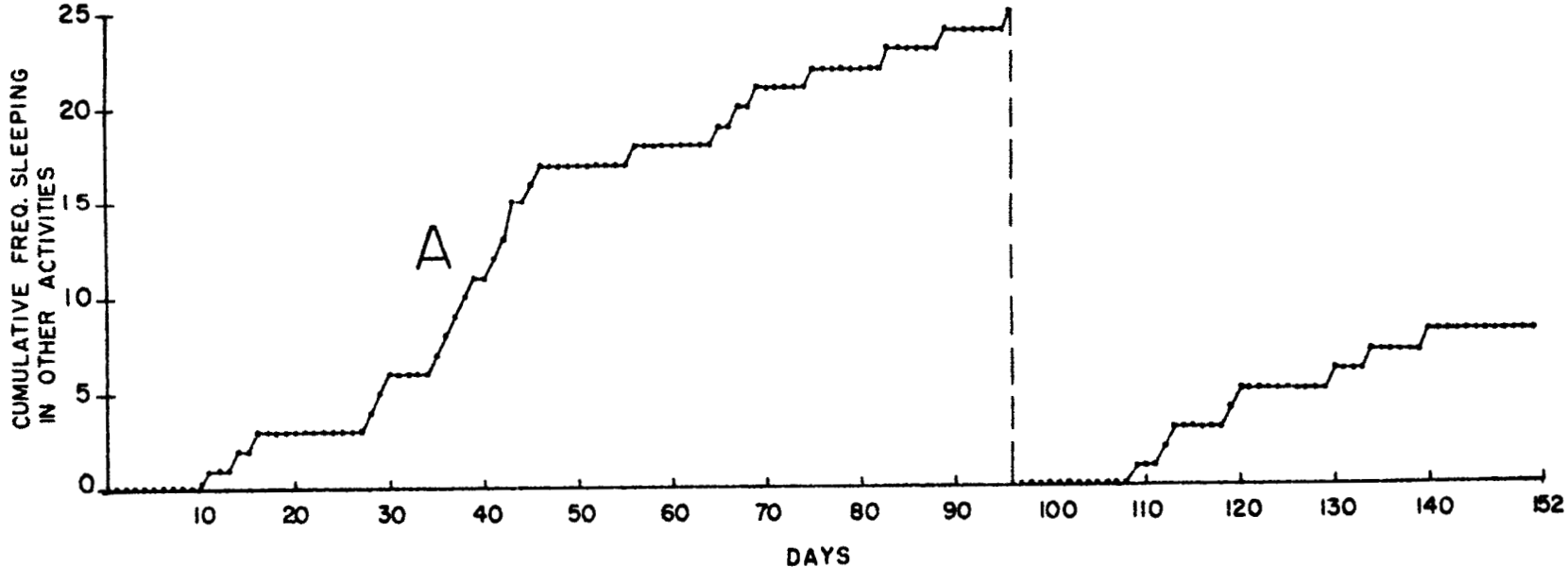

Fig 5. Cumulative frequency subject was observed sleeping on floor of chamber.

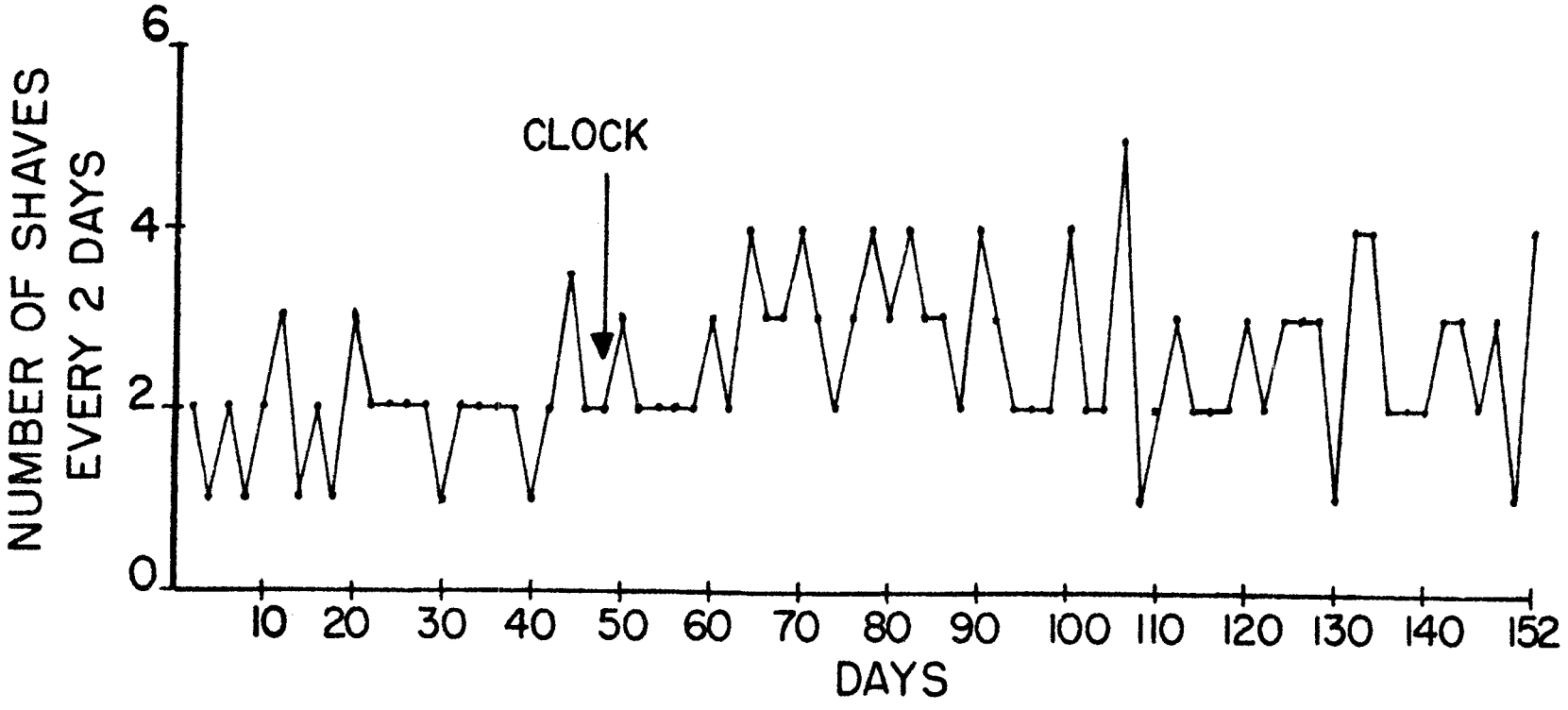

Fig 6. Number of shaves taken every two days of the experiment.

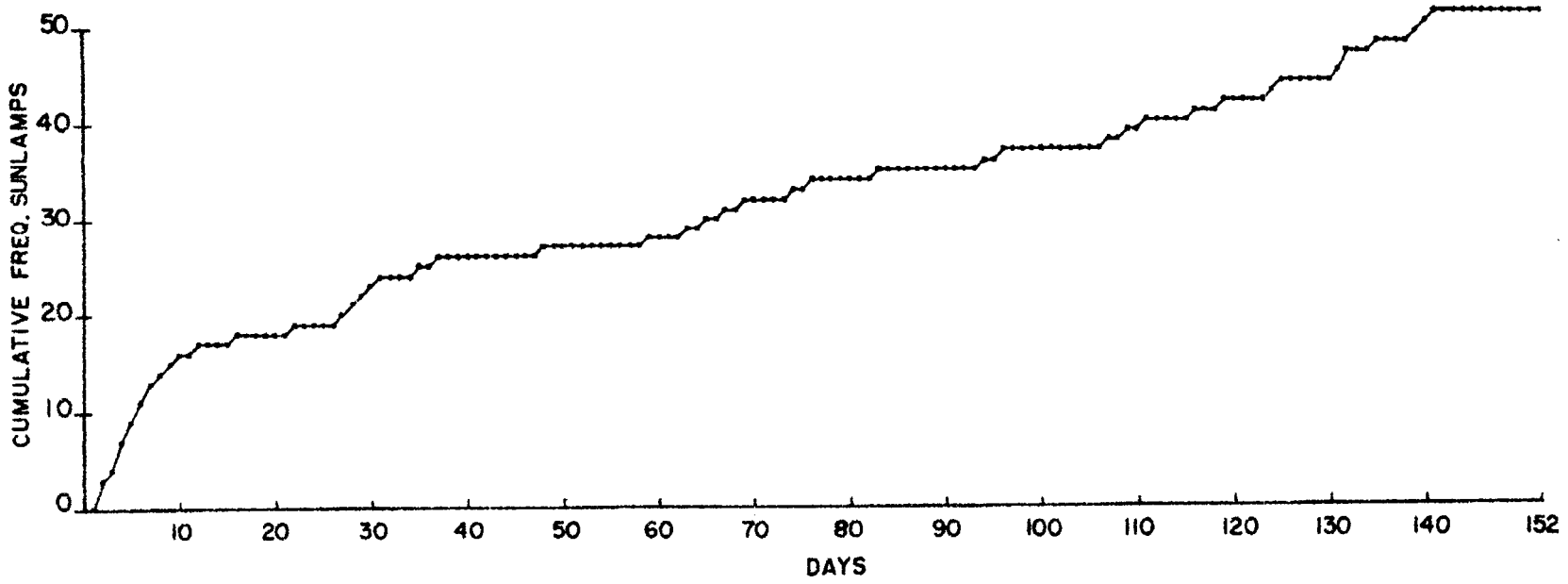

Fig 7. Cumulative frequency of use of the sunlamp facility for the entire experiment.

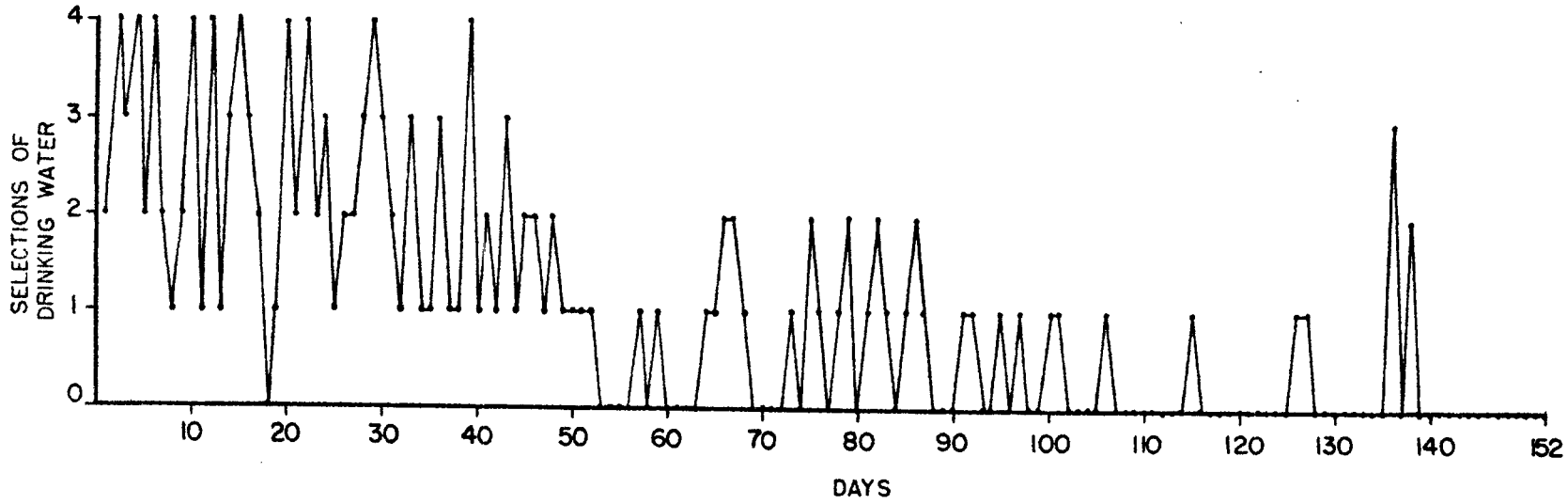

Fig 8. Frequency of use of the fresh drinking water facility for the entire experiment.

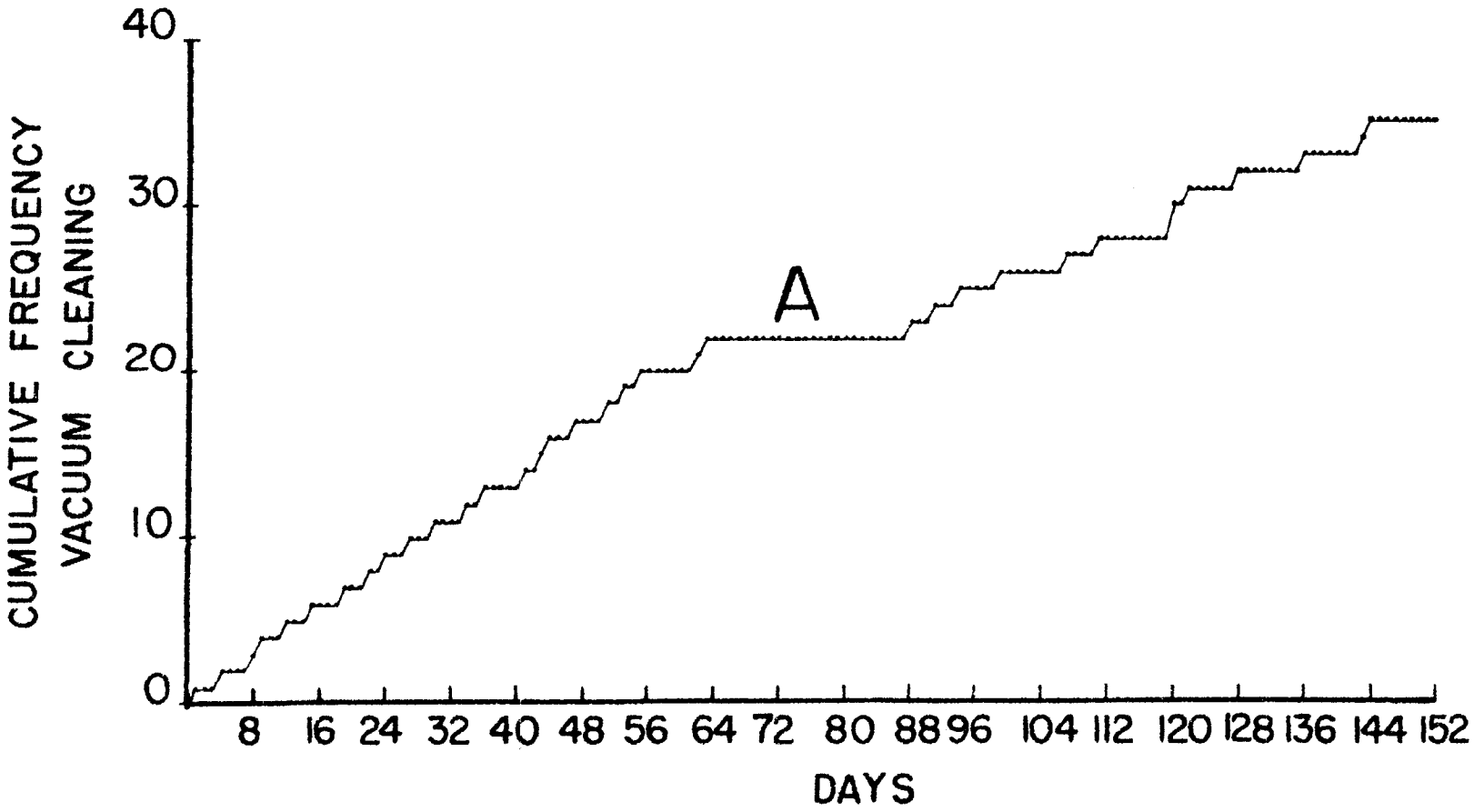

Fig 9. Cumulative frequency of use of the vacuum cleaner for the entire experiment.

respect to the basin facility, which was used approximately three times per day. The frequency with which the subject used the electric shaver (Figure 6) increased from less than once per day to approximately one and one-half times per day. This increase followed the introduction of a clock into the environment, and may be related to the stabilizing effect of the clock on the subject's wake-sleep cycles (described below). Prior to this time, no external cues for the passage of time were available to the subject. Other effects of the introduction of the clock will be described below.

In the first ten days of the experiment, the sun lamp facility was used frequently (Figure 7), but thereafter it was selected at a considerably lower rate, and this low rate was maintained throughout. No precise explanation for this can be given. This effect might be related to the absence of any discriminable consequences for becomming suntanned in this environment.

The fresh drinking water facility was selected at a high, stable rate during the initial 40 days of the experiment (Figure 8). The frequency then declined to low levels and occurred very rarely in the terminal stages of the experiment. On day 121, the subject reported to the experimenters that he was obtaining his drinking water from the basin rather than from the drinking facility, and had been doing this for some time. His reason was that in his opinion the water from the drinking source had lost its quality and had become rusty. No detectable change in the quality of the drinking water, however, could be observed by the experimenters, who also obtained drinking water for their own consumption from the same cooling source. In addition, the subject expressed some question about the possible introduction of drugs into the water from the drinking facility, although no drugs were actually introduced.

The subject used the vacuum cleaner during the TO activity at a low and somewhat declining rate throughout the experiment (Figure 9). At Point A, a complete depression of the rate can be observed. It was during this time that the percent time spent in Activity Group 8 increased noticeably, as shown earlier. During this period the response cost requirements for cigarettes were at their highest values. It seemed most reasonable to account for the disruption in the use of the vacuum cleaning facility

in terms of the concurrent experimental manipulations in the cigarette activity, although the precise mechanism by which this relationship would be established cannot be described at this time. A number of other effects of the cigarette experiment will be described subsequently.

It is clear, therefore, that the increase in time spent in the TO activity cannot be based on an increase in the frequency of use of the facilities available during TO. Visual observation of the subject through the use of the closed circuit TV monitoring system revealed that the rise in TO time was more readily accounted for by the emergence of time-consuming behaviors in the TO activity, for example, excessive sitting, resting, pacing, and general "milling" about.

Sufficient data on the activity level of the subject is not available for presentation, since the subject failed to report his actometer readings on a regular basis after the first few weeks of the experiment. This was probably related to the absence of any programmed consequences for reporting these readings.

Several of the less quantitative results associated with the TO activity, for example, the frequency of somatic complaints and requests for medical supplies, will be presented in a subsequent section.

FD (Flight Duration)

During the course of the entire experiment the subject selected the flight-extend button a total of 459 times, and selected the flight-reduce button a total of six times. The few reduce-flight "responses," which had no direct effect on the duration of the experiment, showed no cumulative trend, and were probably related to transient emotional states in the subject. For example, a flight-reduce response followed the increase in response requirements for the Physical Exercise activity, which will be described further below. In general, the predominant selection of the flight-extend response throughout the experiment, and the absence of a single flight-reduce response in the last 19 days of the experiment, stands in sharp contrast to many other quantitative and non-quantitative indications of accumulating performance decrements and behavioral strain to be presented in this paper.

W-T (Weight-Temperature)

The subject completed several trips per 24 hour period, and an indication of daily weight was obtained by plotting the mean of all the readings per day, excluding any unreliable readings resulting from excessive movement by the subject on the ceiling bar.

Figure 11 presents the weight of the subject for the entire experiment and reveals that the total weight gains and losses over the entire experiment remained within a range of approximately 10 pounds. This rapid decline in body weight was probably based in part upon the sudden change in the subject's daily diet, and, in addition, to the regular and vigorous PE activity. This period of rapid decline in body weight over the first 25 days was related to the acquisition stage of the PE1 activity in which many errors occurred. After approximately day 25, the subject's accuracy on the exercise tasks had reached stable levels. Although there were some fluctuations from day to day, the subject's body weight remained quite stable from days 30 through 105 to 110. A final trend in body weight was seen as a small but consistent weight increase beginning at approximately Point A, with the subject's body weight rising from about 181 to 185 pounds, and remaining at that level until the end of the experiment. This rise in body weight during the latter part of the experiment was most closely related to changes in the PE program. That is, the subject was permitted to bypass the PE activity frequently, as will be described, and, in addition, the other requirements in the activity were reduced. The rise in body weight following these changes was delayed by approximately ten days. On day 121, the subject was given a 24 hour "vacation" which will also be discussed in detail subsequently. After this vacation the general quality of the food was improved for the remainder of the experiment. The rise in body weight to the level of about 185-6 pounds occurred prior to this improvement in food and should, therefore, probably be attributed to the reduction in frequency and difficulty of the PE activity.

