INFORMATION TO USERS

This was produced from a copy of a document sent to us for microfilming. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help you understand markings or notations which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure you of complete continuity.
2. When an image on the film is obliterated with a round black mark it is an indication that the film inspector noticed either blurred copy because of movement during exposure, or duplicate copy. Unless we meant to delete copyrighted materials that should not have been filmed, you will find a good image of the page in the adjacent frame.
3. When a map, drawing or chart, etc., is part of the material being photographed the photographer has followed a definite method in "sectioning" the material. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.
4. For any illustrations that cannot be reproduced satisfactorily by xerography, photographic prints can be purchased at additional cost and tipped into your xerographic copy. Requests can be made to our Dissertations Customer Services Department.
5. Some pages in any document may have indistinct print. In all cases we have filmed the best available copy.

University
Microfilms
International

300 N. ZEEB ROAD, ANN ARBOR, MI 48106
18 BEDFORD ROW, LONDON WC1R 4EJ, ENGLAND

7913122

DE SANTIS, JOSEPH LOUIS
DEVELOPMENT OF SOCIAL BEHAVIOR IN THE COMMON SPINY MOUSE (ACOMYS CAHIRINUS) UNDER VARIED CONDITIONS OF ENVIRONMENTAL MANIPULATIONS AND OBJECT CONTACT.

CITY UNIVERSITY OF NEW YORK, PH.D., 1979

University Microfilms International 300 N. ZEEB ROAD, ANN ARBOR, MI 48106

DEVELOPMENT OF SOCIAL BEHAVIOR IN THE COMMON SPINY MOUSE (ACOMYS CAHIRINUS) UNDER VARIED CONDITIONS OF ENVIRONMENTAL MANIPULATIONS AND OBJECT CONTACT

by

JOSEPH L. DE SANTIS

A dissertation submitted to the Graduate Faculty
in Biology in partial fulfillment of the
requirements for the degree of Doctor of
Philosophy, The City University of New York.

1979

JOSEPH DE SANTIS

This manuscript has been read and accepted for the Executive Committee in Biology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

January 19, 1979
Date

Ethel Tobach
Chairman of Examining Committee
Professor Ethel Tobach

January 25, 1979
Date

Louis G. Moriber
Executive Officer
Professor L. G. Moriber

Prof. J. Griswold
City College
Institution

Stanley Wecker
Prof. S. Wecker
City College
Institution

P M Bronstein
Prof. P.M. Bronstein
Trenton State College
Institution

Prof. R. J. Barfield
Livingston College
Institution

Institution

Institution

The City University of New York

ABSTRACT

In general, research has shown that varied effects of both social and non-social stimuli within a mammal's rearing environment are observable in that animal's behavioral development. The specific influence of the inanimate setting upon developing social processes, however, has never been emphasized. The present study, employing the nocturnally active desert spiny mouse, *Acomys cahirinus*, provided for the rearing of these precocial neonates by lactating females within one of four experimental environments. These varied in both the shape of a sheltering structure (either box or T-tube) and the moveability of the substrate (either sand or balsa wood) and consequently all items upon it. Time spent by the pups in social interactions and also in locomotion across 5 empirically established stages of development provided input for analyses of variance. Results showed that *A. cahirinus* reared from birth to day 21 with a box used this structure more for interindividual activity than did tube-reared pups, the tube. In addition, pups reared in moveable environments engaged in more interindividual activity than did those in non-moveable ones. Each of the four experimental environments stimulated a different level of locomotory response throughout the litter period.

Each experimental pup was removed from the litter environment on day 22 and placed into an observational situation which included *both* sheltering structures and *both* substrates used during rearing. Behavioral data obtained in this setting provided evidence that differentially reared *A. cahirinus*, upon weaning, could distinguish between familiar and unfamiliar inanimate environmental items.

Subsequent to weaning each subject was individually maintained

in a smaller replica of its rearing environment. Eleven days after their introduction to this "home cage," pre-selected individuals were observed in a completely "novel" environment. In this setting subjects were found attracted to stimulus characteristics which the items presented had in common with objects and substrates of their rearing.

Placing A. cahirinus on day 44 into an observational environment like that used at weaning, revealed their maintained ability to perceive the differences between those items reared with and those not. Based on these results it was concluded that the inanimate references of rearing had persistent effects upon behavior.

On day 66 subjects were given their first exposure to conspecifics since their weaning. Although only nose-to-nose contact was permitted by the observational situation, both male and female experimental populations showed differing responses to like as opposed to unlike-sexed conspecifics. Tube-reared animals used the available tubes more than box-reared mice and in this way made more contact with same-sexed conspecifics. Males reared in the non-moveable environments demonstrated less dependence upon the tubes than those from moveable ones in establishing contact with females. Females from non-moveable environments made more social contact with non-experimental males than females; moveable-reared females responded conversely.

For males, the moveable/non-moveable difference in responsiveness to non-experimental females was similarly expressed when on day 73, subjects were given the opportunity for unlimited heterosexual contact. Here, males from the balsa-bottomed environments nosed the ano-genital region of females more than did males reared upon sand, the former doing so with a minimal likelihood of being aggressively chased.

Among females those box-reared were more stimulatory to their non-experimental mates than were those tube-reared as measured by the frequency with which males rapidly followed them.

The results obtained are explained on the basis that the perception of a non-moveable environment is part of the species-typical experience needed for adaptive social responses to develop in *Acomys cahirinus*; box-rearing being similarly effective for females. This interpretation is supported by descriptions of the natural habitat which is primarily of rock and is devoid of tubular burrows.

ACKNOWLEDGEMENTS

This work was made possible by the patient guidance, encouragement and intellectual stimulation of my mentor Dr. Ethel Tobach and in general the invaluable criticisms of my dissertation committee.

My thanks go to all of these as well as to certain outstanding individuals who during the past five years have helped me in the conduct and completion of this project. These include Frederick Solomon, Jenny Sadow, Anne Robinson, Thomas Caperna, Vivian Tom and Cynthia Sam.

Special thanks go to Dr. Rosamund Gianutsos for her assistance in computer analysis and to my fellow employees Robert Stolberg and Patricia Brunauer for their support and understanding.

This work, which is dedicated to my parents, Anthony and Grace, owes its existence to Dadmara who's constancy and friendship provided the emotional "environment" essential to its completion.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

Appendices

LIST OF FIGURES

INTRODUCTION

Experiments with plants and animals have shown that the developing organism reflects the genetic aspects of its structure as they are expressed through diverse and complex interrelationships between organism and developmental medium (Topoff, 1973; Tobach, 1972; Lewontin, 1974). Such investigations have revealed that certain conditions of stimulation during early experience are necessary to the development of species-typical behavior patterns (Schneirla, 1956, 1962). The effects of experience, defined as _all_ stimulus influences upon the organism through its life history at all levels of its organization, even if generalized, diffuse, and variable may be found at the time of stimulation as well as at later stages of development (Schneirla, 1957; Lehrman, 1971). When early development is associated with parental care, as it is with birds and mammals, behavioral development takes place within the physical surroundings of a "home site" (Rosenblatt _et_ _al_., 1969).