Following the weighing procedure, the subject was required to take his oral temperature by inserting the probe into his mouth for 20 seconds. Apparatus difficulties

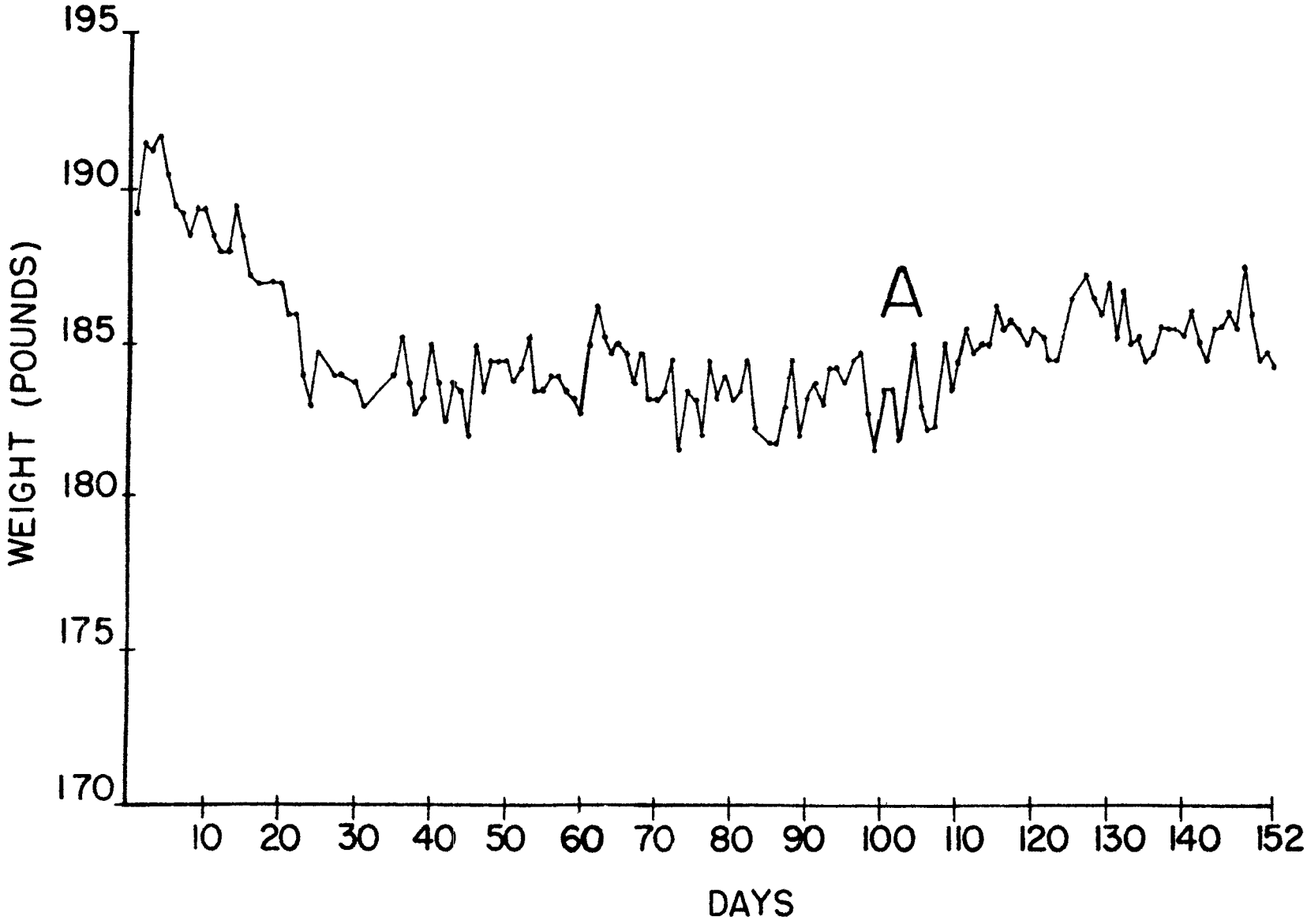

Fig 11. Mean daily body weight of subject for entire experiment.

associated with this activity resulted in the loss of confidence in the measure, and so this data will not be presented. The subject, however, continued to complete this aspect of the program throughout the experiment, in spite of the measurement problems being encountered by the experimenters.

PE (Physical Exercise)

Figure 12 presents a plot of the cumulative frequency with which the subject selected the PE activity. From the beginning of the experiment until day 87, the bypass switch for the PE activity was not available, except during brief periods of apparatus difficulty (Point A). On day 83, Point B, the required number of correct responses for PE1 was doubled from 50 to 100, and the response requirement for PE2 was also doubled from 20 to 40. Prior to this time the frequency of selection was highly stable, since the PE bypass switch was not available and the activity was required in each trip. When the response requirements were doubled, the subject emitted many verbal complaints about the change that had been made. On day 87, Point C, the subject made one of his rare flight-reduce selections in the FD activity. Later in the same trip, the subject entered the PE activity, and during PE1 he accused the experimenters of manipulating the time requirements for the activity without the usual notification. A short time later in the activity, following further verbal agitation, the subject violently threw one of his chairs across the room. At this point the PE bypass switch was operated by the experimenters, and the subject was automatically moved into the next activity in the program. In addition, the experimenters made the PE bypass switch available to the subject for use in subsequent trips, as indicated by Area D. Within the next five days, during which time these conditions remained in effect, the subject bypassed the PE activity on every occasion except one. On day 91, the response requirements were reduced from 100 to 25 responses. In addition, a change was made in the temporal boundaries for the PE1 activity. Specifically, the subject now had to press the button associated with the illuminated pilot light after one second had elapsed, but not after two seconds had elapsed. Prior to that time, the same one second interval had been in effect, but the subject had to press the button a minimum of two seconds after the light had come on, but not later than three seconds. Therefore,

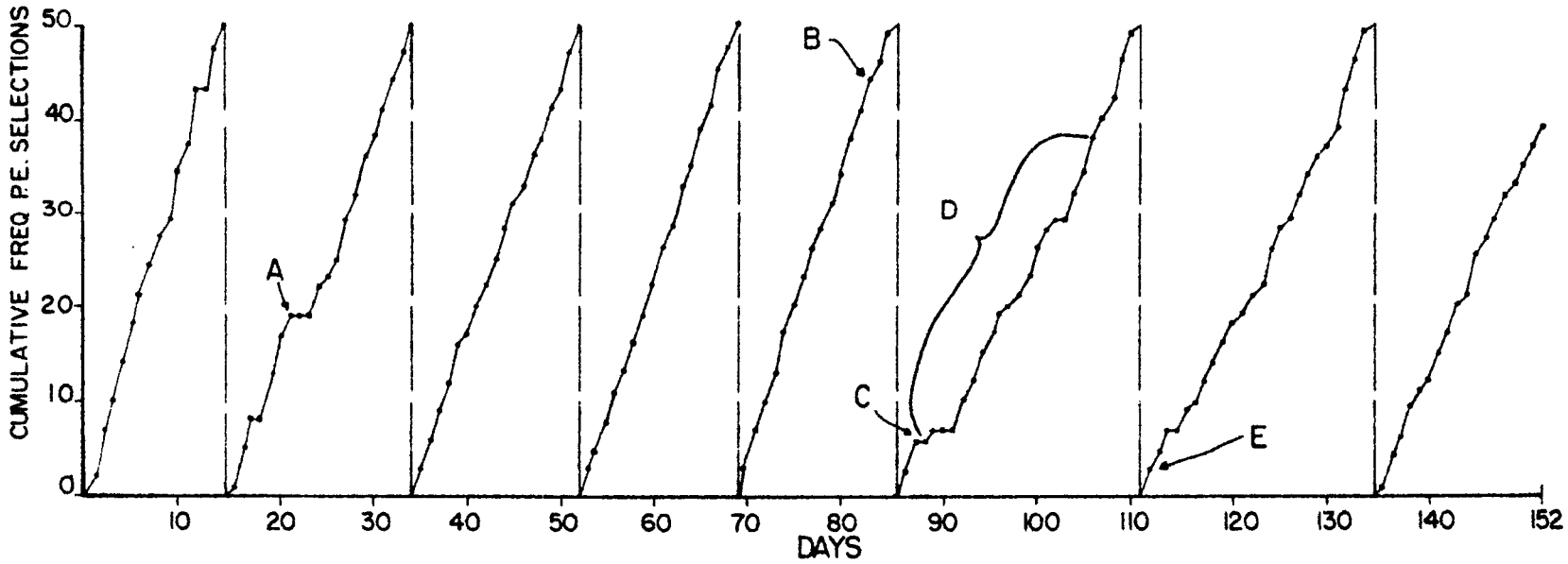

Fig 12. Cumulative frequency of selections of P.E. activity for entire experiment.

on day 91, PE1 was considerably more challenging in the sense that the minimum possible travel time from one light to the other (including the time required to locate which of the five lights was on), was probably being approached, although the reduction in the correct response requirements to 25 substantially reduced the total effort required in PE1. Following these changes on day 91, the subject began selecting the PE activity again. The response requirements for PE1 were further reduced to 20 on day 94. After the subject's rate of selection of PE had resumed, the bypass switch was again removed from this activity. On day 112, Point E, as the delayed reinforcement for an earned requisition, the bypass switch was made available again after two complete trips through the program per 24 hours. From this point until the end of the experiment, the rate at which the subject selected the PE activity was fairly stable, but substantially lower than the rate during the first 90 days of the experiment.

Performance with respect to percent errors in PE1 is presented in Figure 13. Errors in which the subject responded too quickly or too slowly were combined for this figure. The temporal boundaries for the PE1 activity were stabilized on day 4. PE1 was removed from the program because of apparatus difficulties at Point A. In the first 21 days the subject made many errors in PE1 with considerable variability in performance. This period corresponds to the period of rapid loss of body weight shown earlier. Observation of the subject over the closed circuit TV system indicated that he tried numerous variations in procedure with respect to the PE1 activity, and this presumably accounted for much of the variability. During this period the subject frequently complained about the lack of stability in the PE1 task, although no changes were actually being made. After day 30 the task essentially had been mastered by the subject in terms of accuracy, and he was observed to have adopted a consistent response pattern. During the activity he gave the appearance of a skilled tennis player bounding about a tennis court.

At Point A the response requirements were reduced to 25 and the temporal boundaries were made more severe. The percent errors increased greatly, but there were no observed emotional effects, and, although the subject had the bypass switch available during this time, the activity was selected regularly. Therefore, the emotional

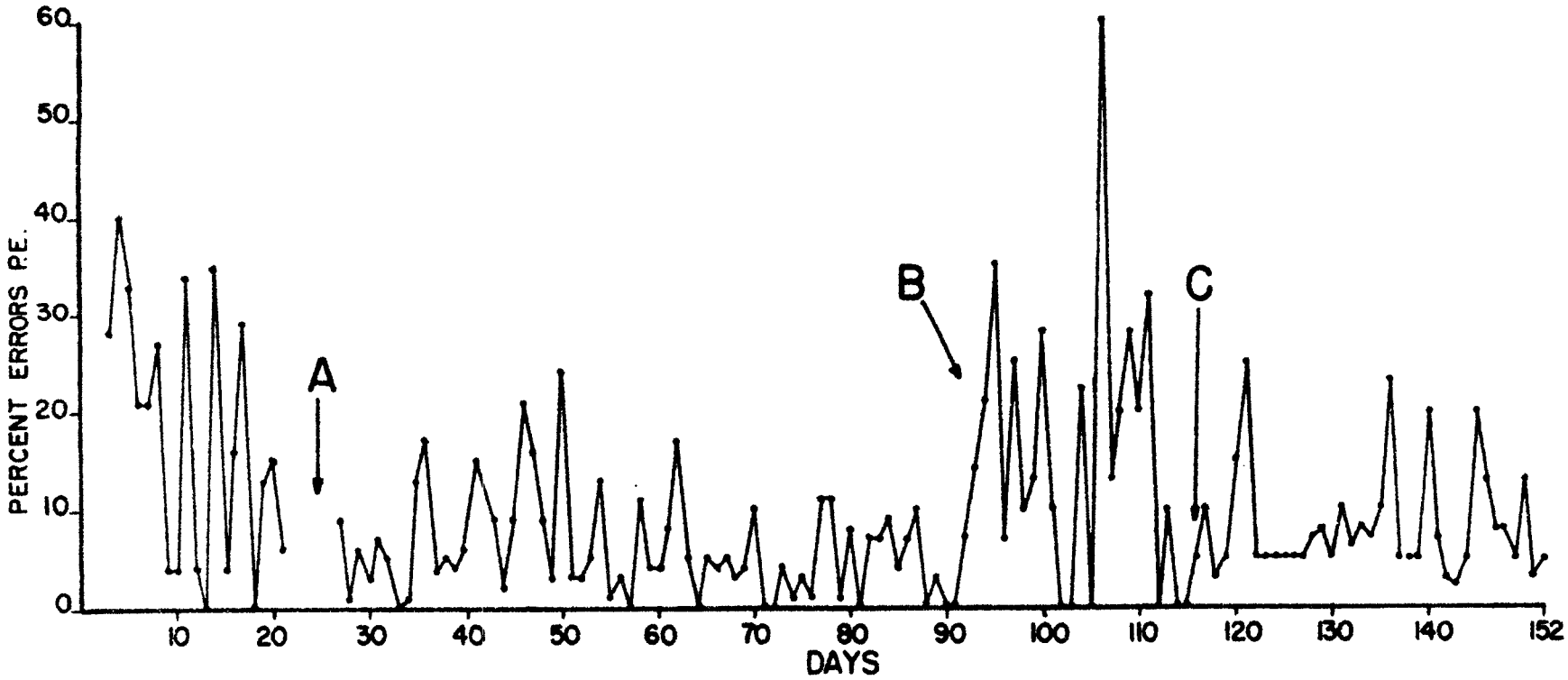

Fig 13. Percent error in P.E. 1 resulting from responses that were made before the minimum or after the maximum time limits.

effects observed earlier, when the PE1 response requirements were doubled, were determined primarily by the increase in the number of response requirements and not by a deterioration in accuracy. On day 115 the temporal boundaries were altered in two ways. The minimum response time was raised from one second to one and one-half seconds, the the maximum response time was raised from two seconds to three seconds, giving a "safe" period of one and one-half seconds over the earlier safe period of one second. This change is noted at Point C. The effect of these changes on the percent error performance in PE1 was indicated by considerable improvement in performance. During the latter phase of the experiment, therefore, the PE1 activity had been made considerably less vigorous and challenging in terms of the response requirements, in addition to the availability of the PE bypass switch.

PE2 was much less difficult for the subject, and his performance in this part of the PE activity was generally uneventful throughout the experiment. In general, the PE1 and PE2 activities maintained the subject in good physical condition during the experiment.

FD1 (Snacks)

Food One (FD1) was the first activity in the program in which the subject could obtain food. Figure 14 (top panel) presents the cumulative frequency with which the subject selected FD1 throughout the experiment. Although he could always bypass the activity, the rate of selection was relatively high and quite stable throughout. However, an examination of the duration of time spent in FD1 revealed a consistent increase, particularly in the latter third of the experiment. This increase in the amount of time spent in FD1 suggested an effect parallel to that found with respect to the TO activity. Since FD1 preceded the selection of either the Sleep activity or the full program, a further analysis of the FD1 duration measure was made in terms of Sleep Trips versus Wake Trips. This data is presented in Figure 15, which shows the mean duration for FD1 for Sleep Trips versus Wake Trips. The mean duration for FD1 prior to entering the full program showed a gradual rise, particularly in the later parts of the experiment. On the other hand, the mean duration of FD1 prior to selection of the Sleep activity was generally lower, although some long durations occurred near the end

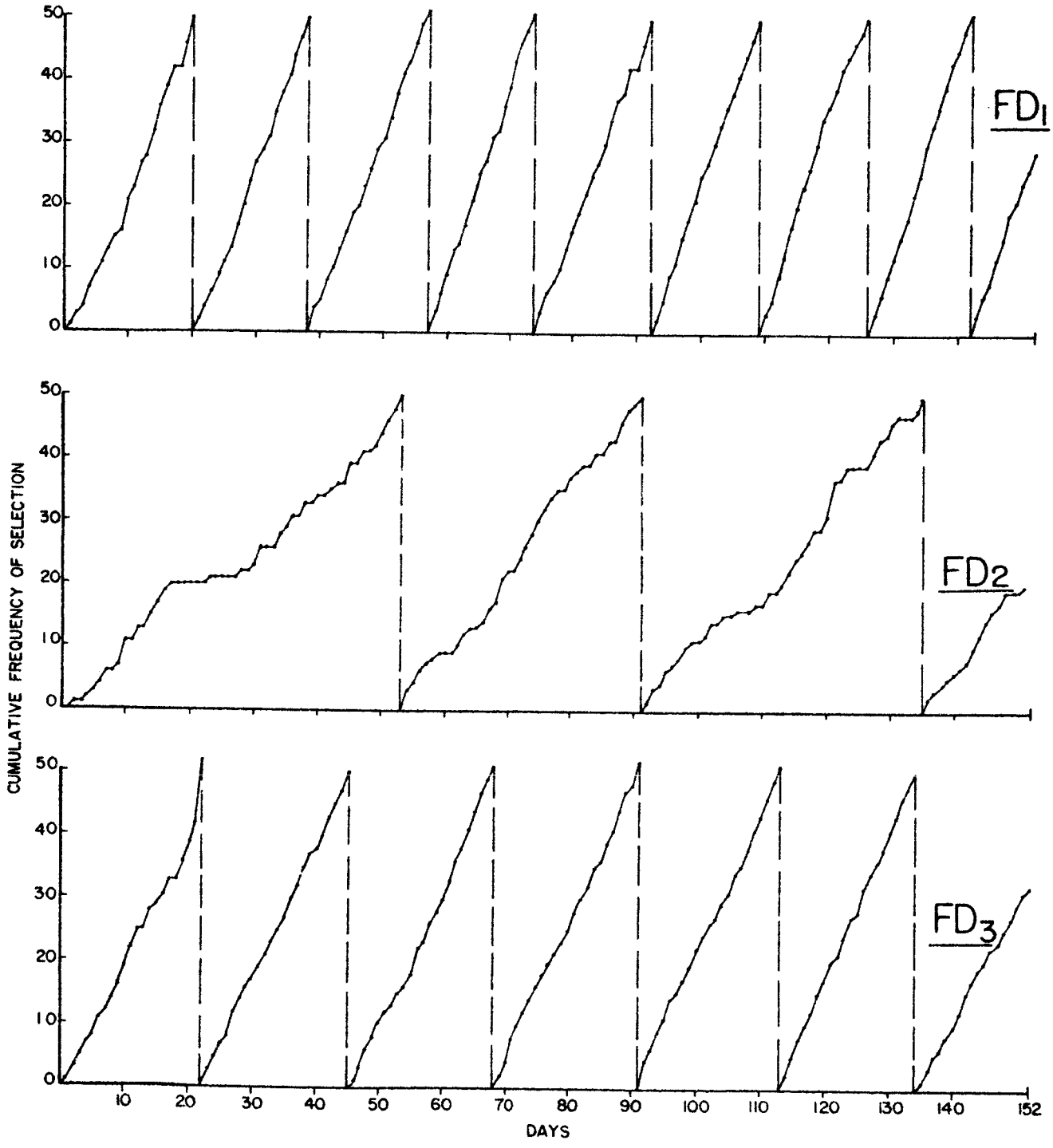

Fig 14. Cumulative frequency of selection of FD1, (top panel) FD2, (middle panel) and FD3 (lower panel) for entire experiment.

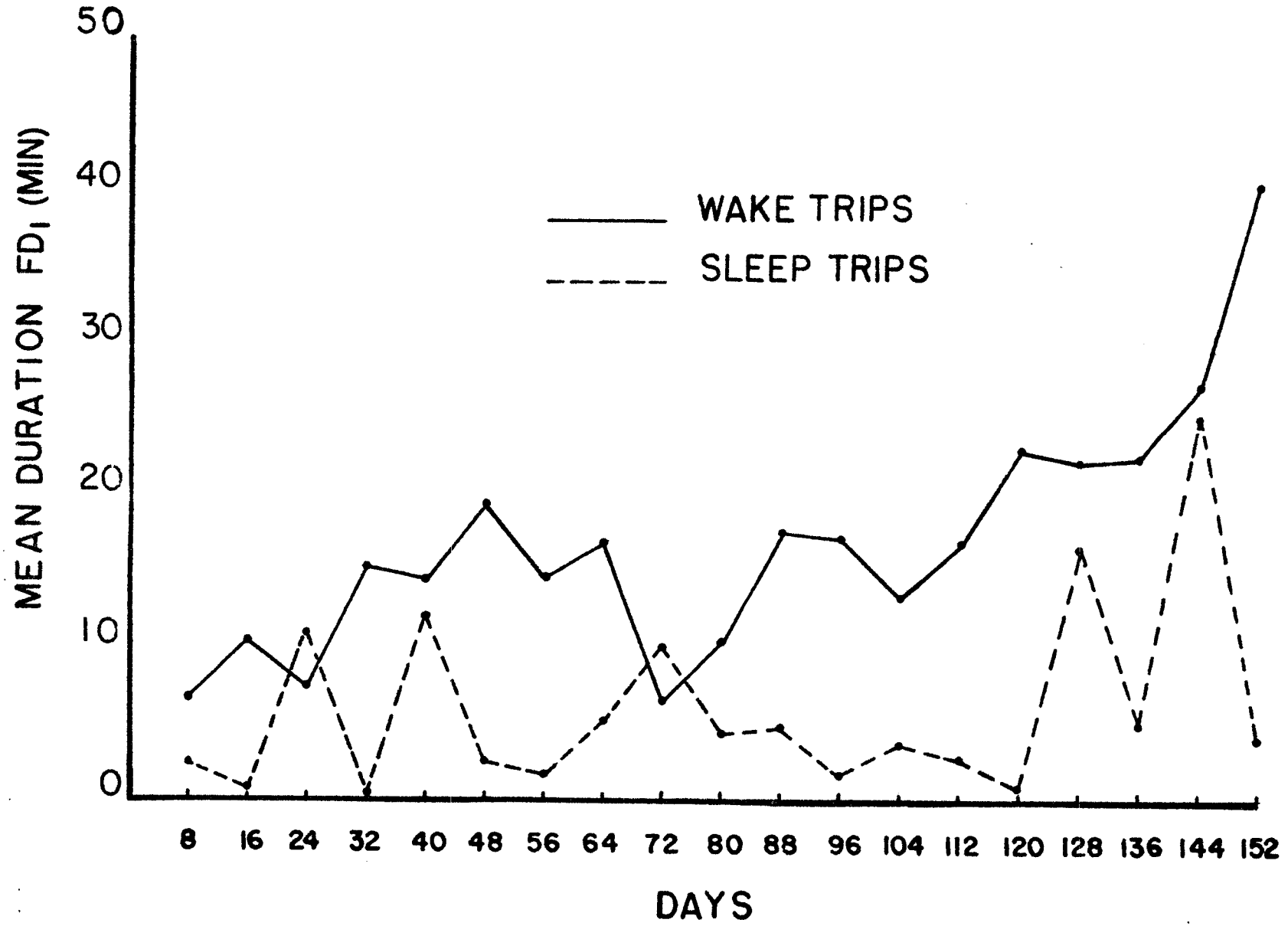

Fig 15. Mean duration of FD1 in Sleep trips and Wake trips plotted separately. Data is plotted in 8 day groups.

of the experiment. This parallel effect in FD1 and TO suggests the same analysis that was made for the TO data, namely, that rising durations, particularly during wake trips, are probably best accounted for in terms of pausing or straining generated by the weakening reinforcing properties of later activities in the program.

From time to time the subject expressed some dissatisfaction with the food. The frequency of occurrence of these food complaints will be presented in a later section.

SLP (Sleep)

After the subject completed the FD1 activity he could then select one of three options in Activity Group 6. These three choices were WK1, WK2, and Sleep.

Figure 3-A showed that the percent time the subject spent in the Sleep activity revealed no consistent trend throughout the experiment. Some fluctuations in the percent sleep time were noted, but no overall marked sleep loss or deprivation nor excessive sleep was observed. The following data will present a more detailed analysis of some other aspects of performance in the Sleep activity. These performance changes involve more subtle changes in this activity, that is, shifts in the relative wake-sleep cycles, duration of the period, mean duration of sleep, and frequency of sleep.

Figure 16 presents a histogram showing the duration of each wake and each sleep period. The top panel of this figure reveals that the subject's initial wake-sleep cycles were quite variable. During this time there were numerous wake periods in excess of 30 hours, and many sleep periods from 10 to 15 hours in duration. In addition, considerable variability in wake-sleep durations can be observed.

On day 49 of the experiment an electric clock was introduced into the chamber as a delayed reinforcement for an earned Variable Consequence. The clock remained in the chamber for 73 days. As shown in the middle panel of Figure 16, the introduction of this clock substantially reduced the number of occasions on which the subject remained awake for excessive periods of time, and reduced the variability of the wake and sleep cycles. During the initial period in which the clock was absent, the subject had been most likely unable to discriminate low long he had been asleep or awake, as indicated by his occasional comments to this effect. The clock was removed for 15 days, and then returned for the duration of the experiment, as shown in the lower

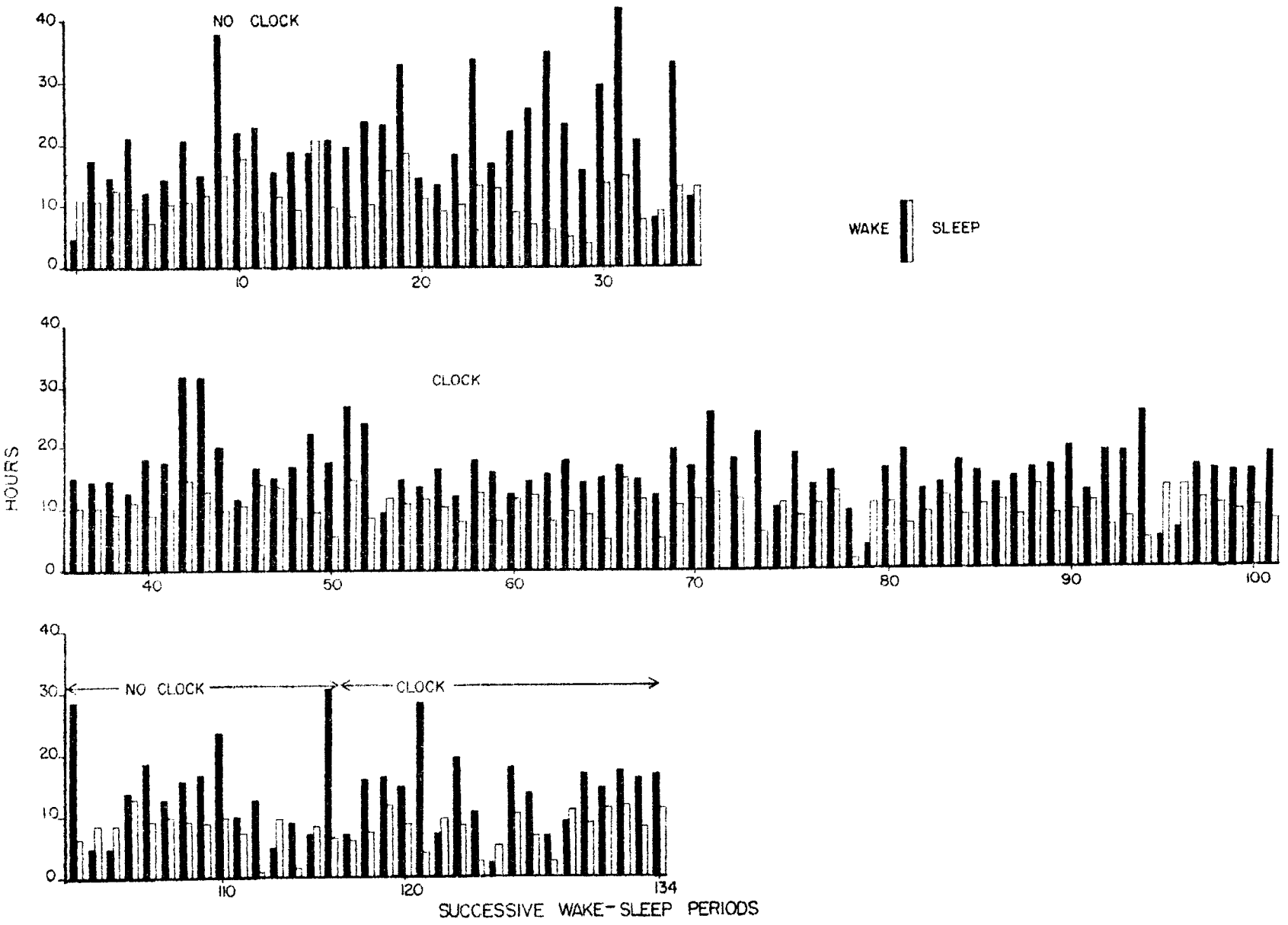

Fig 16. Duration of each wake (black bars) and each sleep (white bars) period for duration of experiment. There were 134 wake-sleep cycles in 152 days.

panel of Figure 16. Some slight disruption of the wake-sleep cycles may be observed, and although the subject expressed his dissatisfaction at the loss of the clock, the erratic wake-sleep patterns seen prior to the introduction of the clock did not return. The effect of the clock, therefore, was found not to be reversible. This lack of reversibility may be related to the relatively short period for which the clock was removed to other unknown variables.

During the latter phases of the experiment when few excessive wake periods occurred the subject made frequent comments indicating his feelings of fatigue, in contrast to the absence of such comments during the earlier period when many extreme wake durations occurred.

The addition of a consecutive wake time and sleep time defines a "period" for the subject. 134 such periods (or "days" for the subject) occurred during the 152 days of the experiment. The duration of these periods is plotted in Figure 17. The horizontal line intersecting the middle of the figure indicates what would be a "normal" 24 hour period. Prior to the introduction of the clock, the periods were quite high and variable. After the clock was introduced, the variability and duration of the periods was gradually reduced. In addition, several very short periods emerged while the clock was present. These shorter periods became more frequent as the experiment progressed independent of the presence or absence of the clock. In general, a progressive decline in the period can be observed throughout the experiment from initial levels considerably in excess of 24 hours to final levels well below 24 hours.

In terms of the real time of day, the time that the subject selected the Sleep activity was independent of the outside environment. Instead, the subject selected Sleep as a function of the events within his own environment. When the clock was introduced into the chamber, the subject did not enter the Sleep activity at any particular time of day, but instead, continued to enter the Sleep activity at varying times around the clock.

Although the period of the subject was changing throughout the experiment, the net amount of sleep in terms of percent time remained generally stable, as shown earlier. However, subtle changes in the frequency and duration of sleep occurred.

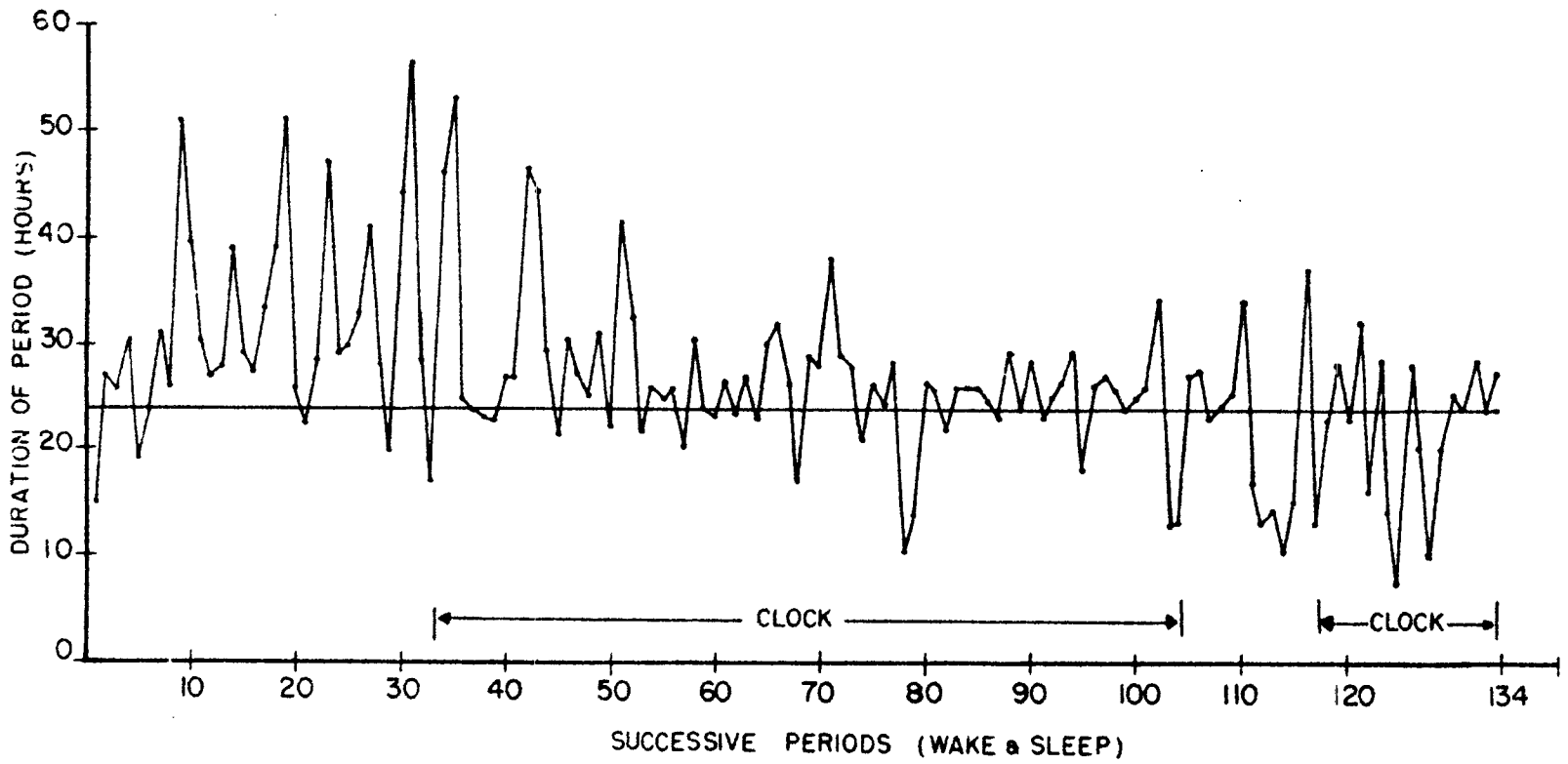

Fig 17. Duration of period for entire experiment, a period equals a consecutive wake and sleep period. A 24 hour period is shown by the horizontal line.

Figure 18 presents the frequency of selection of the Sleep activity (Sleep Trips), the mean duration of the Sleep activity, and the frequency of Wake Trips for the duration of the experiment. The figure indicates that the frequency of entering the Sleep activity increased, while the mean duration of sleep decreased over the course of the experiment. Thus, although there was no systematic loss or gain in net sleep time, the subject slept more frequently but for shorter durations. It is interesting to speculate that the increased frequency of entering the Sleep activity and the declining frequency of wake trips may be related in part to the use of the Sleep activity as a possible "avoidance" response based on the declining reinforcing properties of some activities in the full program. Point A in the mean sleep duration curve in the figure was related in part to the high variability in the periodicity of the subject, and also to the increased frequency of sleeping outside of the Sleep activity, as shown earlier. It is possible, however, that some real but temporary sleep loss may have occurred at this time.

WK1 and WK2

The two work tasks, WK1 (tracking) and WK2 (problem boxes), served as alternatives to Sleep and led into the full program. WK1, the tracking task, was designed to provide an indication of the alertness or vigilance of the subject, while WK2 was designed to provide an alternative work task of a more intellectual, clerical, or manual nature. It should be noted that these two activities provided no differential consequences for the subject for varying degrees of proficiency or accuracy.

The difficulty of the tracking task remained constant throughout the experiment. Initially, the subject had been required to earn 150 points on the basis of accuracy, and was also required to remain in the activity for at least 30 minutes. In the beginning of the experiment, the subject required approximately 30 minutes or more for the completion of the tracking task, although subsequently, with continued practice and with a reduction of the required number of points from 150 to 100 on day 10, the subject was able to complete the tracking activity with approximately 15 minutes of continued effort. The subject's accuracy on this task remained near perfect for the duration of the experiment, following this initial acquisition period. During the course of the experiment, the subject began to make use of his excess time in WK1

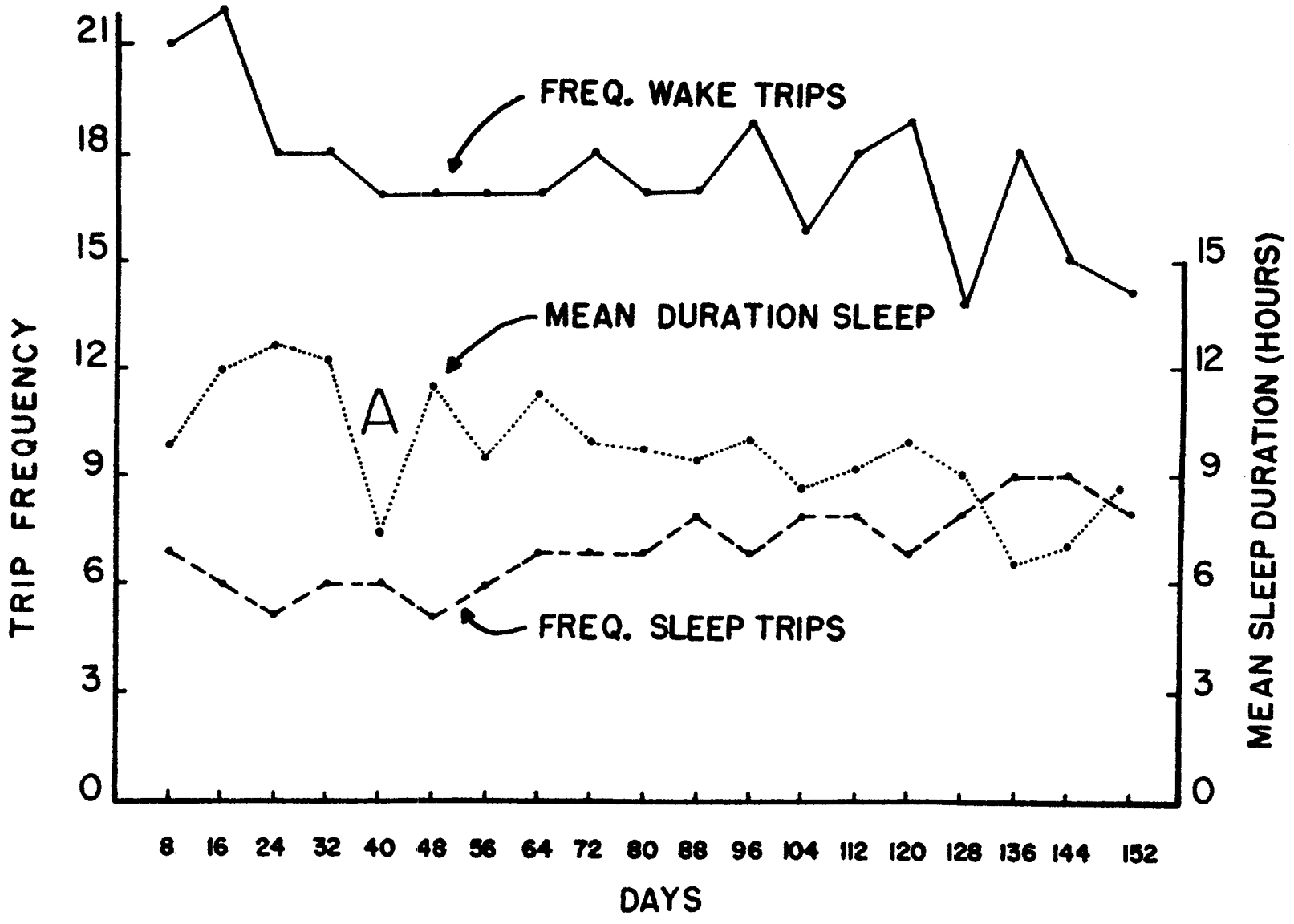

Fig. 18. Mean duration of Sleep activity and frequency of Sleep trips and Wake trips for entire experiment. Data is plotted in 8 day groups.

by composing hand-written notes which were later transmitted over the teletype machine during the Verbal Behavior (VB) activity. This occurred more frequently once the subject began working on a novel in connection with VB, and the experimenters did not wish to interfere with the novel-writing behavior by manipulating the WK1 requirements.

Since significant changes in performance in WK1 were related to changes in performance in WK2, some further comments related to WK2 will be discussed before presenting the data from these two activities.

In WK2, the subject received a box containing various problems, as described earlier in the Procedure section. Explicit instructions were provided with each task, and the requirements for termination of the activity were (a) a minimum of 30 minutes in the activity, and (b) discharge of the box through the return chute. A high level of cooperation was generally maintained in this activity, although the original set of problem boxes failed to sustain sufficient interest in the subject. The nature of the problem boxes was therefore revised and expanded to include more historical and literary problems and fewer mechanical problems, and this change resulted in a revival of interest in the activity.

The interrelations between WK1 and WK2 are most clearly illustrated by a plot of the cumulative durations spent in each of these activities for each day of the experiment. This data is presented in Figure 19 for WK1 and WK2. During the initial ten days of the experiment, the subject showed a high work rate in WK2, which gradually diminished in frequency and duration until the problem boxes were revised (Point A). Paralleling this decline in the time spent in WK2, a compensatory rise in the time spent in WK1 can be observed. This high, sustained rate in WK1 was correlated with a high output level of material for the novel in the Verbal Behavior (VB) activity which will be presented below. Following the revision in WK2, a marked rise in the time spent in WK2 was observed, along with a decline in the time spent in WK1. Concurrent with the decline in WK1, there was a decline in the output level of material for the novel in the VB activity. In the final days of the experiment, an additional reversal in the relative amounts of time spent in WK1 and WK2 occurred, as shown at Point B. Prior to this, the Visitors activity had been introduced on day 136

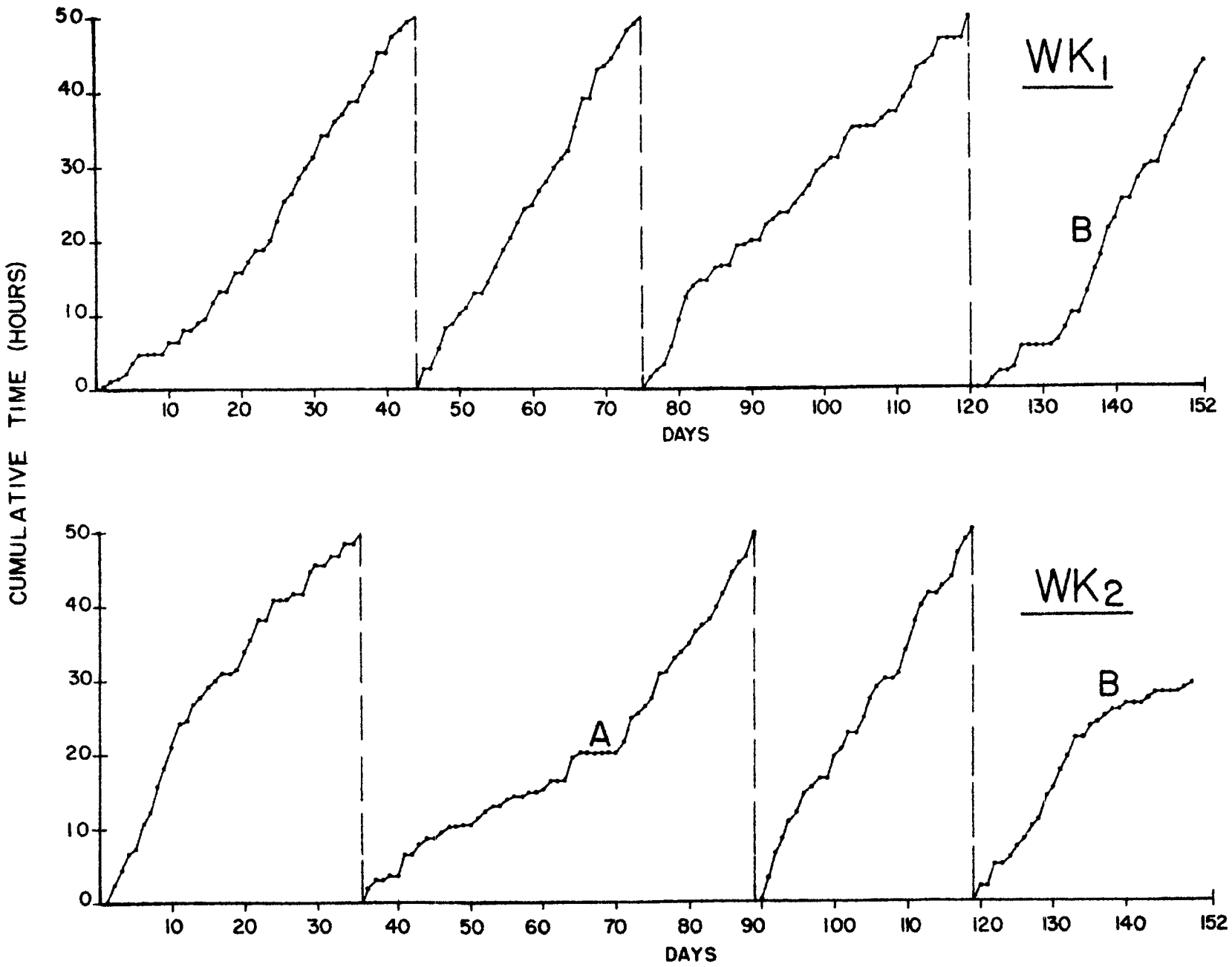

Fig 19. Cumulative time spent in Work Task One (tracking) and Work Task Two (problem boxes) for each day of the experiment.

to reduce the stress of isolation and was associated with the possible termination of the experiment at that time. When the subject elected to continue the experiment and requested that the Visitors activity be removed, he also resumed work on the novel, and prepared much of his material in the WK1 activity.