Here the neonatal mammal is nourished and cared for by its mother, while growing and maturing via newly elaborated and functioning organ systems. Within this context the sensory and motor abilities which had initially mediated mother-neonate contact become refined and integrated with those emerging later. In the course of establishing its first social bonds, the young animal becomes capable of obtaining, retaining and reacting to information about its internal and external environments. Since the social component of these processes is essentially inextricable from the pattern of species-typical development in a species-typical environment, it follows that normal social development is affected by the characteristics of the environmental background in which it takes place. The availability and characteristics (i.e., odor, texture, moveability) of objects or materials in or in the proximity of the nursing site, burrow or den influence both qualitatively and quantitatively the attention and subsequent activities which the developing animal directs toward its mother, littermates (if any) and itself. The selective responses of young rats (Moltz, 1973; Leon, 1974; Tobach, 1977) and the common spiny mouse, Acomys cahirinus (Porter, 1975) to cage materials changed by the chemical secretions of their mothers exemplifies this.

The relationship between the characteristics of an animal's external environment and its behavioral development has been studied by providing different kinds and amounts of animate and inanimate stimuli to a variety of laboratory reared mammals during various stages of their development. Typically the aim is to study the effects of such experience on subsequent behavior. In terms of their underlying design, experiments of this type commonly utilize one or both of two contrasting approaches: "enrichment" and "deprivation." The former involves providing animals with spacious quarters in which conspecifics also live and with the opportunity for contacting novel stimuli. The latter often refers to the rearing of solitary individuals in generally small, visually limited, non-stimulating environments. The effects of these different environments are investigated by later observing the animals in a variety of "learning" situations.

A second "deprivation" technique is described by Lorenz (1965). In this case, to determine what behaviors in an animal's repertoire are not learned (i.e., are innate), one demonstrates their existence in developing young animals from which specific kinds of information and experience have been withheld.

The differences between the two deprivation techniques described above are major ones. The former often makes use of domesticated animals bred for laboratory use, the latter usually does not. In addition these laboratory animals are subjected to artificial, frequently severe environmental conditions as young and are later tested in situations which require responses ranging from species-typical behavior to the limits of their behavioral capacities. In the Lorenzian approach, subjects are reared and tested in nearly species-typical environments where the effects of withholding information are subsequently observed as deviations from normal species-typical behavior.

The results obtainable by either of the above techniques are limited however since the enrichment/deprivation approach does not provide direct information about behavior as it occurs in nature, while the Lorenzian strategy fails to demonstrate the full range of behavioral plasticity upon which natural selection operates. Of the two, enrichment/deprivation experiments have produced a more varied literature. This has largely been generated by the application of the following three experimental methods:

1) measuring "intelligence" by requiring subjects to perform specialized, learned tasks (i.e., maze running) after spending a period of development in a socially and/or physically deprived or enriched environment. Since the goal is to demonstrate ultimate changes in learning capacity as affected by environment, final testing is emphasized. The actual process of enrichment as manifested in the subject's interaction with both physical and social environments is not observed, however.
2) observing the responses to novel social and physical stimuli of young having differential social experiences ranging from isolation at birth to group-rearing. This technique provides information regarding the early social stimuli required for normal development as seen in adjustive responses to social and physical novelty and normal sexual behavior.
3) evaluating the responses to physical stimuli of animals developing within a socially normal milieu, but deprived of specific senses as young. Use of this technique has provided evidence relating to the social consequences of sensory deprivation.

Within the limits of each technique investigators have used different levels of environmental stimuli to produce both "deprived" and "enriched" animals for experimental comparison. The following review categorizes these often disparate levels within a framework of specified behavioral effects. Unless otherwise indicated the studies cited involved comparisons of animals reared under socially and/or physically deprived conditions vs. socially and/or physically enriched conditions.

A. Effect on Learning

1. Total Social-Physical Deprivation

Research conducted on rhesus monkeys demonstrated the effects of solitary rearing in lighted, but visually restricted cages with feeding, cage maintenance and self-produced activity as the only stimulation (Harlow et al., 1969). The test situation involved learning to discriminate objects at nine months of age. The specific task, which required the monkeys to reach through a set of bars and displace the appropriate three-dimensional object associated with a food reward, was performed equally well by both the isolates and the group-reared controls. The isolates, however, took nearly twice as long to adjust to the complex testing procedures prerequisite to the actual learning sessions. Those results parallel the deficient responses reported of isolated rhesus monkeys confronted with environmental novelty and complexity (Sackett, 1972). Harlow's results, however, demonstrate that although the most extreme forms of early isolation do not result in "intellectual impairment" as measured by this task, they do affect the animal's adjustment to new, somewhat taxing situations.

2. Developmentally Delayed Social-Physical Deprivation

Hooded (McGill strain) and albino (Wistar) rats used in studies emphasizing the effects of enrichment upon learning have usually had extensive social experience before being placed in the contrasting experimental environments. This results from the practice of allowing weaning (at 21 to 25 days) to take place before the young are differentially exposed. In addition, the physical stimuli prior to weaning are usually maintained at typical laboratory levels since environmental enrichment during this period appears to have no measurable effect on subsequent performance (Forgays _et al_., 1962). In most cases (Forgays _et al_., 1962; Hebb, 1947; Hymovitch, 1952; Schweikert _et al_., 1966; Ivinskis _et al_., 1976) "performance" is measured by the animal's ability to learn a maze. Typically, young rats having experienced the complex (enriched) post-weaning environment require fewer trials to achieve consistency of performance. According to Barnett (1974) while such research indicates that early (i.e., post-weaning) enrichment can improve a rat's learning of a specific task, it does not result in general "intellectual improvement."

3. Partial Social-Physical Enrichment Compared to Total Social-Physical Enrichment

Recently Gluck _et al_. (1973) extended the research on rhesus monkeys to include subjects reared from birth in a totally enriched environment. The latter gave each young monkey unlimited access to 11 other adult and immature monkeys of both sexes and to a play area containing various types of objects related to exercise and activity. The study compared these animals to others reared individually from birth in bare, climable wire cages providing only visual and auditory stimuli from other monkeys and from laboratory personnel.

As measured by the complex oddity problem, results demonstrated that increased levels of early social-physical enrichment improves learning ability in rhesus monkeys. Specifically, the task which revealed this required the subject to select the one solid object in a group of three not identical to the remaining two. However, when tested on the delay task (which requires the subject to wait a predetermined number of seconds before responding to the appropriate reward stimulus) a different result was obtained. In this case the animals from the totally enriched environment were out-performed by individuals experiencing partial enrichment. The authors base their explanation of this outcome on the disturbance caused to totally enriched animals by the delay which gave these animals more time to perceive the large discrepancy between the stark testing room and their home environment. Also, daily separation from peers becomes stressful for group-reared monkeys (Seay _et_ _al_., 1962) so that the poor response to testing might have been influenced by removal from a familiar social environment as well.