Activity Group 7

In the present section, the results of the subject's performance in Activity Group 7 (Programmed Instruction, Verbal Behavior, and Manual Behavior) will be presented jointly. It will be recalled from Figure 3-C that a gradual decrement was observed in the percent time spent in this activity group as a whole. These activities were designed to provide three different opportunities for behaviors which could offer considerable reinforcement for the subject. Examination of the performance changes within each of these activities in relation to the specific character of the activity is necessary for a proper evaluation of the percent time decline of this activity group. In addition, it has already been shown in Figure 3 that the rise in percent time in the TO activity was closely related to the decline in percent time in Activity Group 7, suggesting the critical importance of these activities to the general reinforcing properties of the environment. Figure 20 presents a plot of the cumulative time spent in the three activities of Activity Group 7 for each day of the experiment, and each activity will be described separately before discussing their interrelations.

The upper panel in Figure 20 presents a plot of the cumulative time spent in the PI activity (reading). An examination of this figure reveals that the time spent in the PI activity accelerated until day 25, with an abrupt increase in duration noted at Point A. At this time, the subject appeared to be under some stress, as indicated by the content and high output volume in the VB activity, as will be shown below, and by a high variability in periodicity. This figure also indicates a decline and later return in strength of the reading activity with a stable and sustained performance beginning at about day 50 and continuing until the final 15 to 20 days of the experiment. At that time the rate became quite variable, and the subject entered the activity only three times in the last five days of the experiment.

Initially, the number of responses on the advance button of the reading machine required to complete the PI activity was set at 120. On day 53, in view of

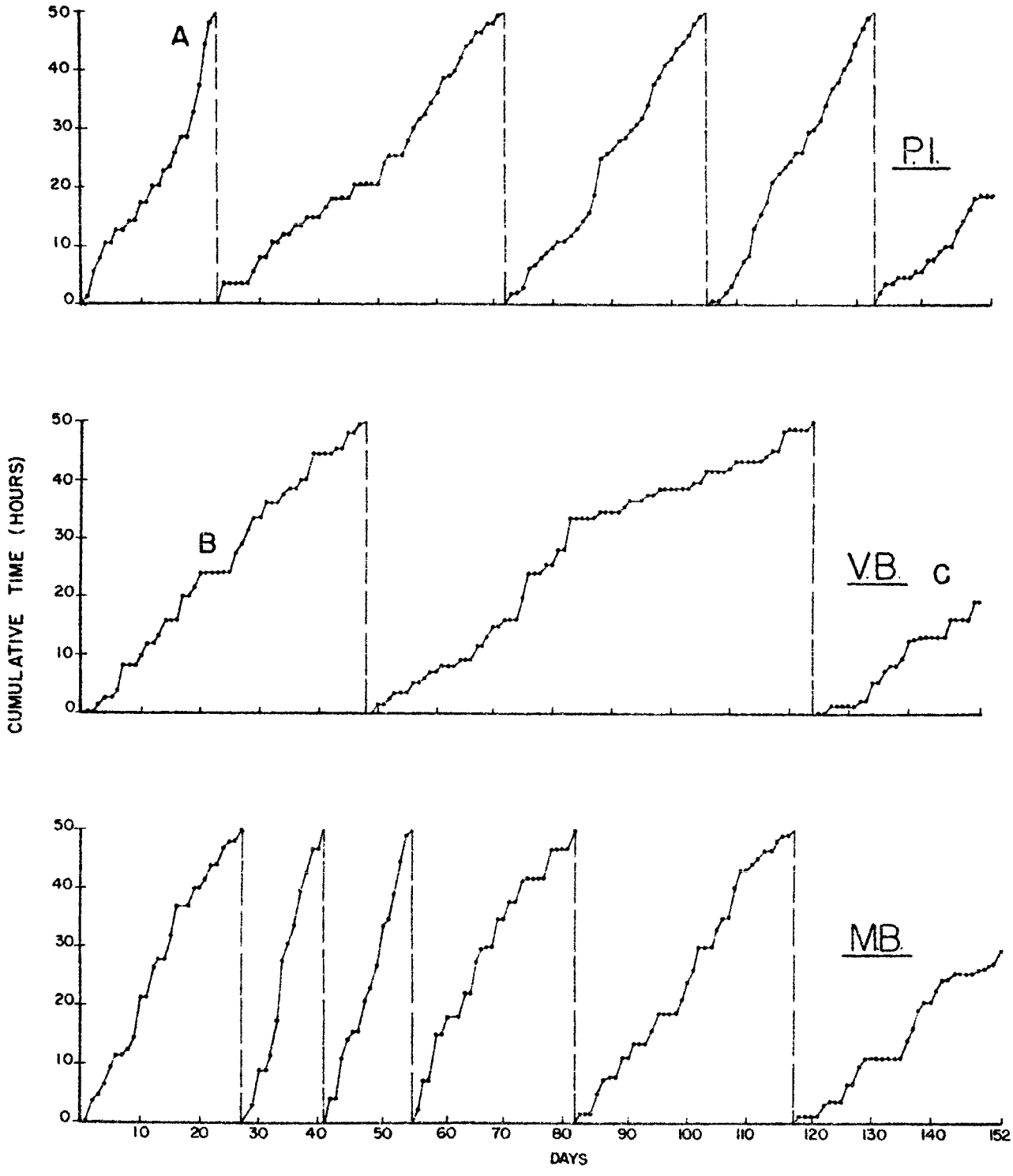

Fig 20. Cumulative time spent in P.I. (reading) V.B.(use of teletype) and M.B.(hobby activities) for each day of the experiment.

the low selection rate of PI and the decline in time spent in this activity, the response requirement was lowered from 120 to 60. This apparently contributed substantially to the return in strength of the reading activity. The reduction in the response requirements probably brought the reading activity into accord with the subject's low reading speed of approximately 10 to 15 pages per hour. The approximate number of words of printed material which the subject exposed in the reading machine during the experiment is presented in Figure 21. The amount of material exposed was quite high initially, then declined through day 55. Thereafter, with the lowering of the response requirements, the performance improved, until the final 15 days of the experiment, in which the subject frequently failed to enter the activity. Generally these results parallel the changes shown in Figure 20, and suggest that the subject read most of the material that was presented. This result is probably attributable to the stimulus control provided by the conditions of the experiment. That is, although the subject frequently criticized the material and its order of presentation, he was observed to be reading the material, although occasionally he did bypass some of it by pressing the advance button a number of times.

The middle panel in Figure 20 presents the cumulative time the subject spent in the VB activity. The overall rate can be seen to decline gradually throughout the experiment. In the interpretation of this figure, two items of importance should be considered. The first of these is that the subject occasionally received written material from the experimenters as feedback related to the subject's VB output material. This feedback was made available through the TO drawer during the TO activity. As a consequence of this procedure, the subject diverted some VB output material through the TO drawer to the senior investigators. This behavior can be accounted for by the subject's lack of confidence in the privacy of the VB material communicated over the teletype machine. Some lack of stimulus control, therefore, was found with respect to the procedures in the VB activity. In addition, at particular times in the experiment some of this personal material transmitted through the TO drawer as VB material was produced outside of the formal VB activity (Points B and C). However, the frequency of these "violations" was low and cannot account for the declining amount of time

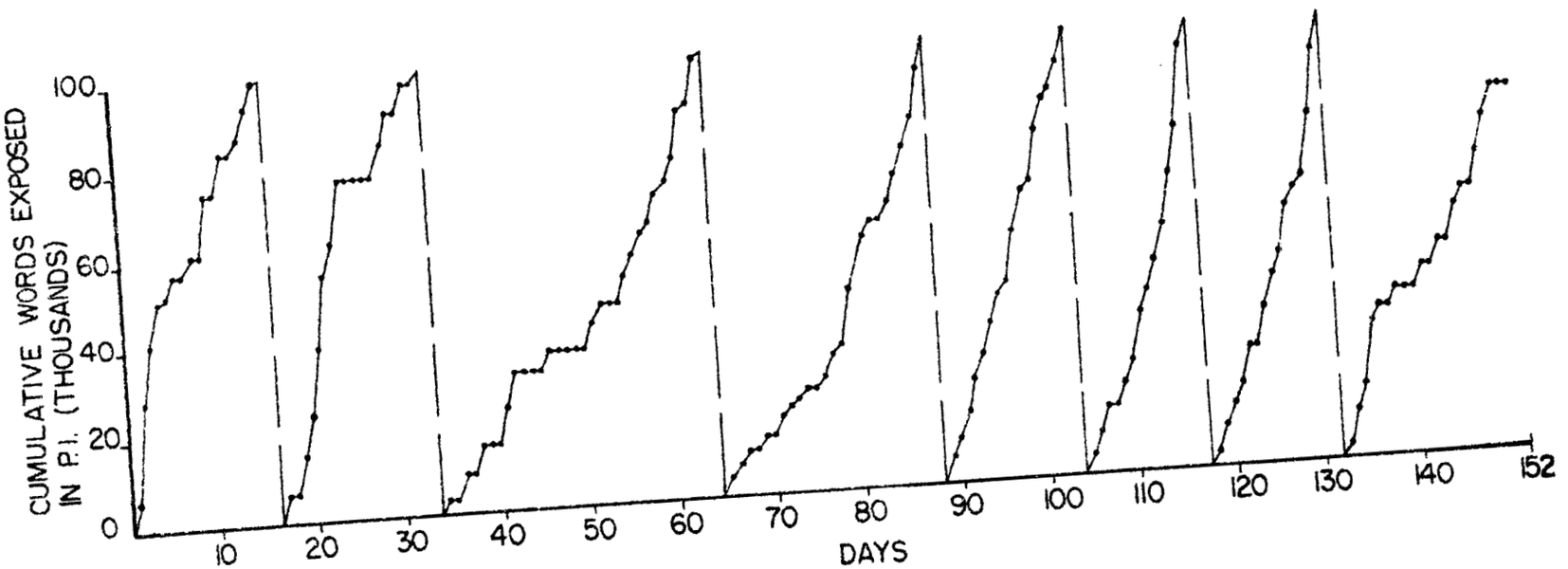

Fig 21. Cumulative number of words exposed in the reading machine during the Programmed Instruction activity for each day of the experiment.

spent in the VB activity. These two points are the principal occasions in which the subject diverted considerable amounts of VB material through the TO drawer, and were closely related to periods of stress.

The second factor to be considered in evaluating the VB performance data is that the subject began writing a novel approximately on day 30, and this effort subsequently consumed the major portion of the subject's time in this activity. Therefore, the decline in time spent in the VB activity, as shown in the middle panel of Figure 20, principally reflects a decline in the novel-writing behavior. Changes in VB performance in terms of volume of output and nature of material produced are shown in Figure 22. The figure presents the approximate number of words submitted as VB material either through the TO drawer or over the teletype machine. This data does not include material for the novel. The large dots in the figure indicate those days of the experiment in which material for the novel (regardless of volume) produced in VB or WK1 was submitted over the teletype machine. The number of words produced exclusive of the novel accelerated to a peak, as noted at Point A. At Point A, a considerable amount of VB material was delivered in which the subject described his anxieties and uncertainties relating to his personal affairs prior to the beginning of the experiment. Point A, therefore, reflects a period of acute stress, as suggested earlier.

Following Point A, the subject undertook the writing of a science fiction novel, and consequently the amount of VB material submitted (other than the novel) abruptly declined, and remained at low levels until the final stages of the experiment. At this later time the subject's personal anxieties reappeared in the VB material, the VB output accelerated again, and several other indications of stress were observed. Throughout this latter period, the subject frequently questioned the motives of the experimenters, became suspicious of the purposes of the experiment, and generally reflected some loss of confidence and realism concerning those events over which he had no control or information. The output rate of material for the novel declined appreciably from approximately days 70 through 135. At this time, as was described earlier, the experiment was almost terminated on the basis of general performance decrements and the general character of the VB output material at that time. With the

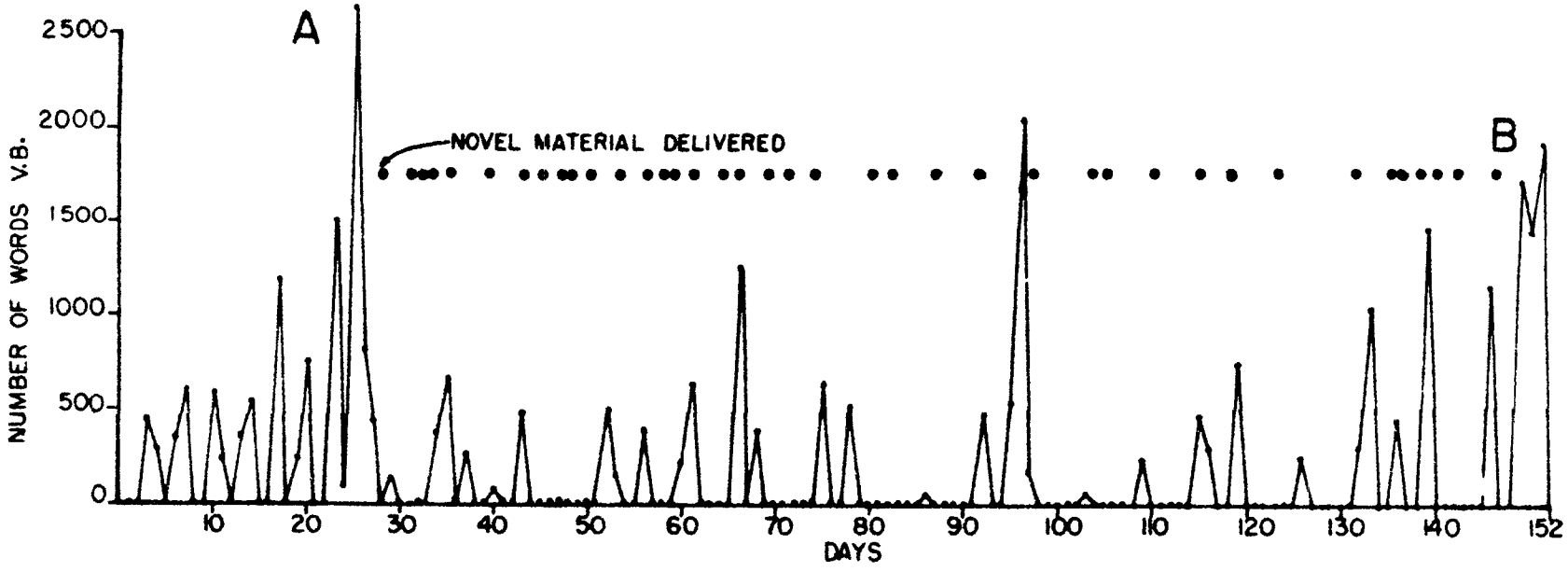

Fig 22. Number of words from the V.B. activity for each day of the experiment. This date excludes material for the novel, which is plotted separately as large dots on day of delivery.

continuation of the experiment past this critical point at the subject's request, a brief resurgence of materials for the novel appeared.

The third and last activity in this group was MB (Manual Behavior). This activity was designed to provide the subject with the opportunity and materials to carry out various creative or hobby activities. Generally, these materials were restocked and supplementary materials were introduced as they were earned through the formal Requisitions activity in Activity Group 8. By virtue of the unstructured nature of this activity, evaluation of the performance in MB is limited to a presentation of the cumulative time spent in the activity throughout the experiment, and the frequency and description of the products generated in the activity.

The lower panel in Figure 20 presents the cumulative time spent in MB throughout the experiment. Examination of the figure indicates that the subject spent a great deal of time in this activity over the first 50 to 60 days of the experiment. After approximately day 60 the amount of time spent in the activity declined gradually throughout the remainder of the experiment.

Figure 23 presents the cumulative frequency of completed projects undertaken in the MB activity and a description or title of each. The figure reveals a declining frequency of completed projects over the course of the experiment. During the early part of the experiment, the subject confined his MB activities to sketching and working with clay. On day 19 the subject made his first attempt at working with oil paints. By the fiftieth day of the experiment the subject had produced a completed clay bust, three oil paintings, and a number of sketches. It should be noted that the comparatively high frequency of delivery of completed projects over the first 50 days corresponds to the high period of cumulative time spent in MB. From day 50 until day 108 the subject worked exclusively on a large canvas which he had earned as a requisition. This particular painting, in which he had invested considerable time, was smashed by the subject on day 108. Following the delivery of a second large canvas as an earned requisition, the subject began another project, which was completed on day 140, approximately. This painting revealed considerable improvement in technique and composition. Plate 1 presents some of these MB products. The subject's skill in the use

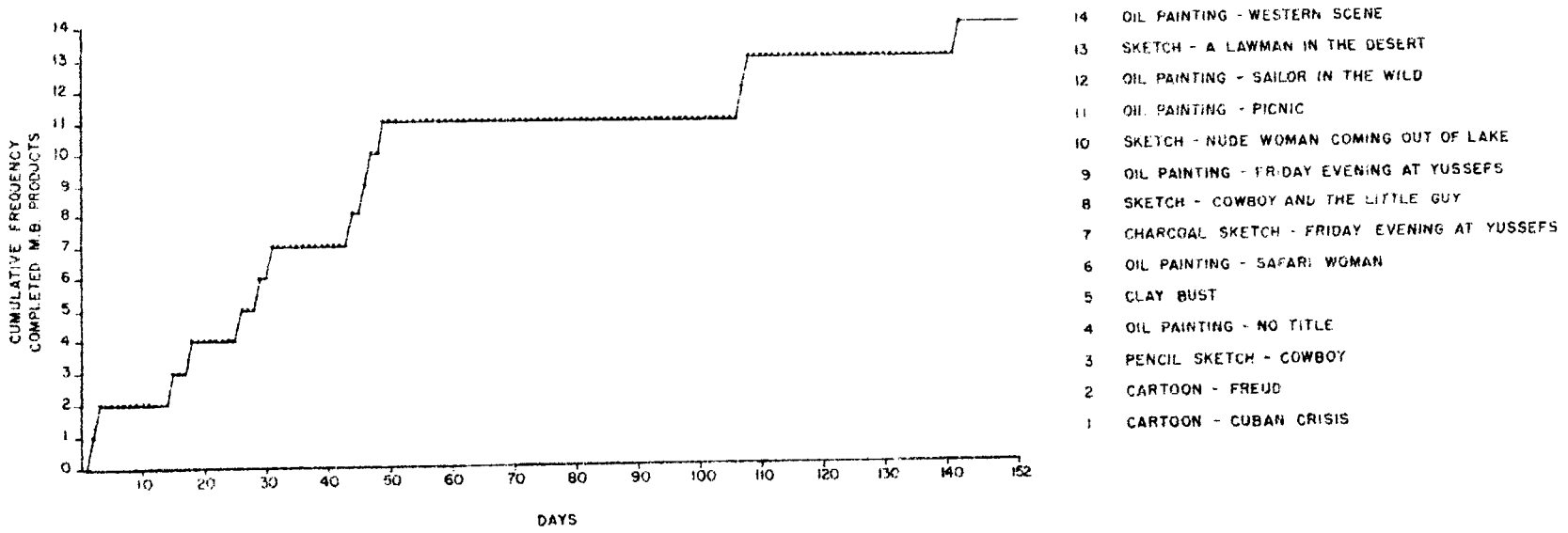

Fig 23. Cumulative frequency of completed projects produced in the M.B. activity for each day of the experiment. Fourteen products were undertaken and their titles or description are indicated on the right side of the figure.

PLATE 1

Upper left	no title (veiled woman)
Middle left	Safari Woman
Lower left	Friday Evening at Yussef's
Upper right	Picnic
Middle right	Sailor in the Wild (damaged)
Lower right	Western Scene

of oil paints was developed entirely during the course of the experiment. In spite of the developing predominance of oil painting as the exclusive activity in MB, and in spite of the subject's considerable improvement in painting technique, the amount of time spent in this activity and the number of projects completed gradually declined as the experiment progressed. Although the subject's general comments with respect to the MB activity were always positive and suggested the highly reinforcing properties of this portion of the program, the strength of this activity was not sustained throughout the experiment. The significance of this effect in MB, along with the observed decrement in VB, can probably be attributed to the long-term effects of confinement and social isolation, and the failure of the environment to provide adequate reinforcement for the subject's creative efforts. Consequently, some of the more important sources of reinforcement for the subject were gradually lost. The maintenance of the strength of PI throughout the main portion of the experiment stands in contrast to the general effect observed in MB and VB, and may be attributed to the apparent independence of reading behavior from explicitly programmed reinforcements. Further evidence for this interpretation was provided by the subject, who commented to the effect that the activity provided new sources of interest and stimulation for him which he was failing to obtain in other activities.

Activity Group 8 -- FD2 (Desserts), FD3 (Major Meals), MU (Music), VC (Variable Consequences), REQ (Requisitions), OC (Oral Communications), VIS (Visitors), PM (Power Maintenance), and CIG (Cigarettes)

After completing one of the three activities in the 7th Activity Group, the subject could then enter into the 8th Activity Group, in which he would be provided with the opportunity for selecting a number of different activities. For the major part of the experiment, the subject was permitted four selections in this activity group. In the final six days of the experiment, however, the subject was permitted five activity selections from this group. This change in procedure was the specific result of an earned requisition.

When the subject selected one of the eight activities, all of the other activities in the group would become unavailable until the selected activity was

completed. After the conditions or requirements of a particular activity were satisfied, that activity would be terminated, and the entire group of eight activities would again become available for the next selection.

With respect to the delayed reinforcers (REQ, OC and VC), the subject generally was required to select the particular activity a number of times before the delayed reinforcement could be earned. The number of selection times required, however, always exceeded the number of selections permitted in a single trip. In addition, after a delayed reinforcement had been earned, that particular delayed reinforcement activity was no longer available for selection until the reinforcement had been delivered. Delivery normally occurred after Activity Group 7 and before Activity Group 8. The Visitors activity was not available for selection during the experiment except for a few hours on day 135, in response to the stress conditions that had developed. However, the Visitors activity was made unavailable at the subject's request on day 136, and the experiment continued with the VIS activity unavailable for the remainder of the experiment.