4. Early Auditory Deprivation Compared to Early Visual Deprivation

Wistar rats, reared in a species-typical social environment, were temporarily deprived of audition or vision from the period before the functional onset of these modalities until weaning. Each experimental population lost in a competition for food when the stimulus indicating the trial's onset corresponded to the modality originally impaired (Wolf, 1943). Further testing showed, however, that the social component of competition was responsible for this outcome. When tested alone the same animals responded properly to both auditory and visual signals for food.

B. Effects on Responses to Novelty

1. Social Restriction Compared to Social Enrichment

In a study of squirrel monkeys (Kaplan, 1972), young were either housed only with their mothers (having visual and auditory access to other conspecifics) or with a group composed of five adult females (including the mother) and five additional young. After being separated from their respective mothers when approximately 22 weeks of age, each of the young was tested in an apparatus which permitted its approach to any of four adjacent cages, one containing its mother, another an unfamiliar adult female, the third an unfamiliar infant, while the fourth was empty. The results showed that most of the young reared in the socially enriched environment consistently preferred their mother to all other options. Most of the socially restricted young, however, did not show a consistent preference for any of the stimulus choices.

Knowledge of the female-young relationship in each of the environments above suggests an explanation for the experimental results. Kaplan observed that while mothers in the socially enriched environment were more protective of their young, mothers in the socially restricted condition were more punitive and apparently "less concerned with their infants." In addition, Wolfheim _et al_. (1970) have presented data for the pigtailed macaque suggesting that group-housed mothers, being more protective of their young, "develop a closer relationship with them" as compared with socially restricted mothers. One can infer that the reciprocal nature of this relationship resulted in the attractiveness of the mother to socially enriched young tested in Kaplan's apparatus. The developing relationship in socially restricted environments is less reciprocal. Here infants seek out their mothers attempting to "play with" (push, pull, slap) them more often and spend more time in their proximity as they become older (Kaplan, 1972). This is clearly an effect of social and not spacial restriction since identical results are obtained when restricted subjects are provided more room per animal than those socially reared (Hinde _et al_., 1967).

2. Total Social-Physical Deprivation Compared to Total Social Deprivation with Physical Enrichment

The question of what role is played by physical stimuli during rearing in mediating normal social development brings us back to an experimental extreme, the total social isolate. Sackett *et al*. (1972) reared four rhesus monkeys in total isolation, two of which received daily non-social stimulation from projected pictures, taped sounds, a chain hanging from the cage ceiling and a variety of novel objects, none of which provided food, warmth, or an embraceable tactile surface. When later observed in social pairings it was found that non-social stimulation failed to offset the typical isolation syndrome. This is characterized by a lack of positive social responses or exploration of the environment, and high levels of self-directed clutching, rocking and other stereotyped motor activities. These results indicate that physical stimuli cannot in themselves substitute for certain social inputs. Mason (1968) has shown, however, that when an inanimate surrogate which supplied food, warmth and a surface tactually specialized for clinging was provided to rhesus monkeys isolated from birth and made to move on an irregular schedule throughout the day, stereotyped rocking did not develop and approach to novel stimuli occurred. Therefore, in the complete absence of a conspecific, a substitute with the added physical dimension of movement results in some degree of behavioral normalcy.

3. Unvarying Environment Compared to Varying or Partially Varying Environments

Tobach and Schneirla (1962) reared some albino mice in environments which were never experimentally altered and others in environments in which either the social, physical or both of these aspects were changed daily. The social aspects changed included littermates and dam while the physical ones involved cage dimensions, type of nesting materials, light availability, olfactory and other chemical cues and the material of the cage itself. When placed in an unfamiliar (novel) open-field enclosure at weaning, those groups reared in an unvarying physical environment had a significantly lower defecatory response than the other experimental groups. Reciprocally, when the physical aspects of the rearing environment were varied, defecatory reactions under disturbing test conditions were higher. Varying the social aspects of the environment increased this effect, so that the level of defecatory reactions in animals which had experienced variations in both environmental aspects was found to be highest. The investigators concluded from this study that defecatory activity, as a response to a novel environment, is affected by the nature of individual developmental experience which in this case was differentiated by the stability or instability of the physical and/or social aspects of the individual's pre-weaning environment.

C. Effects on Mother-Young Interactions

1. Social Restriction with Physical Enrichment Compared to Social Restriction with Physical Deprivation

Jensen et al. (1968) working with pigtailed macaques demonstrated a relationship between certain aspects of the physical environment and the development of social relationships by providing socially restricted mother-young pairs with a "rich (cage) condition" of changing toys for climbing and manipulating. These physically "enriched" young were found to develop specific and refined patterns of social manipulation which affected the mother's intensity of reciprocation. Based on the findings of Kaplan (1972), cited previously, the resulting relationship would tend to develop as if the mother-young pair were not socially restricted.

2. Early Deprivation of Manipulable Objects

Two studies with albino rats investigated the role of post-weaning experience with manipulable materials on the subsequent development of maternal behavior. Riess (1954) found that when female rats were deprived of this experience they proved maternally deficient. Eibl-Eibesfeldt (1955) also reported some aberrant maternal activity with a corresponding loss of young in rats deprived of "manipulation experiences." He discounted the effects of such early deprivation, however, emphasizing instead the role of appropriate stimuli within the maternity cage needed to release "the inborn orienting reactions of the rat."

A critical evaluation of all of the investigations described in A through C above, reveals that each is inadequate for one or more of the following reasons:

1) The degree and type of "deprivation" was disproportionate and often not comparable to "enrichment." Further, enrichment often meant bombarding a developing mammal with <u>many</u> stimulus objects. The specific effects of these were not experimentally definable either individually or in any combination.
2) In the case of rodents, experimental treatment took place after pre-weaning social bonds had formed; in the case of monkeys, bonds with humans may have been formed before or during the experimental treatment.
3) Developmental data relating to young animals interacting with the animate and inanimate stimuli in their environment were not recorded.

These inadequacies are dealt with in the present study in order to properly test the general hypothesis that characteristics of the environment into which an animal is born and is reared influence the development of its social behavior. The method chosen involved the manipulation of two major factors which, although often contributing to the discrepancy between previously discussed "deprived" and "enriched" environments, had been infrequently, if ever, emphasized. The first of these, environmental moveability, was suggested by the studies of Mason (1969), Riess (1954) and Eibl-Eibesfeldt (1955) which provided evidence for a relationship between object moveability and the development of typical social behavior for a species. The second factor, shape of sheltering structure, was chosen to parallel the frequent use of both tubes and boxes as objects to "enrich" the experience of rodents (Rosenzweig and Bennet, 1969; Henderson, 1976; Denenberg et al., 1969; Manosevitz and Joel, 1973). Such objects, which are readily entered and moved through by subjects in laboratory studies, are analogous to burrows, nesting sites, and shelters in nature. The experimental design, therefore, involved the rearing of animals in environments which were non-deprivational with respect to object availability but which differed in the moveability of these objects and their underlying substrates. The animals were studied during their earliest stages of post-natal development in conditions which were present from their birth on. Human interaction was kept at a minimum throughout. The data recorded related to all aspects of the young animals' activities with both animate and inanimate objects in the environment.