Before entering into a presentation of results with respect to each individual activity in Activity Group 8, an examination of some general performance characteristics for the group of activities as a whole will be presented as an introduction.

A general description related to Activity Group 8 concerns the relative reinforcing properties or relative strengths of the different activities, given the response requirements that were established for each. Figure 24 presents the total frequency with which each activity was selected for the entire experiment. The first major point to be made from this figure is that the group of three activities which involved delay in delivery of reinforcement was uniformly low in strength relative to the activities which involved immediate reinforcement, that is, Cigarettes, FD3 (Major Meals), Music, and FD2 (Desserts). Examination of the relative strengths of the immediate reinforcers in Activity Group 8 indicates that Cigarettes and FD3 dominated in frequency of selection. Changes in the strengths of these individual activities over the temporal course of the experiment will be described.

The second general characteristic with respect to performance in this activity group as a whole deals with the sequence of selection of the different activities.

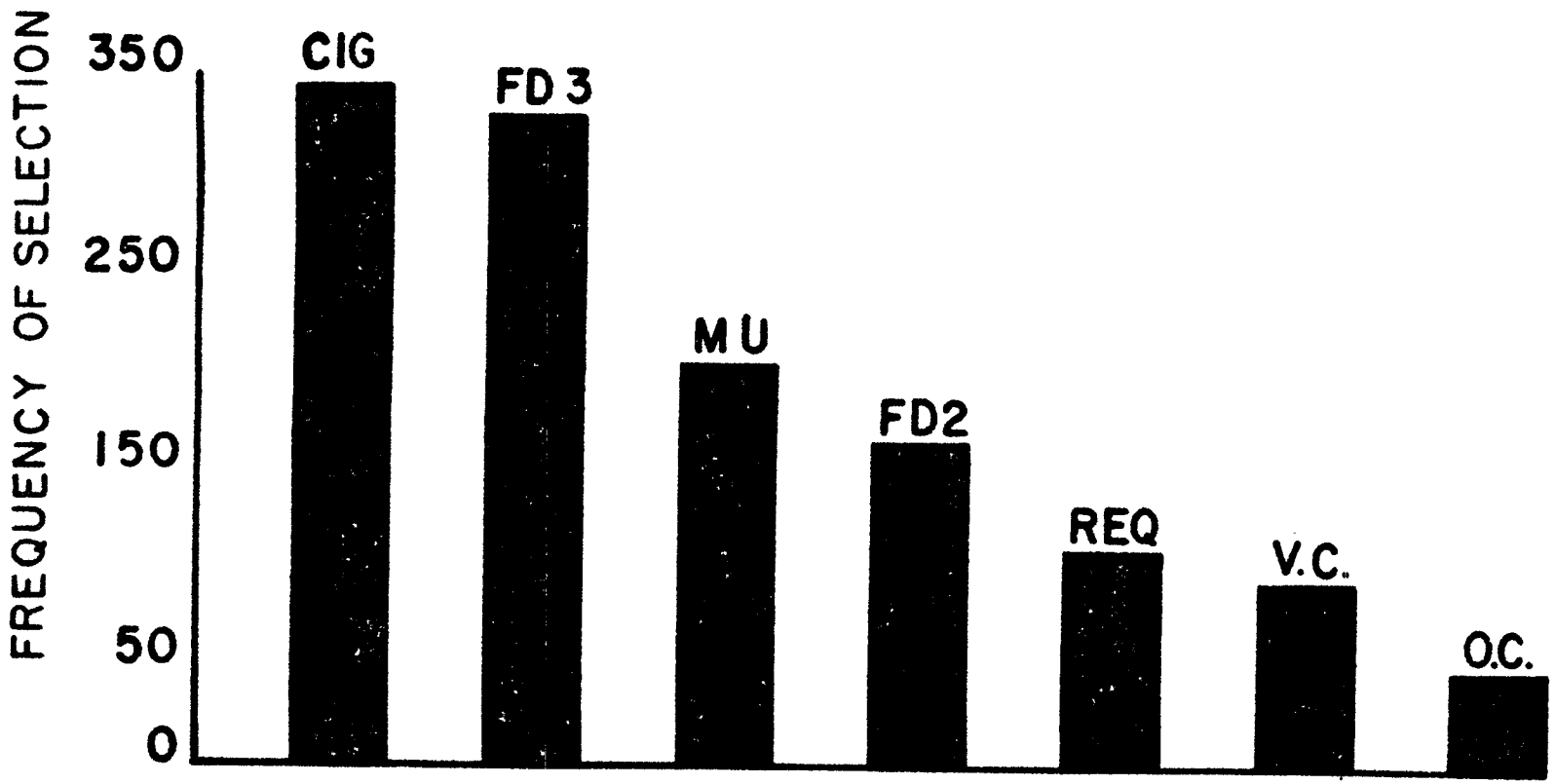

Fig 24. Total frequency with which each activity in activity group 8 was selected for the entire experiment arranged arbitrarily in descending order from left to right.

That is, was there a consistent pattern of selections, and if so, what was generally selected first, second, third, and fourth? The answer to this question for the experiment as a whole is provided by the data in Figure 25, which presents the total frequency of selection for each activity as a function of its location in the sequence of selections. The activities are arranged in such a way that one can follow the general trend of the selection sequence that the subject would be most likely to follow from the top to the bottom of the figure. In general, the first activity selected by the subject was FD3, with very little competition from other activities. Cigarettes and, to a lesser extent, FD2, occupied the middle range in the selection sequence for the subject, their distributions being somewhat more even, but relatively peaked in the second or third selections. Finally, the group of activities consisting of Music and the delayed reinforcers (VC, REQ, and OC) present a rising distribution toward the third and fourth selections, completing the general picture of the selection sequence.

The clear predominance of FD3 and CIG as the activities selected first and second, and the tendency for the delayed reinforcers to be selected last, confirms the data with respect to the relative strengths of these activities as presented in Figure 24. In general, then, a clear relationship was found between the relative strengths of the activities in terms of their relative frequency of selection and the location of the activities in the selection sequence.

FD2 (Desserts) and FD3 (Main Meals)

The foods available in FD2 and FD3 were presented in Table II. A high degree of consistency in the quality of the foods was maintained throughout the experiment, except for two deviations. The first of these deviations refers to the inclusion of special foods (e.g., banana pellets), or the removal of certain unsatisfactory items of the diet on the basis of requisitions, verbal complaints, or unavoidable changes in the food supplied by the vendor. The second deviation in the food program was the addition of higher quality or more appetizing foods to the regular food program near the end of the experiment. This improvement in the basic diet occurred on day 136, following the near termination of the experiment. The improvement in the quality of the food program was an attempt to improve the quality of the environment

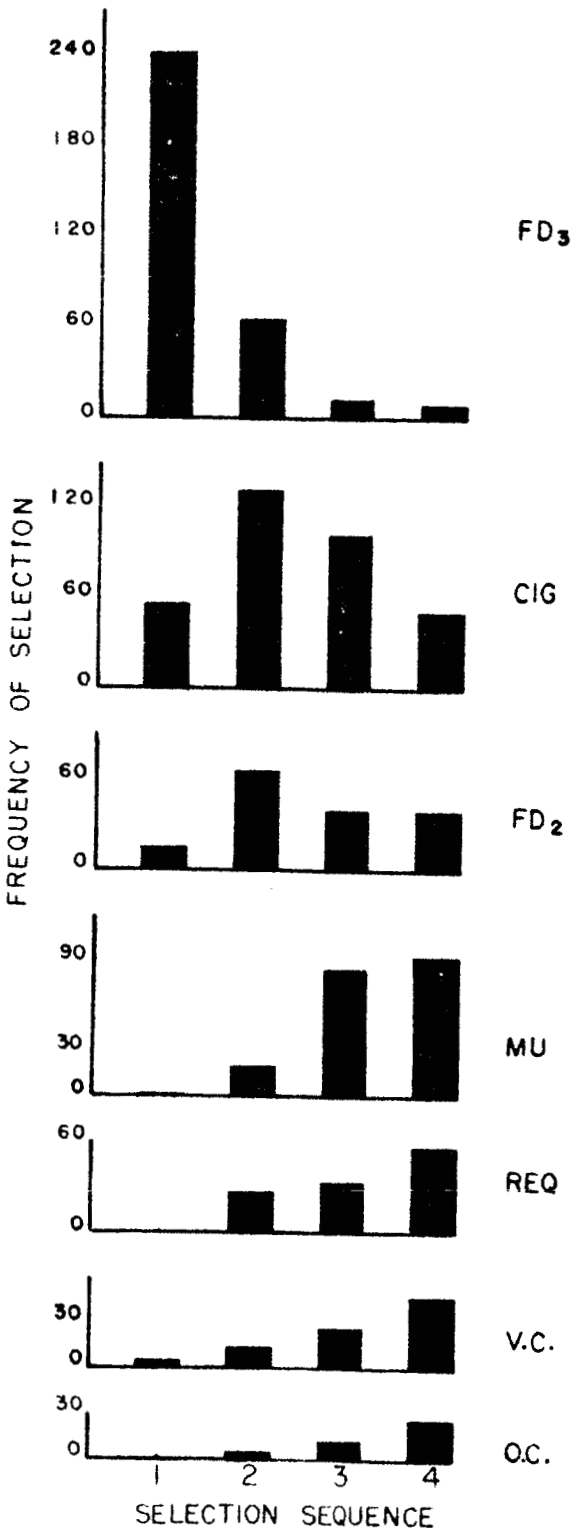

Fig 25. Frequency of order in selection sequence for activities in Group 8 for the entire experiment.

for the subject with regard to continuation of the experiment. The intensity of the subject's verbal complaints about the food programs plus other evidence of accumulating behavioral strain necessitated this change on day 135. The data obtained for the FD2 and FD3 activities were confined to measures of the frequency of selection of the activity, the duration of the activity, and the subject's negative verbal comments about the food programs. The presentation of data with respect to performance in the food programs is related to one of the significant problem areas in the measurement and control of behavior encountered in the experiment. Specifically, the recordings of frequency, duration, and verbal comments do not directly measure eating or consummatory behavior, that is, whether the subject was eating or when he was eating. The use of indirect measures in the present experiment resulted from the practical difficulties of obtaining direct measures of eating behavior.

The cumulative frequency with which the subject selected the FD2 and FD3 activities is shown in the middle and lower panels respectively of Figure 14. It can be observed that the rate of selection of FD3 (the subject's main source of food) was very stable and was maintained at a fairly high rate. The selection frequency for FD2 was relatively unstable and occurred at a considerably lower rate. No systematic changes in performance with respect to the frequency of selection of the food activities was observed over the course of the experiment nor were there any changes in relation to periods of special stress, for example, from days 20 to 25, during the cigarette experiment, and the final 15 to 20 days of the experiment.

Figure 26 presents the data regarding the duration the subject remained in FD2 and FD3. The duration of FD3 remained between approximately 15 and 30 minutes throughout the experiment, with the exception of a few scattered, very high values. The data for FD2, on the other hand, reveals some trend toward increasing durations in the final stages of the experiment. However, considering the location of FD2 in the general selection sequence, it can be presumed that the subject had already completed his major meal, FD3, and had obtained cigarettes. Thus, the emerging long durations in FD2 may represent another case of pausing behavior prior to the termination of Activity Group 8 and the consequent automatic return to the beginning

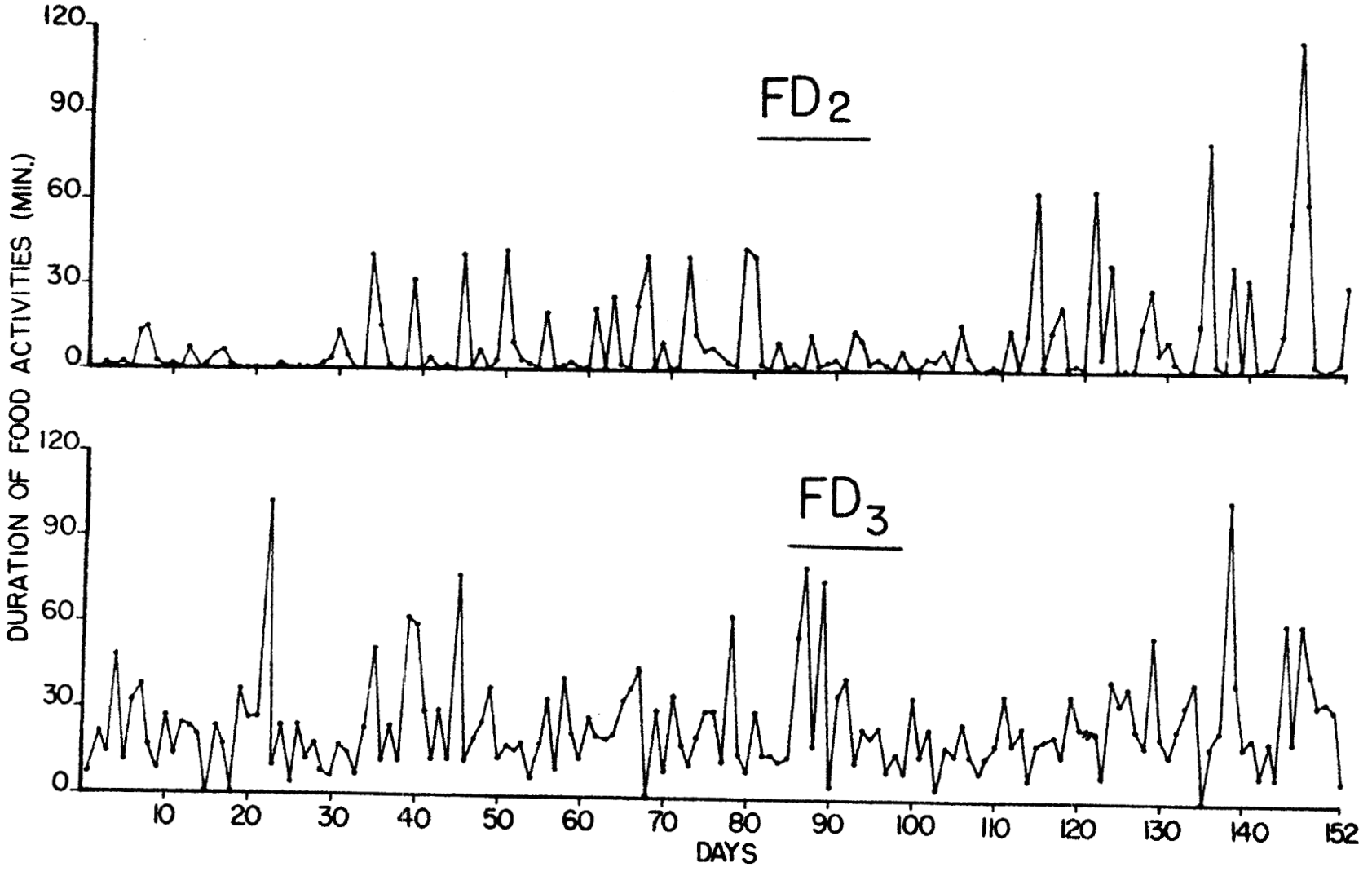

Fig 26. Total time spent in FD2 and FD3 for each day of the experiment.

of the program.

The insensitivity of the frequency and duration measures associated with the FD3 activity, which was the principal food activity for the subject, may be related to a true isolation of this behavior from the effects of accumulating behavioral stress; or, alternatively, the use of the indirect measures of consummatory behavior, that is, frequency of selection and duration of the activity, may have hidden behavioral changes that actually occurred (e.g., meals not being finished).

PM (Power Maintenance)

The Power Maintenance activity provided little information with respect to general behavioral trends during the experiment. Three power failures occurred in the first 90 days of the experiment, and the subject successfully avoided additional power failures thereafter.

Delayed Reinforcements -- REQ (Requisitions), OC (Oral Communications), and VC (Variable Consequences)

In the present experiment, the delayed reinforcements provided for the introduction of new conditions, facilities, or stimuli into the subject's environment. Although for practical reasons the procedures required a delay between the subject's performance and the delivery of the reinforcements, this condition was not without advantage in that the introduction of new conditions could be kept at a relatively low frequency level and spaced out in time. The response requirements for the delayed reinforcements were arranged to avoid the excessive use of the delayed reinforcement activities. The number of responses per selection and the number of selections required for the three delayed reinforcements were not uniform. In the REQ and OC activities, 5 selections were required, while VC required 15 selections. REQ required fifty responses per selection, while OC and VC required 200 responses per selection. Although some changes were made in the exact response requirements for each activity during the experiment, the relative cost of the response requirements for the three delayed reinforcements remained essentially unchanged. In VC the subject could not anticipate the nature of the new stimulus conditions or requirements that might be introduced, and this conveniently permitted the experimenters to introduce arbitrary

changes into the environment. In the REQ activity the subject could and did request a number of changes in experimental procedures, as well as the introduction of new materials in the form of art supplies, documentary movies, etc. In the OC activity, the reinforcement was restricted specifically to the use of the intercom system for a 30 to 45 minute conversation with individuals outside of the experiment, for example, the subject's wife or friends.

Figure 24 showed that the relative frequency of selecting the delayed reinforcements was considerably lower than the frequency of selection of Cigarettes, FD2, FD3, or Music. The two conditions which were assumed to contribute to this lower rate of selection of the delayed reinforcement activities were, (1) the relatively greater response requirements per selection, as well as the number of selections required, and (2) the time delay in delivery of the reinforcements. Figure 27 presents the cumulative frequency with which the subject earned all the delayed reinforcements combined (VC, OC, and REQ). The horizontal lines and circles indicate the delay interval, in days, from the day the subject earned the delayed reinforcement to its delivery. Omitting the vacation effect, the figure shows a relatively stable rate of earning delayed reinforcements, with a small increase in rate in the latter part of the experiment. Examination of the delay intervals shows that the delays were made relatively shorter as the experiment progressed and presumably contributed to the higher selection rate. More direct evidence for the presumed relationship between the delay of reinforcement and the low selection rate of the delayed reinforcement activities was provided by the effect of the vacation on the frequency of selection of the delayed reinforcements. On day 121, there was an arbitrary introduction of an experimental vacation for a 24 hour period, during which the activity bypass switches for the entire program were made available to the subject. These bypass switches, in effect, allowed the subject to enter any activity after completing any other activity, but did not permit him to escape from an activity once the activity had been selected. The subject spent almost his entire time in Activity Group 8 and in TO. Significantly, he repeatedly worked for and earned delayed reinforcements of all three types in Activity Group 8, with the experimenters delivering the reinforcements with minimal delay. This is indicated

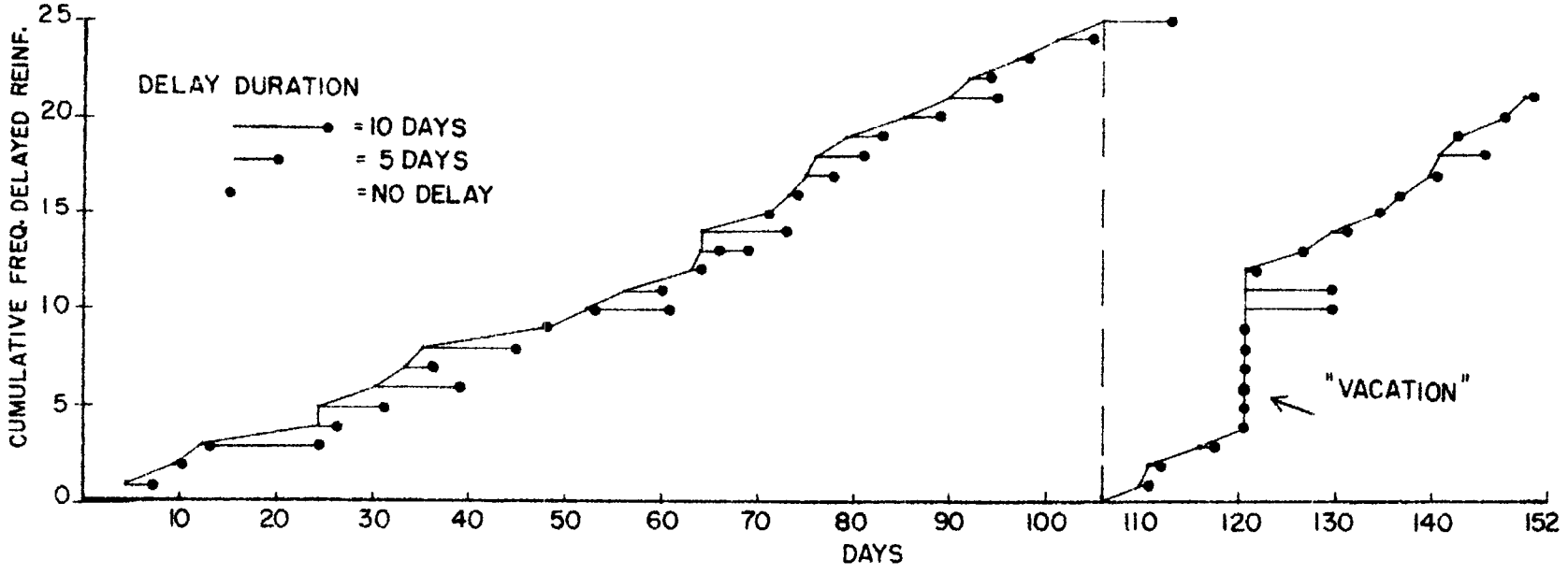

Fig 27. Cumulative frequency of earning all delayed reinforcements (REQ., V.C., and O.C.) combined into one curve. Duration of delay in delivery of reinforcement is shown by circles and horizontal lines. The curve was constructed by connecting the days on which reinforcements were earned.

by the vertical line and circles in the figure. A motion picture was shown, various supplies, special foods, conversations over the intercom, and other delayed reinforcers were delivered. During the later hours of the vacation, the experimenters had exhausted their stock of delayed reinforcers, and after the subject had again earned all three delayed reinforcers, delivery was withheld. The subject then selected PI, TO, and finally Sleep. During Sleep the vacation period was terminated, and when the subject awoke the original conditions of the experiment were restored.

Since the response requirements for the delayed reinforcement activities were unchanged (as well as the response requirements for all other activities in the program), it was concluded that the high frequency of selection of the delayed reinforcements during the vacation could be attributed to the very short delay intervals in the delivery of the reinforcements. This clearly suggested that the delay interval, rather than the high response costs, was generally responsible for the low selection rate of the delayed reinforcement activities during the course of the experiment.