The experimental animal chosen for this study was the common spiny mouse, Acomys cahirinus, a nocturnally active, murid rodent from Israel. The subjects were derived from a laboratory breeding colony of 85 females and 86 males maintained in the American Museum's Department of Animal Behavior. The original field-caught population, which was shipped from Israel in 1969, included 7 females and 3 males. These were bred randomly to maximize initial colony growth. Subsequent generations were bred systematically to prevent any genetic line from dominating the colony's composition. In 1972, after growing in size to 24 females and 14 males, the colony population was supplemented with 12 wild caught animals (5 females and 7 males). All were crossbred with the original colony by the start of this research in 1974.

As a species Acomys cahirinus lends itself to studies of behavioral development. Characterized by an advanced sensory-motor state at birth, the young can soon establish and maintain contact with all elements of their laboratory environment, animate and inanimate, as they would within their natural habitat of stone outcroppings, rubble and desert vegetation. Consistently measurable behavior items, some requiring much coördination, can therefore be recorded from the onset of social bond formation. In addition, since the number of A. cahirinus young per litter averages only two, the species-typical social grouping need not be reduced in size to facilitate the accurate recording of data during periods of extremely complex social activity. The behavioral development of individuals can thus be followed throughout the litter period, as well as beyond.

Therefore, using differentially reared Acomys cahirinus, this study was designed to supply additional evidence that early experience affects later behavior in mammals and to uncover the role of the inanimate environment in this developmental process. More specifically, the following 4-part inquiry was made, i.e., can systematic relationships be found between:

1) developing patterns of social behavior and the moveability of inanimate items in the rearing environment?
2) social interaction during the litter period and the shape of the available sheltering structure?
3) the environment of rearing and an animal's behavior upon its first exposure to unfamiliar conspecifics after weaning?
4) the environment of rearing and the outcome of the sexually mature animal's first unlimited encounter with a like-aged unfamiliar conspecific of the opposite sex?

By answering these questions the contribution of the environment to the social development of the animal was uncovered, enabling speculation as to the importance of this relationship to the processes of natural selection. Finally, in gathering information heretofore neglected, specific hypotheses concerning the mechanism involved in social development were generated.

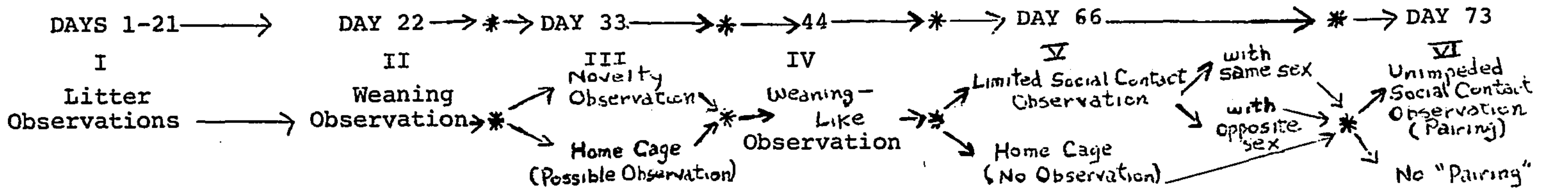
METHODS AND MATERIALS

Acomys cahirinus litters were born in each of four groups of experimental environments which differed in their internal moveability and "shelter" characteristics. Each litter and its lactating female were observed during the active phase of their activity cycle on a predetermined schedule for 21 days post-partum. At and subsequent to weaning the young were observed alone in new environments where any effects of their differential rearing might be revealed in their responses to inanimate objects and substrates. Observations of social behavior were resumed when experimental animals reached sexual maturity. Recordings of male/female interactions were particularly stressed. All data recorded were prepared for computer analysis; the null hypothesis was rejected at "p" values less than .05 except as indicated. The primary statistical analysis used was the BMDP2V Biomedical Program for Analysis of Variance (ANOVA) of a two (box/tube) by two (moveability/non-moveability) by two (female/male) factorial design with Repeated Measures enabling the simultaneous analysis of the litter period's 5 developmental stages. Subsequent analyses of group differences were carried out by use of Studentized "t" tests for unequal variances, Newman-Keuls paired comparisons and non-parametric treatments as required.

Table 1, by describing the possible sequence of conditions within which any animal might be observed, outlines the overall experimental design. As indicated, each pup was maintained with its littermate(s) and the lactating female for 21 days post-partum within one of the four experimental environments. At weaning, and before its transfer to a smaller home cage, it was observed in a special non-social

TABLE 1

DESCRIPTION OF THE SOCIAL AND PHYSICAL CHARACTERISTICS OF THE ENVIRONMENTS FOR OBSERVATIONAL SITUATIONS I - VI



SOCIAL DESCRIPTION: With Littermates and Lactating ♀	Non-Social	Non-Social	Non-Social	With Adult Conspecifics	With "Mate"
PHYSICAL DESCRIPTION: Four possible rearing environments differing in structure/substrate combinations were used: 1. Box-Moveable (Box-Mov) 2 Box-Non-Moveable (Box-N-Mov) 3. Tube-Moveable (Tube-Mov) 4. Tube-Non-Moveable (Tube-N-Mov) with Mov substrate of sand; N-Mov substrate of balsa Mov environments include loose food and straw. N-Mov environments provide food at a fixed location only no straw is provided.	A presentation of both familiar and unfamiliar objects and surfaces	A presentation of a completely unfamiliar (novel) environment having analogs of both Mov and N-Mov substrates and of both box and tube structures	This was a replication of the weaning observation carried out at a juvenile stage of development. Added to this environment were two portable items basic to colony maintenance (i.e. straw and food pellets) which were excluded from the non-moveable experience & were added to complete the comparison with moveable-reared animals	Animals were able to make limited contact with conspecifics. The observation environment contained structures, substrates, and materials already familiar to all. Three conspecifics were used, all colony-reared adults and unrelated to the experimental animal. All 3 were either the same or its opposite in sex.	This Unimpeded Social Contct with a like-aged, colony-reared Acomys of the opposite sex took place either in the home environment (for males) or a suitable facsimile (for females)

*Indicates an animal's first introduction to its home cage (a small replica of its litter environment) on day 22 and indicates return to this cage after any observation environment to assess its responsiveness to familiar and unfamiliar cage items. Additional observations of its responsiveness to inanimate environments were made before the animal reached sexual maturity, a stage of development appropriate for a renewed emphasis on social observations. Here an animal's responsiveness to conspecifics was measured first under restricted conditions and subsequently by means of actual heterosexual pairing. The procedures and results for each of the six experimental periods and observations shown in Table 1 are reported separately.

Table 2 shows the number of animals in each of the experimental populations. Subjects were assigned to groups on a predetermined plan. Unequal sample sizes resulted from various factors: differing sex ratios at birth, subject loss due to escape, accidental stress or death and record loss through equipment failure.

TABLE 2
EXPERIMENTAL POPULATION

(Numbers of Animals Observed in Each Observational Situation*)

		I	II	III		IV	V			VI	
				N	HC		SS	OS	NONE	P	NP
BOX-MOV (10 litters)	♀♀	11	9	5	4	9	3	3	1	3	5
	♂♂	10	9	2	6	8	5	2		3	4
DATA UNAVAILABLE: DIED	♀♀			2							
	♂♂			2							
ESCAPED	♀♀						1				
	♂♂										
ACCIDENTAL STRESS	♀♀						1				
	♂♂										
EQUIPMENT FAILURE	♀♀		2								1
	♂♂		1					1			1

* Roman numerals refer to observational situations described in Table 1
N="Novelty" observation; HC="Home Cage" observation; SS=Limited Social Contact With Same Sex; OS=With Opposite Sex; P=Paired; NP=Not Paired

TABLE 2 (CONT'D)
EXPERIMENTAL POPULATION
(Numbers of Animals Observed in Each Observational Situation*)

		I	II	III		IV	V			VI	
				N	HC		SS	OS	NONE	P	NP
	BOX-N-MOV (10 litters)										
	♀♀	11	10	3	8	10	4	3		4	6
	♂♂	12	10	5	6	10	2	5	1	5	5
DATA UNAVAILABLE	DIED										
	♀♀					1					
	♂♂					1					
	ESCAPED										
	♀♀						1				
	♂♂		1								
	ACCIDENTAL STRESS										
	♀♀						1				
	♂♂						2				
	TESTING ACCIDENT										
	♀♀							1			
	♂♂										
	LOST RECORD										
	♀♀		1								
	♂♂		1								

TABLE 2 (CONT'D)
EXPERIMENTAL POPULATION
(Numbers of Animals Observed in Each Observational Situation*)

			I	II	III		IV	V			VI	
					N	HC		SS	OS	NONE	P	NP
	TUBE-MOV (9 litters)	♀ ♀	11	7	3	7	10	4	5		6	4
		♂ ♂	9	6	2	4	6	2	3		4	2
DATA UNAVAILABLE	DIED	♀ ♀										
		♂ ♂										
	ESCAPE OF LACTATING ♀ ON DAY 20	♀ ♀		1								
		♂ ♂		2								
	ACCIDENTAL STRESS	♀ ♀							1			
		♂ ♂						1				
	EQUIPMENT FAILURE	♀ ♀		3								
		♂ ♂										
	LOST RECORD	♀ ♀		1								
		♂ ♂										

TABLE 2 (CONT'D)
EXPERIMENTAL POPULATION
(Numbers of Animals Observed in Each Observational Situation*)

		I	II	III		IV	V			VI	
				N	HC		SS	OS	NONE	P	NP
	TUBE-N-MOV (10 litters) ♀♀	7	5	2	4	5	3	3		2	4
	♂♂	13	11	6	6	12	4	2	3	9	3
DATA UNAVAILABLE	DIED ♀♀			1							
	♂♂			1							
	ESCAPED ♀♀										
	♂♂		1								
	ACCIDENTAL STRESS ♀♀								3		
	♂♂										
	EQUIPMENT FAILURE ♀♀		2								
	♂♂		1								
	LOST RECORD ♀♀					1					
	♂♂										

I. The Litter Period

A. General Procedures

1. Subjects

Female _Acomys_ _cahirinus_ approaching parturition were separated from the breeding male, removed from the colony room and placed into one of the four experimental environments at least one week before delivery. Their litters constituted the experimental population for this study.

2. Apparatus

In all cases parturition took place in 57-liter aquaria (61.0 cm x 30.5 cm x 30.5 cm). The four experimental groups were based on different preparations of these aquaria. For two groups a fine moveable (Mov) sand was provided as a substrate to a uniform thickness of 1.3 cm. One group of sand-bottomed aquaria (Box-Mov) contained a transparent, 5-sided plastic box (12.7 cm x 6.4 cm x 8.9 cm) placed at one end. The other group (Tube-Mov) contained a transparent, plastic T-tube instead (5.7 cm i.d., 20.3 cm across, 5.1 cm stem). Five 7.6 cm strands of straw were provided at aquarium center for both sand-bottomed groups (see Fig. 1).

The remaining two groups of environments had a non-moveable (N-Mov) substrate of balsa wood .3 cm in thickness glued above the aquarium floor to produce a height equivalent to the thickness of the sand. All borders were sealed with silicone cement to prevent possible manipulation by subjects. One group of balsa-bottomed aquaria (Box-N-Mov) contained a plastic box (as previously described) which was screwed into

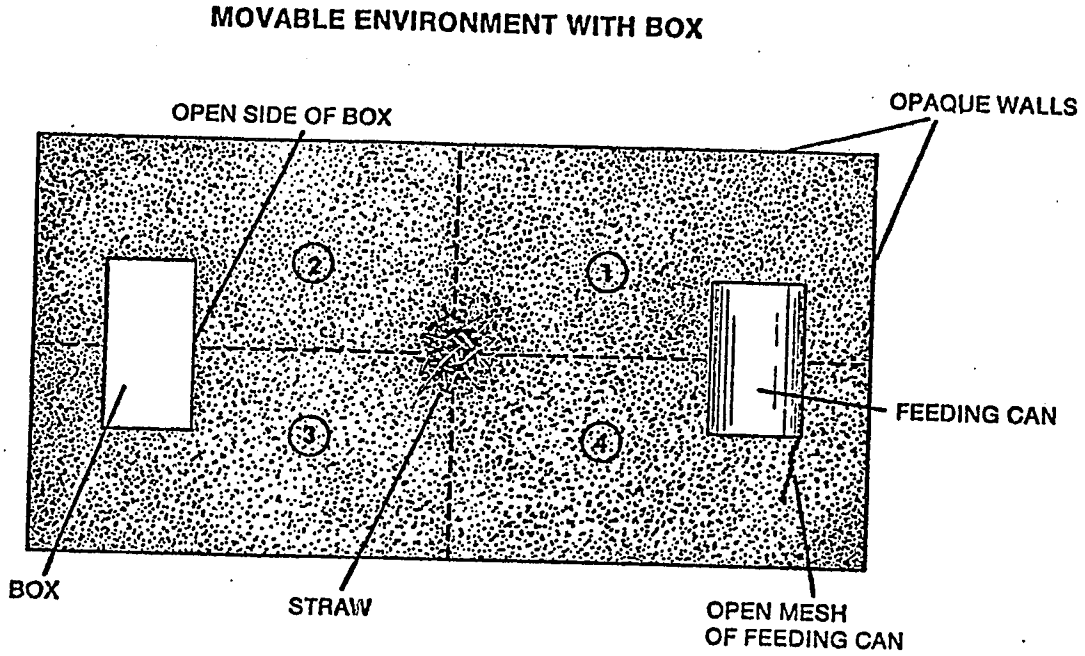
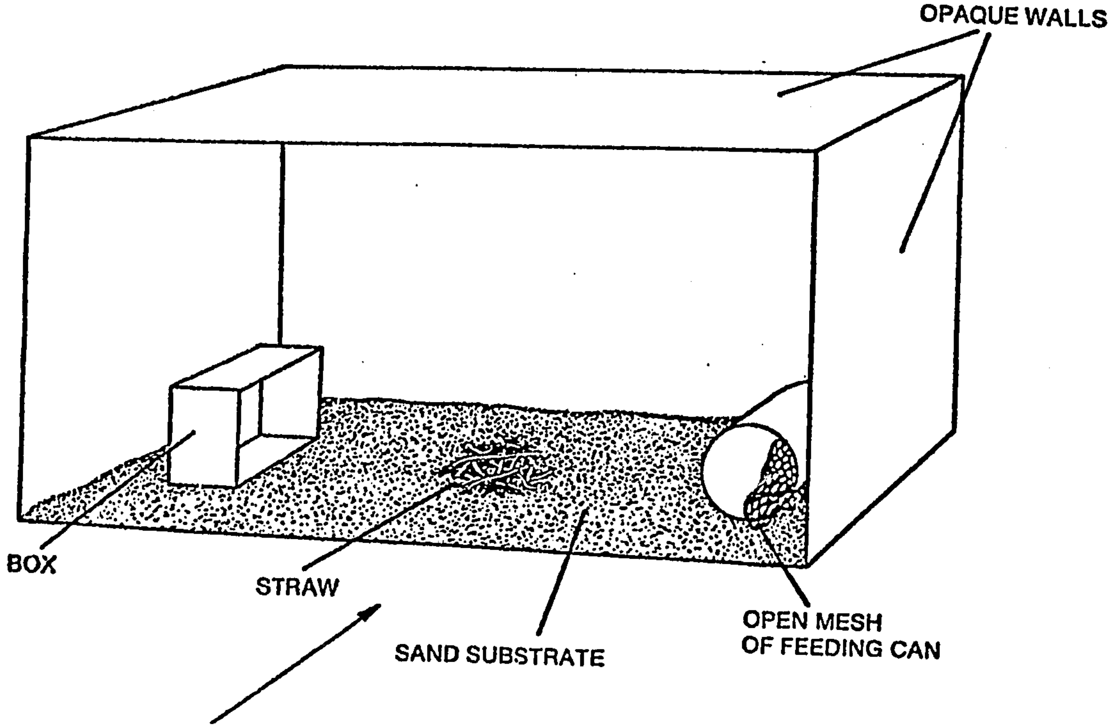