The general consequences on the subject's behavior following the vacation, interestingly enough, were most clearly related to those behaviors which prompted the introduction of the vacation in the first place, namely, the high frequency of the subject's verbal complaints. The progressive changes in performance in TO, VB, and MB were also partly responsible for the introduction of the vacation. The vacation had a clear but temporary effect in suppressing the verbal complaints of the subject (to be presented below), but there was essentially no effect on the general performance levels of the subject throughout the program.

The suggested rise in the frequency of earning the delayed reinforcers in the latter stages of the experiment, shown in Figure 27, is further elaborated by an examination of the cumulative frequency for each individual delayed reinforcer, as shown in Figure 28. In this figure it will be observed that the VC delayed reinforcement was selected at the lowest frequency. Some specific variable consequences were the showing of a motion picture, the introduction of the clock, the subsequent removal of the clock, the introduction of a tape recorder, delivery of beer and pretzels, and several others. Some of these VC's were reinforcing and some were not, as indicated by the verbal

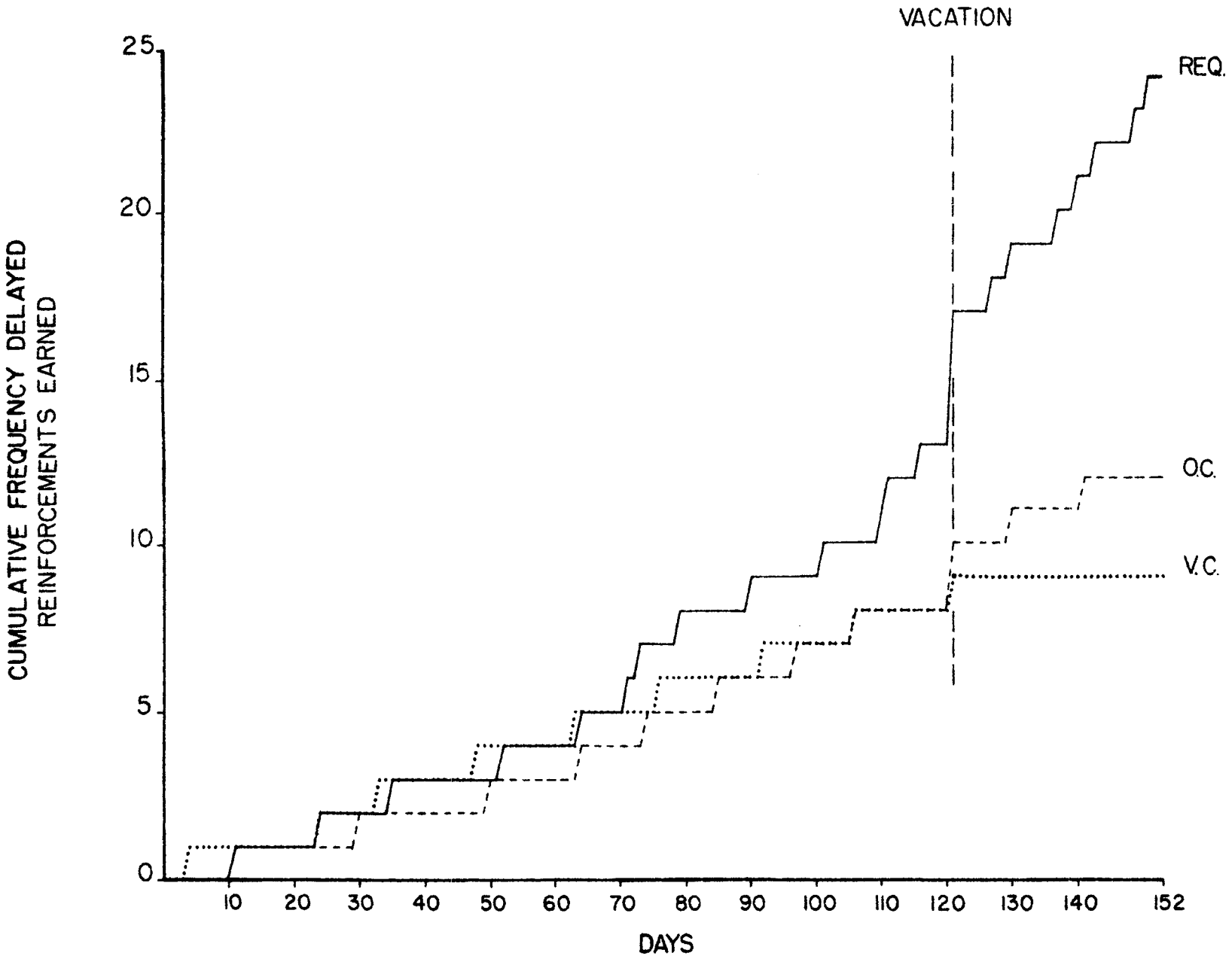

Fig 28. Cumulative frequency of earning individual delayed reinforcements (REQ., V.C. and O.C.) for each day of the experiment.

comments of the subject. One of the VC's of the less reinforcing type was delivered on day 36. This consisted of the removal of all standard foods from the three food activities, and their replacement with banana pellets, milk, and oranges for three days. This VC resulted in numerous comments from the subject, although there were no notable effects on his general performance throughout the program. One of the more positively reinforcing VC's was the introduction of three old "Playboy" magazines, which were delivered during the vacation. The final VC occurred on day 130 and consisted of the playing of a long classical symphony three times. This final VC apparently functioned as a negative reinforcer, as indicated by the failure of the subject to select the VC again during the remainder of the experiment. In general, VC was found to be low in relative strength throughout the course of the experiment, even before the subject stopped selecting that activity. Possibly the effect of an occasionally punishing variable consequence became less tolerable as the experiment progressed.

The frequency of Oral Communications was also low, as shown in Figure 28. No noticeable rise occurred during the later stresses of the experiment, when increased communications with the outside might have been expected.

The absence of continued selection of the VC activity following the vacation did not reduce the overall selection rate of the delayed reinforcers as a group. Instead, the subject selected the alternative delayed reinforcers more frequently, particularly REQ. The preference for REQ may be expressed in terms of the differential consequences of OC versus REQ for the subject. That is, Oral Communications provided essentially no change in the subject's environment within the chamber, and provided very little information about events in the outside world. Thus, the effects of the Oral Communications were limited essentially to the stimulating properties that might be found in a brief and content-restricted conversation. In contrast, the reinforcements delivered via the Requisitions activity had consequences which could be important to the subject in terms of the resulting changes in the environment. Two important changes of this type were his request for and subsequent delivery of an increase in the number of selections permitted in Activity Group 8 from four to five, and the reduction in the response requirements for all activities in Activity Group 8 from their various current

values to two responses. This occurred four days before the experiment was terminated. The most frequent requests, however, were for the projection of sound-motion pictures into the chamber. These documentary films presumably provided a good source of stimulation for the subject. Toward the end of the experiment, the subject spent considerable effort working in the REQ activity to produce these effects within his environment. The increase in frequency of requisitions for motion pictures suggests a possible parallel with the effect shown earlier with respect to the PI activity, in which the frequency of use of the reading machine increased during the experiment. Both effects suggest the reinforcing properties of motion pictures and reading in this kind of environment, particularly during the later stages of prolonged social isolation and confinement.

CIG (Cigarettes)

One of the activities most frequently selected in Activity Group 8 throughout the experiment was the Cigarette activity. As shown earlier, the subject generally selected the Cigarette activity as his second or third choice in his selection sequence. Once the subject had selected the Cigarette activity, he was then required to operate the appropriate push button on the modifier panel a predetermined number of times for each cigarette. The subject was required to earn ten cigarettes with each selection of the Cigarette activity during the first 90 days of the experiment. Twenty-five responses were required for each cigarette, except for the period when a systematic manipulation of the response requirement for cigarettes was undertaken. The cumulative frequency of the subject's consumption of cigarettes throughout the entire experiment is shown in Figure 29. The subject generally smoked from 20 to 25 cigarettes per day. Figure 29 also gives some indication of the effect of the manipulations in the response cost per cigarette on the selection rate of the activity. As the response cost per cigarette was increased from the initial value of 25, to 50, 100, 200, 300, and 500 over a period of 37 days (as shown in the figure), the selection rate was reduced gradually, and at 500 responses per cigarette the subject's consumption rate was about 50 percent of its baseline rate. This will be shown more clearly in the next figure. After the period in which 500 responses were required per cigarette, the subject was placed on an adjusting

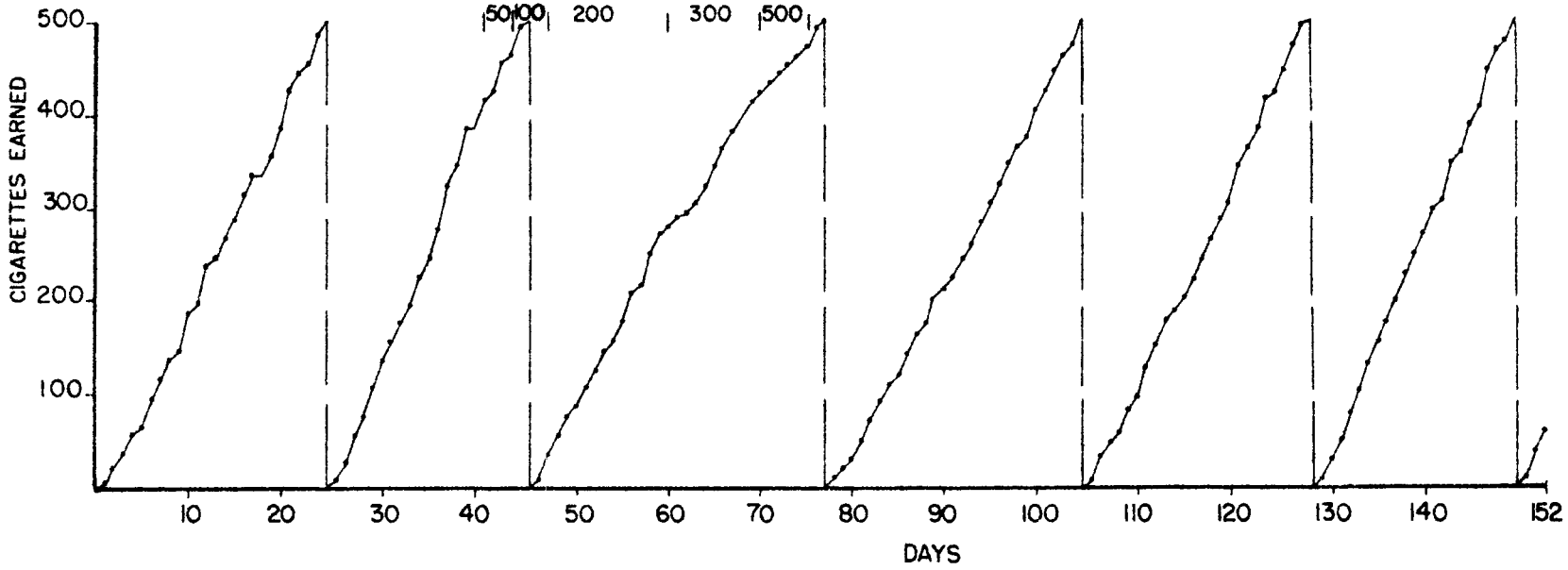

Fig 29. Cumulative number of cigarettes earned for each day of the experiment. Twenty-five responses were required per cigarette except during the cigarette experiment when the response requirements were increased as shown at the top of the figure. (see text)

contingency for a period of approximately 10 days, in which the response cost was 25 responses per cigarette for the first 10 cigarettes in a 24 hour period, and 1000 responses per cigarette thereafter. During the last seven days of this procedure, the requirements were reduced and the subject was permitted 20 cigarettes per day before the response cost per cigarette increased to 1000. After the adjusting contingency was removed, the response requirements were set at 25 responses per cigarette, with seven cigarettes permitted per selection.

The general effects of systematically increasing the response requirements for cigarettes can be more clearly observed in Figure 30. In this figure the number of times the Cigarette activity was selected per opportunity to make a selection (of any activity in Activity Group 8) is plotted as a function of the response cost per cigarette. It can be observed that the selection of the Cigarette activity remained essentially unaffected until the response requirement per cigarette reached 200. When the response cost was increased further to 300 responses, the subject announced his intention to stop smoking altogether. However, shortly thereafter he resumed working for cigarettes, but at a lower selection rate, as indicated in the figure. When 500 responses were required per cigarette, or 5000 responses (requiring approximately one hour) per selection, the subject again announced, with increased vigor, his intention to stop smoking. Once again, however, the subject reversed his verbal announcement and resumed working for cigarettes. Under this final high response cost per cigarette, the subject restricted his intake of cigarettes to approximately ten per day, representing a reduction of approximately 50 percent from his baseline consumption rate. During this period, the subject each day expressed considerable negativism, and on day 77, during the adjusting contingencies, became quite agitated, and threw his chair and other items violently about the chamber.

The manipulations in the cigarette requirements not only reduced the intake of cigarettes and produced verbal and physical expressions of hostility, but in addition, these procedures had consequences in other aspects of the program as well. Some of these effects have been mentioned. For example, the rise in percent time spent in Activity Group 8 has already been shown, and is related to the increase in time required

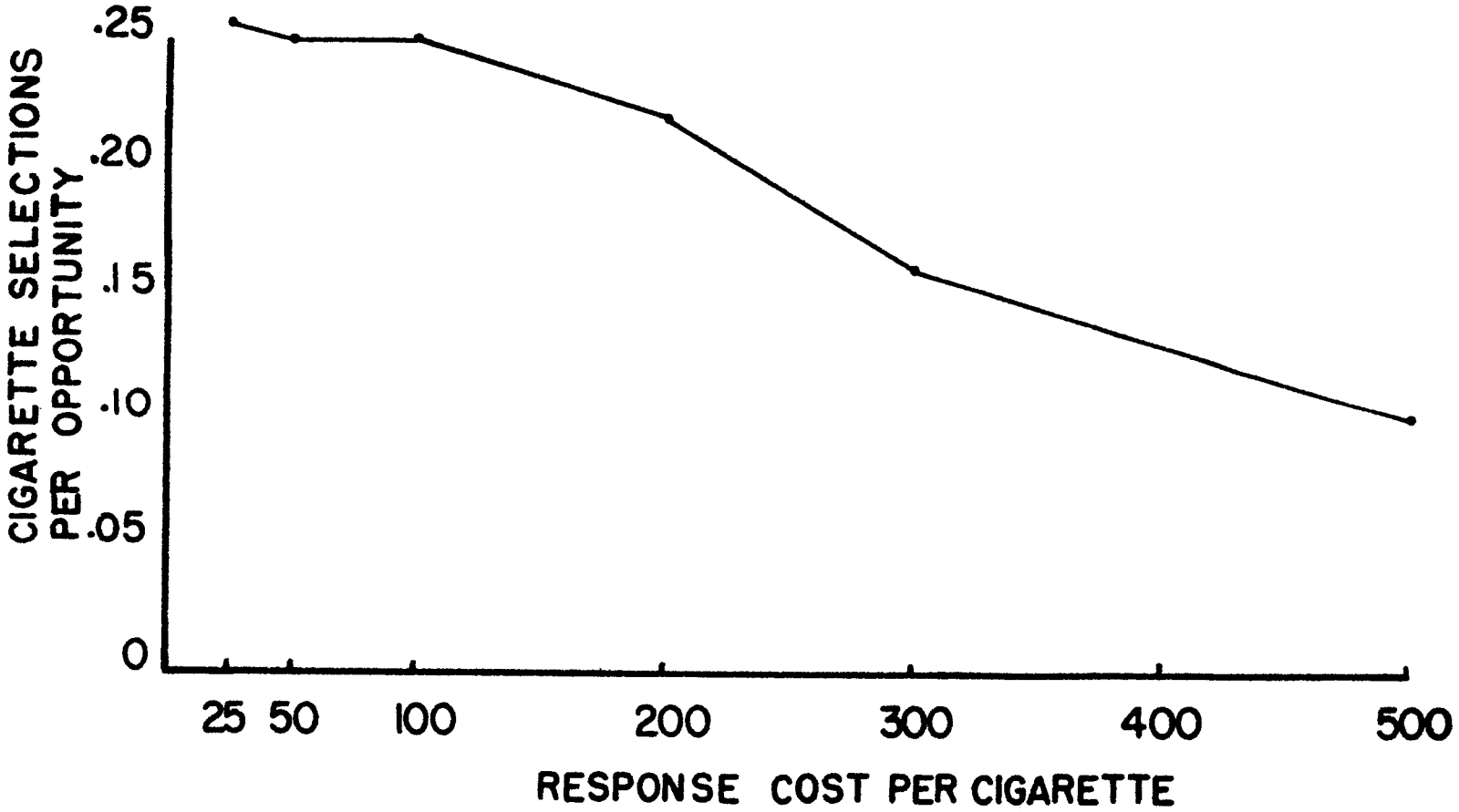

Fig. 30. Relationship between selection of cigarette activity (selections/opportunities for selection) and response cost per cigarette.

to complete the Cigarette activity. In addition, the effect of the cigarette experiment in terms of the virtual elimination of the use of the vacuum cleaner during the TO activity has also been described. An additional effect related to the cigarette experiment was the change in the distribution of activities selected in Activity Group 8. This data is presented in Figure 31, in which the relative frequency (percent) with which the subject selected each activity in Activity Group 8 is plotted for the period prior to (A), during (B), and after (C) the depression of the cigarette selection rate. Figure 31-B includes the period when the response cost per cigarette was raised to 200, and also includes the final adjusting contingencies. Prior to the cigarette experiment, the frequency of selection of the delayed reinforcers was relatively low, although their combined frequency, shown on the right side of the figure, was high. During the cigarette experiment, the percent selections of the Cigarette activity dropped sharply. The effect to be noted in this figure is the sizeable decrease in the percent selections of the Music activity. The figure also shows the compensatory behavior of the subject, that is, those activities that were selected instead of the Cigarette and Music activities. In general, the delayed reinforcers, as well as FD2, were selected more frequently by the subject. Following the termination of the cigarette experiment, the frequency of selection of the delayed reinforcers as a group returned to approximately their original levels, as did the FD2 activity. The percent selection of the Cigarette activity returned to its previous high levels, and the percent selection of the Music activity also increased, but did not return to its original level.

In general, the cigarette experiment revealed that the consumption of cigarettes, which was a strong reinforcer for the subject in this environment, was not substantially affected until the response requirements became excessive (300 to 500 responses per cigarette). The cigarette experiment was not undertaken in an attempt to seriously change the subject's long-term history of smoking, but was rather pursued in order to examine the feasibility of systematic manipulations of this type in the context of a complex experimental environment in which several long-term changes in the subject's behavior were taking place. In spite of these factors, it was feasible to observe the effect of these systematic manipulations not only on the frequency of

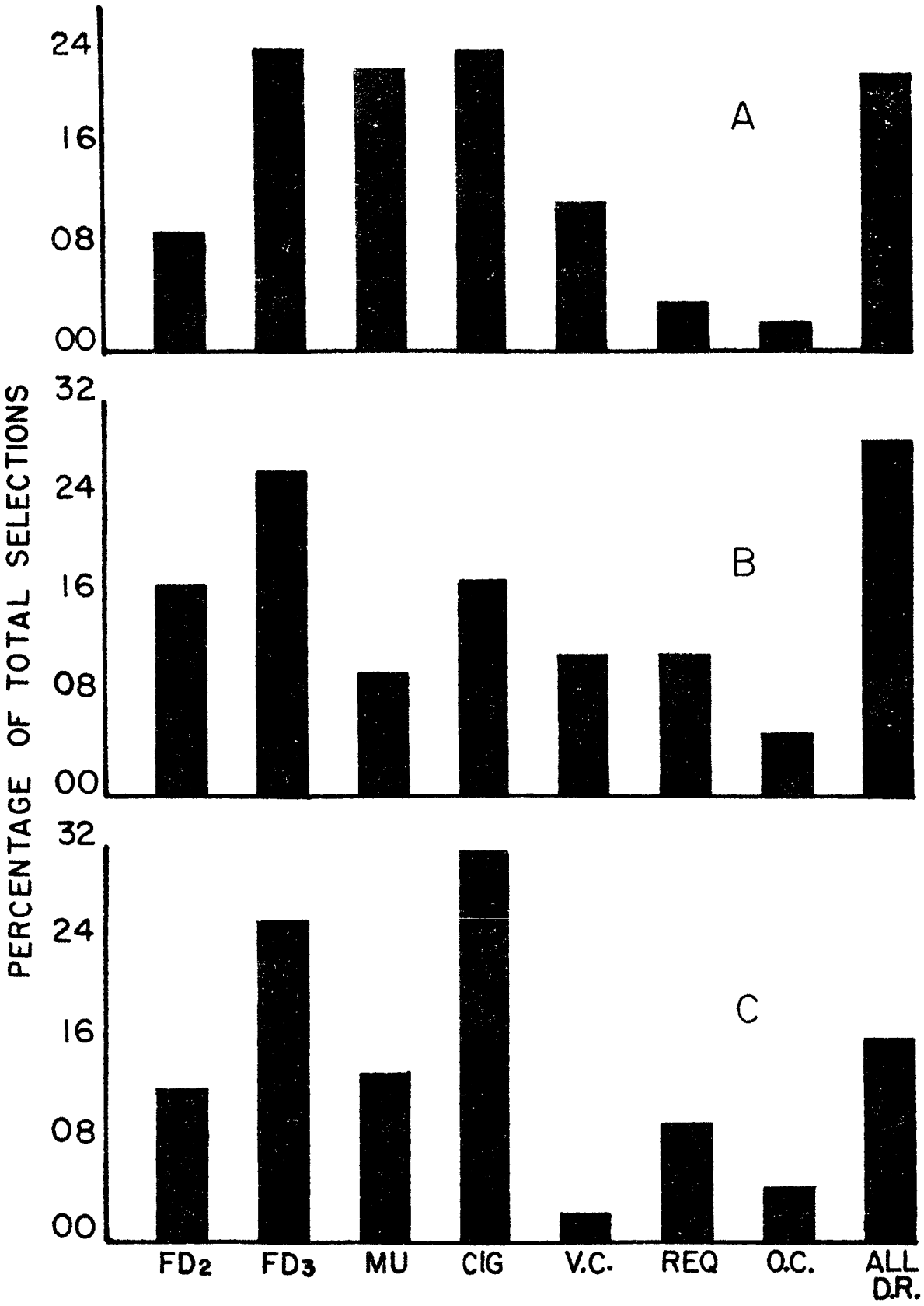

Fig 31. Percent of total selections of each activity in Activity Group 8 for period prior to depression of cigarette selection rate (panel A) during depressed cigarette selection rate (panel B) and after return to prior response cost per cigarette and baseline selection rate of cigarettes (panel C).

selection of the Cigarette activity, but, more interestingly, on behaviors other than those which were directly related to the consumption of cigarettes. Thus the depression in the frequency of use of the vacuum cleaner and the decline in selections of the Music activity and its associated dancing (to be described) were additional activities which were affected by the cigarette experiment. It should be noted that it would not have been possible to observe and measure these side-effects except in a total experimental environment.