Figure 1. The moveable environment with box as viewed from above (top) and from the observer's angle (arrow, bottom).



the wooden substrate. The second group (Tube-N-Mov) contained a plastic T-tube likewise fastened rigidly to the balsa (see Fig. 2).

All four experimental aquaria contained a feeding can (11.2 cm long, 7.4 cm in diameter) placed at the opposite end of the aquarium from the plastic "shelter" (see Figs. 1 and 2). A dry food source (Purina Lab Chow) was made available from one end of the can, while the other provided moisture (lettuce). All feeding cans were weighted internally to prevent rolling. Those resting on sand could be slid across this substrate by the persistent activity of an animal while movement of those on balsa was not possible. In the former case the ends of each can were loosely capped by wire mesh allowing removal of single large quantities of food; in the latter the mesh pieces were tightly fixed in place making it necessary for an animal to restrict its feeding activity to the can site.

3. Maintenance

Experimental environments of each group were maintained on shelves within a Scherer-Gillette (model #2-112) environmental chamber set on a 12D/12L reversed light cycle corresponding to temperatures of 24° C/30° C. Illumination for "night" observations was provided by a 40W incandescent bulb shielded to provide diffuse white light. Daylight was provided by two 40 watt Sylvania Powertubes each 1.2 m in length situated along the chamber ceiling. Humidity was maintained steady at 50%. Two exhaust fans provided air circulation and "white"

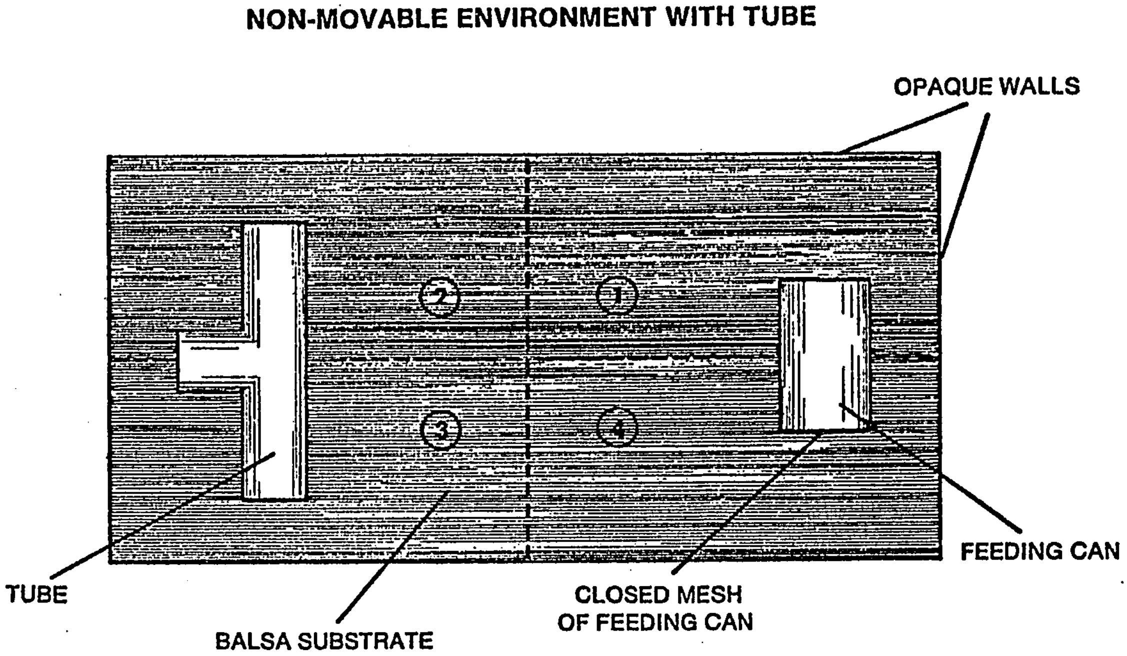
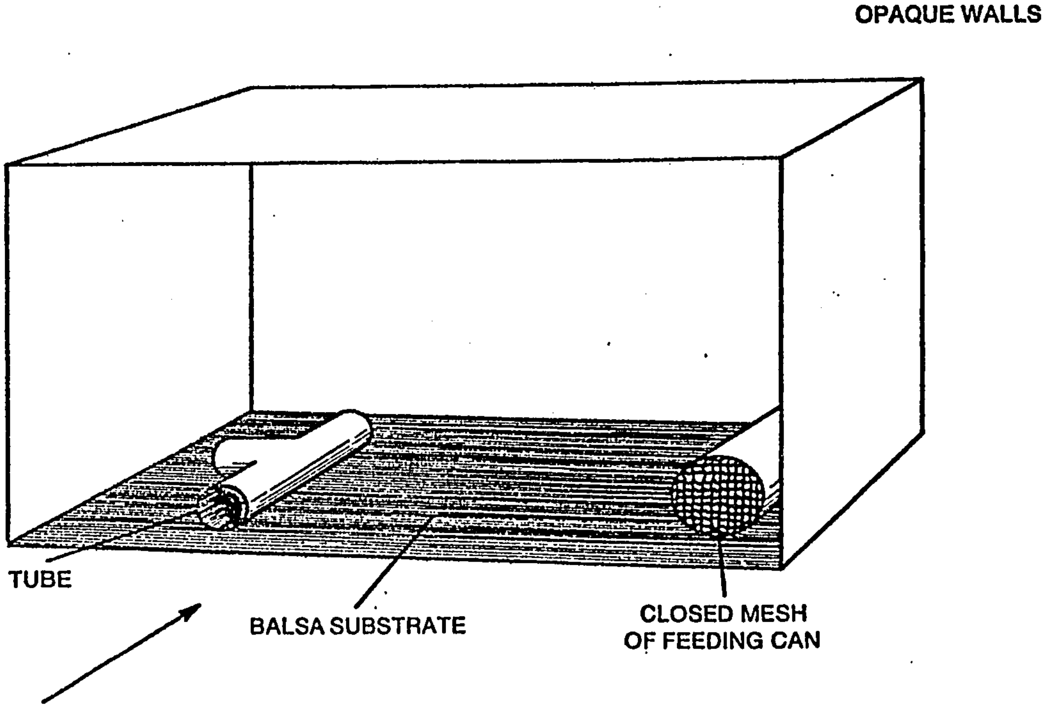


Figure 2. The non-moveable environment with tube as viewed from above (top) and from the observer's angle (arrow, bottom).



noise of 40 db.

4. Observational Procedures

Prior to the introduction of the females, the experimental environments were permanently distributed via statified randomization among the 9 potential locations within the environmental chamber. This was done to offset the possible effects of position (i.e., height, closeness to chamber door, etc.) within this otherwise controlled environment. After introduction of pregnant females daily checks were made to monitor the progress of each towards parturition. This included recording the environmental modifications each made before giving birth.

On the day of their birth, all members of the litter were weighed and marked after at least one nursing bout had been observed. To accomplish this the female was cup-captured, taken out of the chamber, weighed and placed into a sound-buffered isolation tank. Each pup was then removed individually by gloved hand and taken to a work area outside the chamber. The pup was weighed, sexed and given a number. The tail of each pup was then stained appropriately using a 1:1 solution of a non-toxic blue ink and a 70% EtOH applied with a cotton swab. Pup #1 was identified by a blue tail tip, #2 by a blue tail base, and #3 by an entirely blue tail. Weighing, sexing and staining took 5 minutes per pup and was carried out under high ambient illumination enabling detailed inspection of each and reducing the possibility of injury or escape. Each pup was returned to the litter environment at the approximate site of its capture before the next pup was removed. After all pups were processed and returned, the female was carried back to the litter and deposited within the center of the environment. Due to the temporary nature of the stain, remarking of each pup was required every 5 days at which time the litter members and the female were reweighed.

From the day of its birth and for a period of three weeks post-partum each litter was the subject of several in-chamber observations. A randomized observation schedule was employed which provided developmental data during those time periods typical for Acomys cahirinus activity. These included pre-dusk, dusk, mid-night, pre-dawn and dawn. Five minutes of data collection were allotted each animal during an observation session. No litter was observed more than once in a day nor more than on twelve of the twenty-one days post-partum. The order in which litter members were observed was systematically changed for each succeeding session to offset possible sequence effects. The data were collected via a 20 pen Esterline-Angus (model A620 X) event recorder receiving impulses from a hand operated microswitch keyboard which made it possible to register both the frequencies and durations of behavioral items.

5. Data Recorded

All 20 keys both singly and in various combinations were needed to record the animals' activities. The site of each activity was also recorded. Appendix A lists the behavioral events considered.

6. Data Analysis

For this analysis time spent in locomotion was employed as a general measure of activity. Duration of interindividual activity including all behaviors in Appendix A (as well as resting) taking place in contact with a sibling or lactating female, provided a measure of social development. Sample variability was decreased by using data from 2-pup litters only which included 3 litters reared in the box-moveable (Box-Mov) condition, 5 in the box-non-moveable (Box-N-Mov) one, 5 from the tube-moveable (Tube-Mov) situation and 4 from the tube-non-moveable (Tube-N-Mov) one.

Since the method of data taking (see I, A, 4) produced small sample sizes for any given litter over its development, representative values derived from the raw data were used for analysis. These values were obtained by averaging, according to behavioral measure, the litter's data within each of the five age groupings corresponding to stages of behavioral development which were empirically distinguishable (see Table 3). Tests of Skewness and Kurtosis (Snedecor and Cochran, 1967) supported the validity of this procedure in that for both behavioral measures (i.e., locomotion and interindividual activity) the raw data from each age grouping were normally distributed about a different mean.

TABLE 3

STAGES OF DEVELOPMENT FROM BIRTH TO WEANING

Developmental Stage	AGE (days)	Weight (mean in grams)	Behavioral Profile
1	1-4	6.9*	.frequent suckling .close huddling with littermates .little locomotion beyond "nest" site .self-directed mouthing
2	5-7	10.6	.frequent suckling .locomotion beyond "nest" site .increased investigation of inanimate environment .establishment of self- and other-grooming patterns
3	8-12	14.4	.reduction in suckling .mouthing fecal boluses .beginning of solid food consumption .climbing structure and feeding can

TABLE 3 (CONT'D)

STAGES OF DEVELOPMENT FROM BIRTH TO WEANING

Developmental Stage	AGE (Days)	WEIGHT (mean in grams)	BEHAVIORAL PROFILE
4	13-15	18.0	.decline in suckling .activities associated with the getting and retention of solid food increase .scuffling between littermates over food occurs .pups tend to avoid social contact
5	16-19	22.5	.suckling resumes at level of stage 3 .pups become increasingly gregarious
6	20-22	26.5	.periods of spasmodic locomotion preclude accurate data taking

Note: Box-Mov animals had the lowest birth weights. By the second developmental stage, however, they had attained weight levels typical of box-reared pups. No effects of this anomaly were observable in their behavioral profile across development.

B. Results

Environmental moveability was a significant factor in the total amount of interindividual activity taking place during the litter period. As such, a difference was found between Mov-reared (Mn=241.9 sec) and N-Mov-reared (Mn=225.3 sec) pups (see Table 4-a; Studentized "t", $p < .01$, d.f.=79). When analyzed for the quadrants of the structure side (i.e., quadrants 2 and 3) however, the difference found was related to shape of rearing structure, with tube reared pups spending more time (Mn=89.9 sec) making contact in these quadrants than box-reared (Mn=42.6 sec) (see Table 5 A-1). Adding to this analysis the duration of interindividual activity spent both within and upon the plastic structures does not change this relationship. This was true despite the observation that the box, as opposed to the tube, was the more frequented structure for social contact throughout the litter period. As an environmental structure, the feeding can was the least important site for interindividual activity.