MU (Music)

Selection of the Music activity in Activity Group 8 permitted the subject to operate a push button on the auxiliary panel to earn record selections. The number of accumulated earned records was shown by an illuminated indicator panel. When records were accumulated on the indicator panel, the subject was allowed to select any one of 100 records from a selection device mounted on the wall of the main room. Records could be played at any time in any activity in the program, except, of course, when the subject was in the work room.

When the subject entered the Music activity, he was required to earn a fixed number of records. The number of responses required per record was 25. Figure 32 presents the cumulative frequency of selection of the Music activity for the duration of the experiment. Examination of this figure indicates a relatively high selection rate for the first 20 days of the experiment, followed by a somewhat lower rate thereafter, until approximately Point A, when a substantial reduction in frequency occurred. At this time the response requirements in the Cigarette activity were raised to 200 responses, and the subject began selecting the Cigarette activity less frequently, as shown earlier. When the frequency of selection of the Music activity declined, the number of records permitted per selection of the Music activity was increased from four to five in order to increase the amount of reinforcement for selecting the activity, but the low frequency of Music selections persisted. At the conclusion of the cigarette experiment, Point B, the selection rate of the Music activity promptly increased, and remained at a fairly high and stable rate throughout the rest of the experiment.

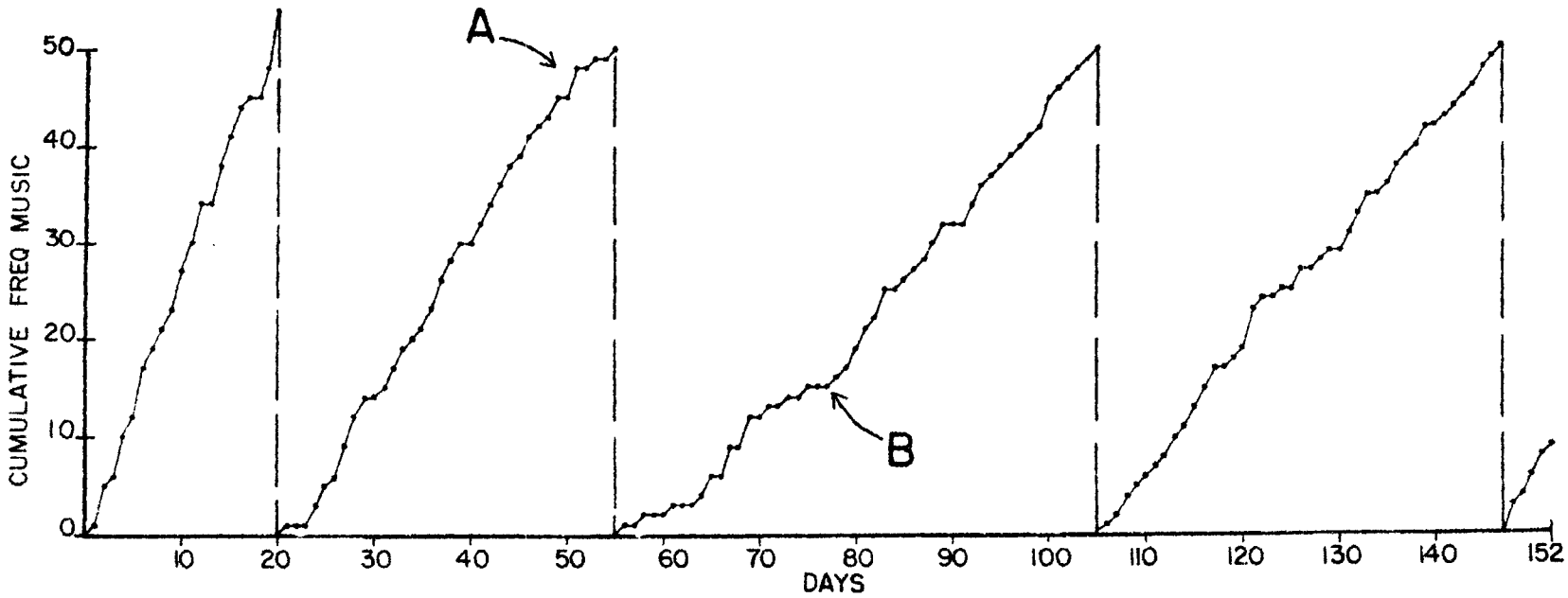

Fig 32. Cumulative frequency of selections of Music activity for each day of the experiment.

Earned records were played predominantly in the TO activity and in the food programs (FD1, FD2, and FD3). By means of the closed circuit TV system, the subject was observed to engage occasionally in various dance routines while listening to the music, particularly in the TO activity. These observations were recorded as they occurred, and the cumulative frequency of dancing is presented in Figure 33. The dancing behavior was observed at a relatively low frequency for the first 25 days of the experiment. Thereafter, a steady rate of dancing while playing records was observed, until approximately day 58. For about 20 days thereafter, Point A, the frequency with which the subject danced was very low. Reference to Figure 33 reveals a correlation with the low frequency of selection of the Music activity in this same period of time. During the remainder of the experiment, in which the frequency of Music selections returned to a stable and fairly high rate, the frequency of observed dancing also returned to its earlier rate. The depressed rate in the selection of the Music activity and the correlated depression in the rate of dancing was clearly associated with the period of high response costs in the cigarette experiment. The nature of the stresses the subject encountered at this time as a result of the cigarette experiment cannot be described precisely, but the side effects of the cigarette experiment in terms of the low frequency of Music selections and, consequently, the low frequency of the dancing behavior, can be clearly observed here. In the final days of the experiment, there was some increase in the frequency of dancing, as seen at Point B.

One of the interesting findings with respect to the Music activity was the persistence in the rate of selection of the Music activity over the entire second half of the experiment, suggesting important reinforcing properties of this activity during prolonged social isolation and confinement.

General Negative Comments, and Somatic Complaints and Health Requests

Much of the data that has been presented from the formal activities of the program combine to suggest a cumulative buildup of behavioral stress in the subject. This generalized stress, as seen in performance decrements in a number of specific activities, is further amplified by several measures of behavior which were concurrent with all other activities in the program. The two sources of this type of data were

(1) the verbal behavior of the subject as monitored over the intercom system, and (2) the use of the LTO activity. Both behaviors could occur at any time during the program. The subject was instructed that he was being monitored over the intercom, and was allowed to make special reports, which were acknowledged by a return "click" by the technician. In addition, the subject was allowed to write brief messages for transmission through the TO drawer. The use of the special reports and the TO notes was generally restricted to requests for health items, reports of apparatus difficulties, or "personal" material. Although the subject was aware of the auditory monitoring system, his comments generally appeared to be spontaneous and not under audience control. The verbal comments obtained from the TO drawer and from the intercom system, including the special reports, were analyzed for their negative content. Those that were negative were sorted into two classes. The first category included those comments of a general nature concerning the environment, for example, complaints about specific activities, apparatus problems, temperature or humidity levels, changes in experimental procedure, etc. The second category included somatic complaints, in which the subject expressed some concern related to his physical health. This category also included requests for health or medical items, such as aspirin, scalp lotions, etc.

The cumulative frequency of general negative comments (the first type) is presented in Figure 34 for the entire experiment. It should be noted that not all verbal comments of the subject were, in fact, monitored, since the monitoring system was not installed in the toilet or work room. Figure 34 reveals a relatively low rate of general negative comments during approximately the first 40 days of the experiment, followed thereafter by an increased and sustained rate for most of the remainder of the experiment, with two main exceptions, noted at Points A and B. At Point A, which immediately followed the vacation, one of the few effects of the vacation which lasted for more than the duration of the vacation was observed. That is, the specific effect of the vacation procedure was on the subject's verbal behavior, rather than on his deteriorating performance in various activities of the program (for example, TO, VB, and MB). Specifically, there was a temporary low frequency of general verbal complaints for

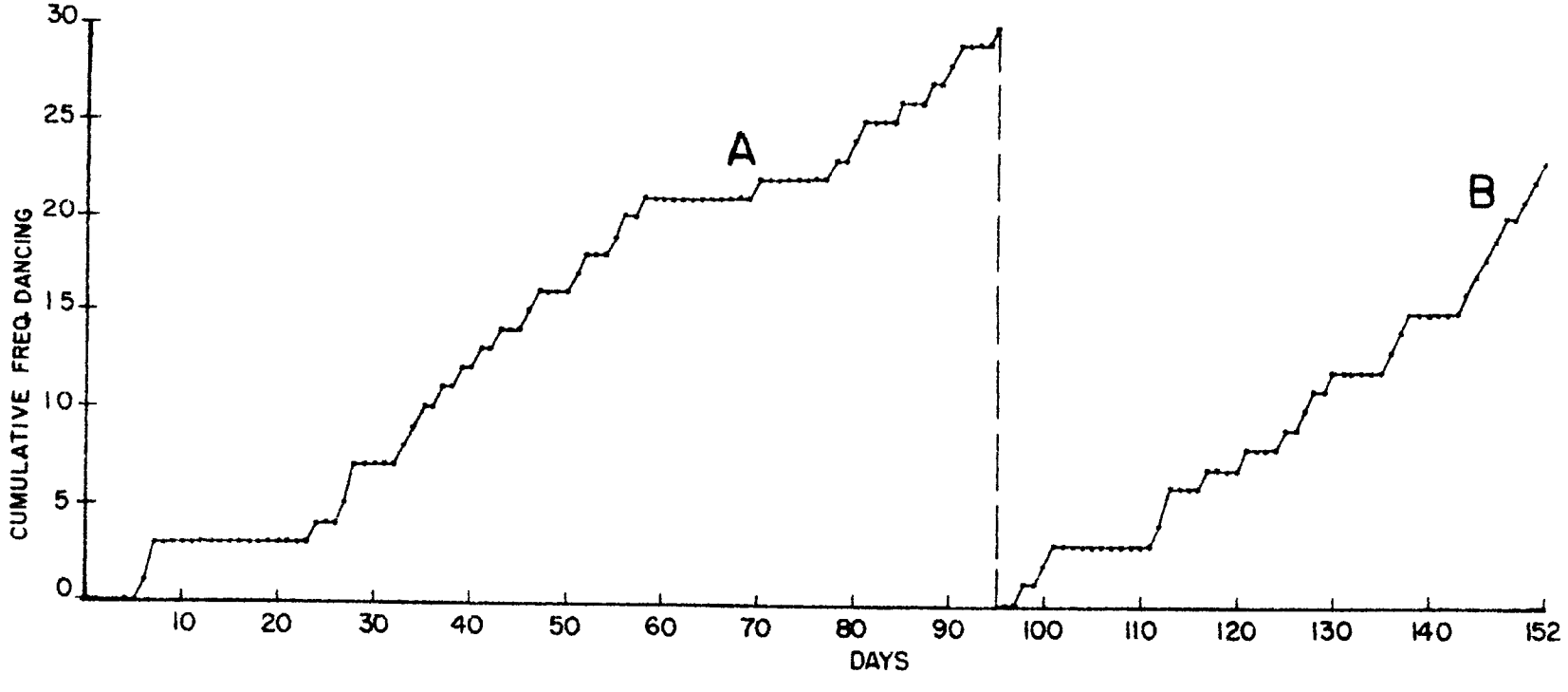

Fig 33. Cumulative frequency of observed dancing for each day of the experiment.

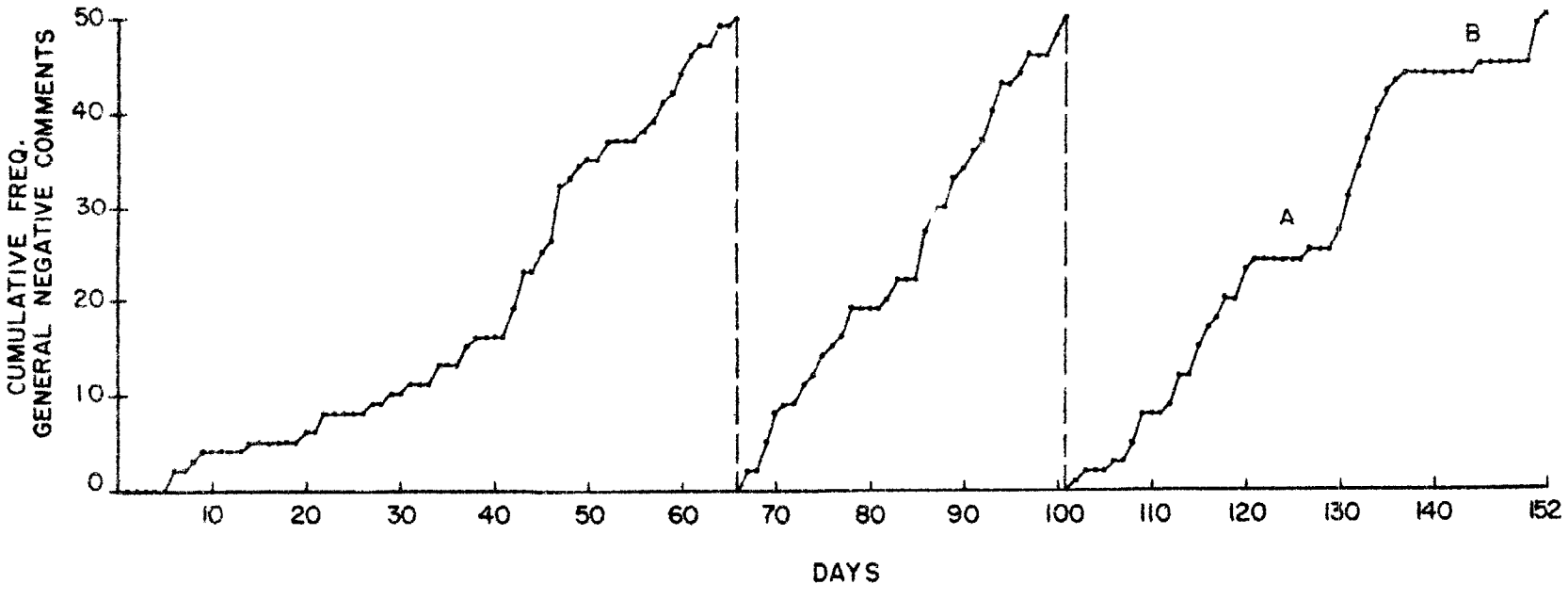

Fig 34. Cumulative frequency of general negative comments, received from intercom system, special reports, and T. O. notes, for each day of the experiment.

several days following the vacation. At Point B, the low frequency of negative comments followed the improvement in the food program which was initiated on day 136. The increase in the general frequency of negative comments during the course of the experiment is only partly revealed by the frequency data shown in this figure, because an increase in the emotionality of these comments throughout the experiment adds an important dimension not readily quantifiable. As the experiment progressed, the intensity of the complaints became greater, and the content shifted from minor complaints to a more general criticism of the environment and the experiment. During the final stages of the experiment, these complaints became even more intense, containing considerable aggression. In addition, suspicions and verbal aggressions directed toward the experimenters and toward psychology in general emerged.

The second broad category of negative verbal comments (somatic complaints and requests for specific medical or health items) is of additional interest in the generalized description of accumulating behavioral stress in the subject. The combined cumulative frequency of occurrence of both the subject's somatic complaints or negative statements about his general physical health, and his requests for specific health items, was plotted for the entire experiment as shown in Figure 35. The nature of the somatic complaints presented in this figure includes reports of headaches, skin problems, and other minor complaints. On one occasion the subject reported an "uncommonly fast heartbeat and sensations in the chest." However, in connection with this report, the subject later took his pulse and reported that it was 86 beats per minute (approximately normal). Requests for medical supplies were generally confined to minor items, for example, eye drops, Cortodome (a skin lotion), eye wash, aspirin, and anti-acid tablets for indigestion. Examination of the figure reveals, first, that the total frequency of occurrence of complaints in this category was lower than the total frequency of the more general complaints, and, second, that the onset of this behavior was delayed in time, relative to the general negative comments. The figure also indicates that once this behavior was initiated, it was maintained at a low but relatively steady rate for the duration of the experiment.

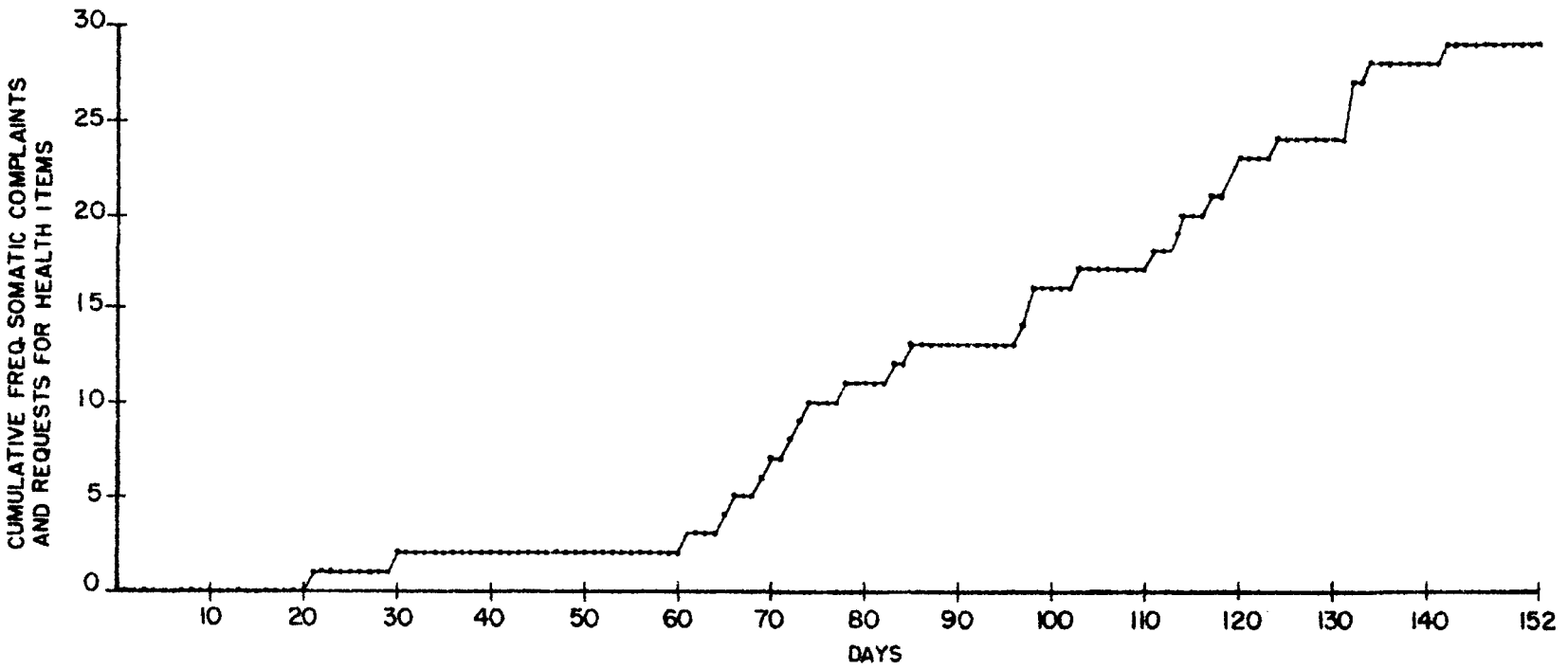

Fig. 35. Cumulative frequency of somatic complaints and requests for health or medical items received from the intercom, special reports, and T. O. notes for each day of the experiment.

LTO (Limited Toilet Operations)

The nature of the results revealed by the data from the general and somatic complaints is supported in a general way by the data from the use of the LTO facility, which was available concurrently with all activities in the program. Figure 36 presents the cumulative frequency of selection of the LTO activity for the entire experiment. It is apparent that during the latter period of the experiment the frequency of LTO increased substantially. For example, during the first 40 days the subject used the LTO activity 200 times, while during the last 40 days of the experiment the subject entered the activity 298 times. The increased frequency in the use of LTO as the experiment progressed was observed throughout the behavioral program. Unfortunately, apparatus difficulties associated with the operation of the toilet did not permit accurate recording of the actual use of the toilet facility during the experiment. Therefore, the behaviors in which the subject engaged during the LTO activity cannot be documented.

The general significance of the increased selection of the LTO facility may be understood by the fact that the selection of the LTO activity temporarily terminated and removed the subject from whatever activity he was currently engaged in. For example, if the subject was in the MB activity, selection of the LTO activity would extinguish the lights in the main room, and would permit the subject to enter the illuminated toilet, in which only the commode could then be used. It is possible, therefore, that the increased frequency of selection of the LTO activity does not reflect an increased frequency of urination or defecation, but rather reflects an additional measure of behavioral strain. In these terms it may be related in a general way to the observed rise in the time spent in TO, FD, and FD2.

The increasing frequency of LTO's, the rise in frequency of general negative complaints, somatic complaints, and requests for health items, the increased frequency of entering the Sleep activity rather than the full program, the increased duration of TO, FD, and FD2, and the declining time spent in the creative activities (MB and VB) all combine to describe a progressive deterioration of the subject's behavior during the experiment.

The final figure to be presented is of a somewhat speculative nature and possibly reflects the more critical cumulative behavior changes taking place during the experiment. Figure 37 contrasts the rising percent time spent in the TO activity with the declining percent time spent in the major work and creative activities (WK1, WK2, PI, VB, and MB). A striking convergence of these curves can be observed, with the percent time spent in TO rising from an initial level of approximately 10 percent to a final level of approximately 25 percent, and with the percent time spent in the second group of activities declining from an initial level of approximately 33 percent to a final level of less than 20 percent. During the last 10 days of the experiment, as noted in Figure 37, it can be observed that not only had the functions converged, but that the subject was actually spending more total time in the TO activity than in the work and creative activities combined. It was at this time, interestingly enough, that the experiment was terminated by joint consent of experimenters and subject. At that time neither was aware of this convergence effect. Should this general effect be observed in subsequent work in this area, a quantitative although complex description of "depression" or "emotional stress," etc., may become available.

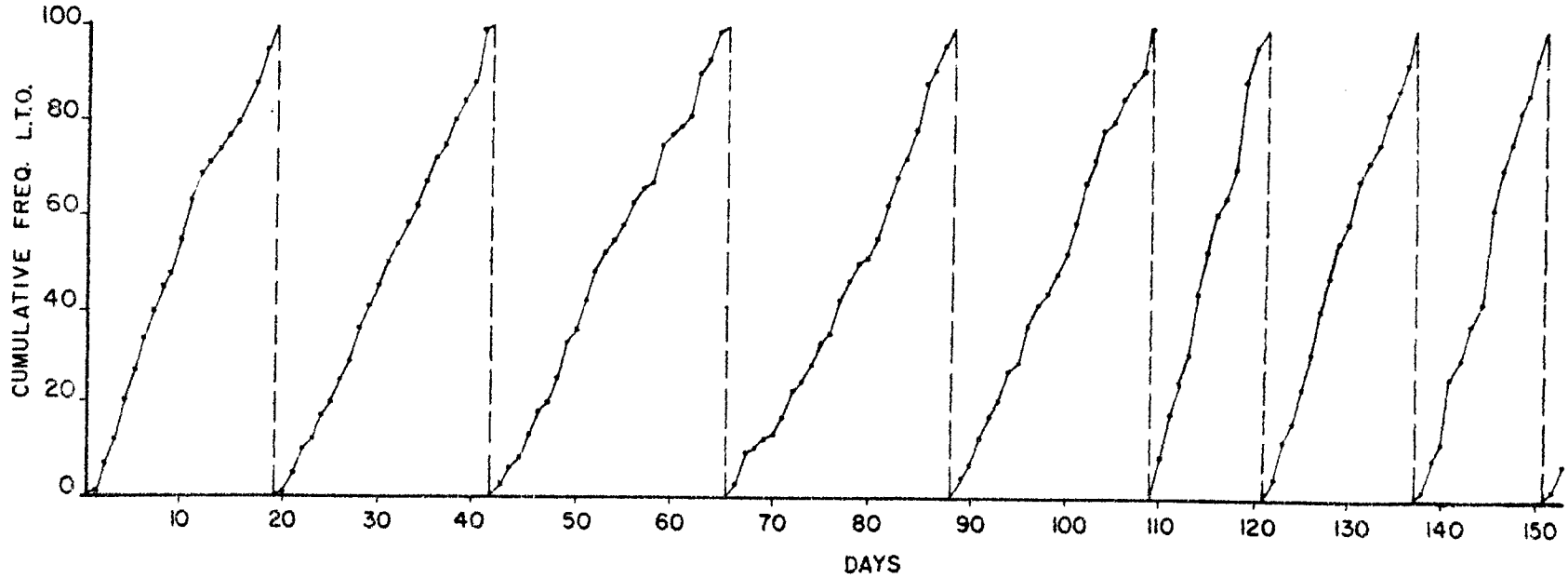

Fig. 36. Cumulative frequency of selection of the Limited Toilet Operations activity for each day of the experiment.

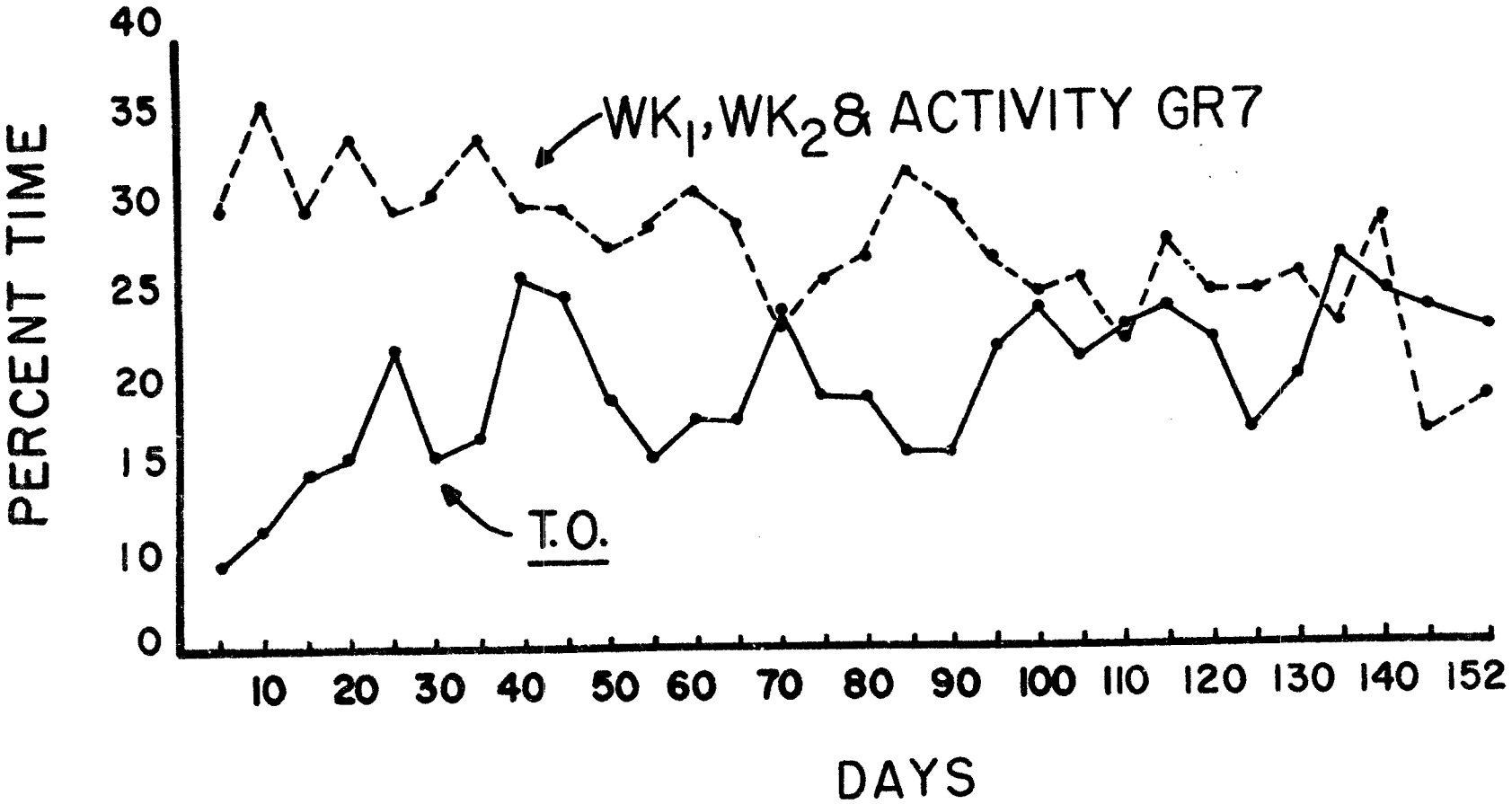

Fig 37. Percent of total time spent in Toilet Operations versus percent of total time spent in the Work Tasks and in Activity Group 7 (reading, writing and creative activities) for the entire experiment.

GENERAL DISCUSSION

In the preceding section, data has been presented and discussed which describes the subject's performance in each of the activities of the program; in addition, numerous interrelations among the activities have also been presented. In the present section, an attempt will be made to focus on some of the most general findings. This will be followed by a discussion of the implications of the present work for future research in the experimental analysis of human behavior.

With respect to the behavioral measures, or dependent variables, three categories emerged, all of which provided parallel indications of accumulating behavioral strain in the subject. The first category includes those measures of behavioral strain which have a direct reference to measures of behavioral strain at the lower animal level. Specifically, under conditions of insufficient reinforcement or excessive response requirements, lower organisms spend increasing amounts of time pausing or "straining," particularly in early members of response chains. Thus the increasing percent times spent in the TO and FD1 activities prior to entering the Sleep activity, emerge as analogous measures of behavioral strain at the human level.

A second group of behavioral measures emerged which has not yet been described in the research literature as measures of behavioral strain at the animal level. Specifically, the increased frequency of entering sleep, the reduced duration of the sleep periods, and the increased frequency of selection of the LTO activity (Limited Toilet Operations) were highly suggestive as measures of accumulating behavioral strain. It should be noted, of course, that these measures are not necessarily restricted to the human level, that is, these effects could be observed at the animal level. The basis for these changes in behavior is, of course, open to alternative interpretations. For example, the increased frequency and reduced duration of sleep, as well as the increased frequency of LTO, may have had a physiological basis in terms of metabolic or other changes. (Some urine specimens were collected and analyzed in the beginning of the experiment, but the data were not sufficient for presentation.)

The third group of measures that emerged was related strictly to human performance and also described the increasing behavioral strain during the experiment. This included

the rise in frequency of verbal complaints, either about specific or general aspects of the environment; the late development and maintenance of somatic complaints; the increased frequency of working for and requisitioning changes in experimental procedures or new stimuli in the environment; and the decline in the amount of time spent in the more intellectual activities of the 7th Activity Group, particularly VB and MB.

Thus a rather comprehensive picture of the behavior changes of the subject (dependent variables) was provided by the present experimental procedures. The environmental conditions, or independent variables, that were responsible for these changes in behavior undoubtedly were related to the effects of social isolation and geographical confinement. Since these were not directly manipulated during the experiment, one must infer, in the most reasonable way, the effects of these conditions upon the subject's behavior. Social isolation was not complete in this experiment in the sense that limited use of the intercom system and limited exchange of written notes was possible; but, other than these, the subject had no direct contact with other human beings. Those behaviors which are dependent on the behavior of other organisms for their maintenance (social reinforcements) were most affected by the social isolation condition. In particular, in our judgment, the absence of social reinforcements resulted in the deterioration of the more creative activities, VB and MB, over the time course of the experiment.

The effect of confinement to a limited space played a relatively small role in the experiment, as far as could be determined. Insofar as confinement normally reduces the kinds of behavior which may be emitted and reinforced, the effect of this variable can be overcome, as was attempted in the present procedures, by the design of an environment in which many and varied behaviors can occur and can be reinforced.

During the course of the experiment, a "sub-experiment" was carried out in which the independent variable of response cost for one of the principal reinforcements for the subject (cigarettes) was manipulated, and its effect on several dependent variables was observed. The interesting finding here was that the effect of very high response costs for cigarettes reduced not only the frequency of selection of the cigarette activity, but produced several side effects as well. That is, the frequency of use of

the vacuum cleaner and the frequency of selection of the Music activity were also reduced. Furthermore, apparently as a consequence of the reduction in the selection of Music, the spontaneous dancing behavior during Music was also reduced in frequency. Thus the effect of manipulating the independent variable was observed not only locally, that is, in the behavior most closely affected (the selection of cigarettes), but also remotely, that is, in behaviors not directly related to the manipulation of the independent variable (the music and dancing, and vacuum cleaning).

The future use of the technique of the "total environment" is recommended here for a more thorough experimental analysis of human behavior. This recommendation is based on the demonstrated feasibility of measuring large segments of the subject's repertoire and placing these under experimental control as well as the variety of complex behavioral effects that were observed and described quantitatively during the experiment. Some uses to which this research tool may be employed are suggested below.

SOME SUGGESTIONS FOR FUTURE RESEARCH

As a research tool, the kind of environment described in the present work can be used in the study of a wide range of problem areas. For example, measurements can be made of the broad behavioral effects of various kinds of stress of physiological manipulations, drug or hormone administration, circadian (24 hour) rhythms, artificial light-dark periods, and many other experimental procedures. Moreover, the introduction of one or more additional human subjects, with full measurement and control of their behavior, would open up possibilities for basic and applied research in certain areas that are closely tied to some current needs of society. Some of these problem areas and the related research questions which could be pursued in the kind of environment described here are presented briefly below.

Alcoholism and obesity represent two serious disorders which are based, in many if not most cases, at least in part on psychological problems. Specifically, an individual eats or drinks excessively, and has difficulty controlling this behavior. Although several approaches could be taken in the analysis and control of this behavior in a programmed environment, one particular procedure is highly suggestive, namely, the gradual training or shaping of self-control behavior which the subject could "carry away" from the environment.

One might define self-control behavior as a response which switches an S^D (a stimulus in which certain behaviors are rewarded) to an S^Δ (a stimulus in which certain behaviors are never rewarded), that is, a response which makes a reinforcement unavailable. There are degrees of self-control, however, so that several different durations of S^Δ might be available, and the degree of self-control would be indicated by the selected duration. On the other hand, the response might switch the S^D not to S^Δ but to an S^D in which the schedule of reinforcement was less favorable. Thus, in a programmed environment, alcohol or food could be continuously available from a dispenser only when a certain stimulus was on. A prescribed response by the alcoholic or obese individual could extinguish the stimulus for some fixed duration, or introduce a high work requirement, or some combination of these. As a consequence of this

self-control response, the environment could provide immediate and significant biological and/or social reinforcements to the subject. Initially, very small self-control responses could be followed by reinforcements of large magnitude, particularly in those activities where the eating or drinking was unlikely to occur in the first place (on the basis of earlier recorded behavior of the subject). After the initial self-control behavior had developed, the magnitude of the required self-control behavior, or the number of self-control responses, could be gradually increased, in addition to a gradual reduction in the magnitude of the programmed reinforcement. At a later stage, the subject could be periodically released from the environment, not for increasing amounts of time, necessarily, but to engage in increasing numbers of specific activities (for example, specific work tasks, or hobby activities) in which the self-control behavior was known to be at high strength.

This outline, of course, is meant only as a suggestion of the kind of approach to these problems that would be possible using a programmed environment. Thus a basic research problem, that is, the analysis and control of self-control behavior, and an applied research problem, that is, the analysis and control of alcoholism or obesity, could be pursued concurrently.

A second broad problem area is concerned, in general terms, with the interactions of individuals with other individuals. A general approach to the analysis and control of social behaviors will be described briefly in terms of the total environment technique.

Changes in the frequency or nature of social interactions can be conceived of as a problem in the training of new behaviors and the extinction of other behaviors. At the animal level, the technique of shaping particular responses by successive approximations to the new behavior is a very rapid and effective technique for changing behavior or for bringing out new behaviors. This technique, therefore, has become a widely used tool in animal research. Where possible or practical, automatic recording or measurement of behavior and automatic dispensation of reinforcements is used as the behavior develops. In other cases, the experimenter observes the behavior directly and delivers reinforcements for particular behaviors. In the latter case,

the technique is called "hand shaping." The limits of the shaping procedure in terms of what behaviors can be shaped, and the limits for particular species, are not known, but are probably determined to a great extent by the skill of the experimenter and the limits of his apparatus. Social behavior in human subjects, and, in particular, disturbed social behaviors, are not excluded from the range of usefulness of this procedure. What is needed is a specific technique and an environment in which to apply the technique.

In a highly programmed environment in which several individuals of both sexes were living, one could undoubtedly separate out and measure quantitatively many kinds and intensities of social interactions. For example, these behaviors could range from the social distribution and consumption of the "natural" resources given to the environment, such as water and electricity, to more obvious social behaviors such as verbal interactions and even sexual behavior. However, regardless of the particular behavior or behavior repertoire selected for study, the main point here is that the technique of the total programmed environment would permit these behaviors to come under precise experimental manipulation or shaping. Where particular social interactions can be defined and measured automatically, then automatic consequences can be programmed to successively approximate some desired final behavior. Where the behavior cannot be handled automatically, the social behavior can be "hand-shaped" by the research investigators (using appropriate reinforcements) in order to eliminate selected behaviors over periods of time and to produce new social behaviors.

The final research area to be suggested here is somewhat different from the first two, in which certain problem behaviors would be gradually eliminated while new behaviors were being developed. In this last illustration, the problem is not to eliminate any specific behavior, but to bring a weak behavior to full strength for the benefit of both the individual and his society. Education is specifically referred to here.

In a special purpose total environment designed to explore new approaches to education, the critical specific feature would be the automatic educational devices. That is, these devices must be capable of presenting a wide range of stimuli (educational material), and must accept, and automatically and immediately verify, a wide range

of responses. The opportunity for obtaining the various reinforcements that are available in the environment can then be made contingent on the performance of the subject on the educational devices. Thus, access to food, hobby activities, TO, social interactions, etc., could be obtained only after some specified amount of educational "behavior" had been emitted. For example, the response cost of each of the various facilities or reinforcements in the environment could be specified in terms of the number of frames of a programmed text (Skinner, 1958) which are successfully completed, as presented and verified by the machine. For example, access to a major meal might require 100 frames in computer programming at perhaps 90 percent correct; access to an outdoor area for a tennis match might require 50 frames in French; social interaction with the opposite sex might require 200 frames in sociology, etc.

Given such an environment, one can suggest a number of possible applications. For example, one could design a nursery school or public school in which young children could spend several days at a time living under conditions similar in principle to those just described, but modified in subject matter for the particular age level. Reading has already been successfully taught to very young children, and it is possible that the educational and creative potential of young children has been enormously underestimated. The programmed environment could very well expose this behavior and bring it to full flower. Additional possibilities for the amplification of potential behavior repertoires can be extrapolated by the reader for mentally "deficient" or "retarded" children.

In general, therefore, the scientific and social uses to which these environments can be put can be only partially visualized at present, but the possibilities for more intensive analyses of man's current behavior repertoire and for the potential development of new repertoires are clear.

RECOMMENDATIONS FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Some specific recommendations for the National Aeronautics and Space Administration regarding the design of behavioral environments for long-term space flights will be made in this special section of the report. These recommendations are, of course, relevant to any subsequent study of the effects of long-term social isolation and confinement on man.

1. Perhaps the most general, although controversial, recommendation generated by the present research concerns the use of a highly programmed environment. This recommendation for the use of a highly programmed environment is based on several specific results. First and foremost is the fact that this environment sustained the subject in good health and maintained good work performance at a variety of tasks under conditions of extreme social isolation and confinement for an unprecedented duration of 152 days, or approximately five months. In our view, the programmed environment achieves a number of desirable objectives. Most important of these is the virtual elimination of the need for the aversive control of behavior. That is, weak, unreliable, or unreinforcing behaviors which are necessary for the mission (for example, exercising regularly; taking frequent physiological measurements, e.g. weight, temperature; performance of uninteresting but necessary work tasks; etc.), can, of course, be sustained by implied threat of punishment, or by issuance of orders, or by threat of undesirable changes in work distribution, or other kinds of aversive consequences. In the programmed environment, these kinds of behaviors can be sustained, as was done in the present research, by placing them in early members of chains of behaviors, where access to the final portions of the chain, in which the most reinforcing activities are located, is achieved by passing through the earlier members of the chain. This not only provides a reasonable assurance that these important behaviors will be performed regularly, but should also contribute to the maintenance of a generally positively reinforcing environment, as opposed to that which would be generated by the use of aversive controls.

2. The increased frequency with which the subject entered the Sleep activity, coupled with the decreasing duration of Sleep, produced a progressive decline in the period (wake + sleep cycles) of the subject in the course of the experiment. The main observed effect of the clock was to reduce sharply the variability of the period, although the clock did not prevent the continuing decline in the period, particularly near the end of the experiment. Thus the suggestion that fixed work-rest cycles be used in prolonged space flights is contra-indicated by the present data. Instead, a flexible procedure is indicated, in which the duration of required work or rest periods is determined not by a clock but by the level of performance. Furthermore, where two or more individuals are participating, the distribution of work should also be based on performance levels rather than on an equitable time sharing of the work loads. In combination with the argument presented above for the use of programmed environments, it should be noted that a necessary adjunct to the procedures recommended here is that high performance levels on work tasks should have certain prescribed reinforcing consequences.

3. One of the activities which was sustained throughout the experiment, and even showed some increase in the final stages of the experiment, was the reading activity. This suggests the relatively strong reinforcing properties of this kind of behavior under the conditions of social isolation and confinement. Taking this cue, a specific recommendation for the design of future behavioral environments would be the amplification of this activity into a more intensive educational program, utilizing current developments in audio-visual instruction and programmed instruction, with automatic scoring devices. This could permit the in-flight acquisition of an expanded educational repertoire in a number of areas, and should definitely contribute to an improvement in the general reinforcing properties of the environment.

4. The frequency of selection of the Music activity was also sustained throughout the entire experiment and again suggests another activity whose reinforcing properties were maintained under the conditions of social isolation and confinement. Taking this cue, another recommendation can be made that in addition to the passive behavior of listening to music, the subjects should also take an active role by performing on a

musical instrument. Furthermore, the instrument could be learned in flight by special programming techniques. This should also contribute, although perhaps in a small way, to the general reinforcing properties of the environment.

5. The decline in the creative and intellectual behaviors suggests the possibility of a similar effect with respect to scientific activities that might be expected in a prolonged space flight. There was little doubt that a determinant of this decrement in performance was the condition of social isolation and the constriction of social feedback for these behaviors. Therefore, a specific recommendation for future work in this area would be, first, the inclusion of one or more additional subjects in the environment, and, second, the initiation of explicit contingencies or consequences (for example, in-flight awards) for these behaviors, not only from the other individuals in the environment, but also (and possibly more importantly) from the social environment on the ground.

6. The increased frequency with which the subject worked for and requisitioned changes in the environment, particularly in the later stages of the experiment, specifically suggests the need for some facility of this kind for a prolonged space flight. The recommendation here would be to install and store certain facilities in the chambers which would not be available during the early phases of the flight. These would become available in later stages of the flight as they were needed and earned, in order to introduce new forms of stimulation and interest if excessive behavioral strain should develop. They would, of course, need to be realistic. Some possibilities here would include new exercise devices, new music selections, new foods, new games or entertainment, and even new work tasks.

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