All three analyses of interindividual activity, that is, as it occurred throughout the entire environment and separately within quadrants 1 and 4 when including the feeding can as well as within quadrants 2 and 3 when including the structure, revealed that a different pattern of response across development typified each of the four experimental groups (see Tables 4-b; 5 B-2; 6-A). The patterns observed within experimental groups were most consistent between the total analysis and that for quadrants 1 and 4. This outcome reflected the greater incidence of social behavior within these two quadrants which was exhibited by all groups

TABLE 4

TOTAL TIME (sec) ENGAGED IN INTERINDIVIDUAL ACTIVITY DURING THE LITTER PERIOD (All Locations Combined)

a *

Mov-Reared Pups		N-Mov-Reared Pups	
Mn	SD	Mn	SD
241.9	64.1	225.3	78.8

b **

	BOX				TUBE			
	MOV		N-MOV		MOV		N-MOV	
Developmental Stage	Mn	SD	Mn	SD	Mn	SD	Mn	SD
1	286.5	29.4	269.5	60.8	289.6	22.7	256.2	83.0
2	283.0	45.2	283.0	33.8	266.8	36.2	274.8	32.6
3	162.3	96.1	189.7	38.6	235.1	42.8	250.8	63.6
4	254.7	47.8	163.2	120.5	196.7	81.4	188.0	96.2
5	277.3	25.4	179.5	43.6	233.9	50.8	217.4	71.2

Using Analysis of Variance (BMD P2V computer program):

* Main Effect of Environmental Moveability, p=.062
** Interaction Effect of Developmental Stage x Structure x Moveability, p=.047

TABLE 5

TOTAL TIME (sec) ENGAGED IN INTERINDIVIDUAL ACTIVITY DURING THE LITTER PERIOD (In Quadrants 2 + 3)

A. Excluding Time In/On Structure

1. *

Box-Reared Pups		Tube-Reared Pups	
Mn	SD	Mn	SD
42.6	75.6	89.9	107.5

2. **

	BOX				TUBE			
	Mov		N-Mov		Mov		N-Mov	
Developmental Stage	Mn	SD	Mn	SD	Mn	SD	Mn	SD
1	17.7	40.8	1.1	0.3	178.8	136.3	75.8	137.8
2	28.7	60.3	50.7	106.1	60.7	78.6	75.9	132.4
3	13.8	30.9	56.5	68.7	76.3	70.8	174.6	124.0
4	59.7	72.8	48.7	89.8	42.5	60.3	37.9	67.6
5	47.0	71.7	84.0	106.9	73.7	101.4	106.8	77.4

Using Analysis of Variance (BMD P2V computer program):

* Main Effect of Structure, p=.001
** Interaction Effect of Developmental Stage x Structure x Moveability, p=.001

TABLE 5 (CONT'D)

TOTAL TIME (sec) ENGAGED IN INTERINDIVIDUAL ACTIVITY DURING THE LITTER PERIOD (In Quadrants 2 + 3)

B. Including Time In/On Structure

1. *

Box-Reared Pups		Tube-Reared Pups	
Mn	SD	Mn	SD
79.1	91.6	96.7	108.9

2. **

	BOX				TUBE			
	MOV		N-MOV		MOV		N-MOV	
Developmental Stage	Mn	SD	Mn	SD	Mn	SD	Mn	SD
1	51.8	83.3	54.0	110.5	180.0	136.4	78.8	136.7
2	46.3	64.8	51.8	106.3	84.2	114.5	77.3	132.2
3	53.7	58.4	87.8	66.5	79.8	72.7	176.9	121.0
4	155.5	9.1	70.6	104.6	59.1	63.7	42.0	61.1
5	147.3	121.7	95.7	88.2	78.7	98.9	111.3	77.0

Using Analysis of Variance (BMD P2V computer program):

* Main Effect of Structure, p=.014
** Interaction Effect of Developmental Stage x Structure x Moveability, p=.001

TABLE 6

TOTAL TIME (sec) ENGAGED IN INTERINDIVIDUAL ACTIVITY DURING THE LITTER PERIOD (In Quadrants 1 + 4)

A. Including Time On Feeding Can

1*

	BOX				TUBE			
	MOV		N-MOV		MOV		N-MOV	
Developmental Stage	Mn	SD	Mn	SD	Mn	SD	Mn	SD
1	234.7	76.1	215.5	126.7	109.6	141.6	177.5	136.9
2	236.7	68.7	231.2	116.2	182.3	118.7	185.0	121.7
3	108.7	87.9	101.8	65.5	155.3	82.6	61.4	65.7
4	69.2	52.4	92.6	122.2	117.6	114.2	146.0	123.3
5	129.0	127.8	83.8	50.1	145.2	95.4	105.1	66.9

Using Analysis of Variance (BMD P2V computer program):

* Interaction Effect of Developmental Stage x Structure x Moveability, p=.011

throughout development. In general, results obtained for the litter period indicated that both structure shape and environmental moveability influenced the amount and distribution of social activity exhibited by A. cahirinus pups. That these factors have a potent effect upon general activity is seen in the results which follow.

Each of the four experimental rearing environments stimulated a different duration of locomotory response in A. cahirinus pups during the litter period (see Table 7-a). Analysis of time spent locomoting within quadrants 2 and 3 (exclusive of the structure) also provided four different outcomes (see Table 8 A-1). Including the time spent in locomotor activity both within and upon the structure itself, did not change this result appreciably (see Table 8 B-1). The analysis, as done by developmental stage, however, was affected by the addition of these data which decreased the Mov/N-Mov difference substantially. When these data are excluded, the direction of the difference between Mov and N-Mov-reared groups, for each developmental stage, forms a pattern which predicts the outcome for total locomotion (see Tables 8 A-2; 7-c). Therefore quadrants 2 and 3 have the quality of stimulating developmental differences in locomotor activity between Mov- and N-Mov-reared animals which influence the course of all locomotor activity combined. The influence of quadrants 1 and 4 upon the response levels of Mov- and N-Mov-reared groups, although locally demonstrated in both a cumulative difference (see Table 9 A-1) and a developmental difference (see Table 9 B-2), was not directly reflected in the overall analysis of locomotory activity. These quadrants,

TABLE 7
TOTAL TIME (sec) ENGAGED IN LOCOMOTOR ACTIVITY DURING THE LITTER PERIOD (All Locations Combined)

a *

Box-Reared Pups				Tube-Reared Pups			
MOV		N-MOV		MOV		N-MOV	
Mn	SD	Mn	SD	Mn	SD	Mn	SD
89.0	48.0	116.2	67.5	110.2	66.4	93.3	62.6

b **

		BOX		TUBE	
		Mn	SD	Mn	SD
Developmental Stage	1	73.8	38.8	69.4	39.8
	2	66.3	48.8	86.1	42.4
	3	145.6	50.6	93.3	49.7
	4	118.8	65.2	140.6	84.3
	5	125.6	67.2	123.9	74.6

c ***

		MOV		N-MOV	
		Mn	SD	Mn	SD
Developmental Stage	1	77.5	38.9	66.1	39.0
	2	79.4	47.5	74.4	45.8
	3	109.4	51.6	125.6	60.1
	4	150.6	81.3	112.2	67.3
	5	94.4	50.7	151.7	75.2

Using Analysis of Variance (BMD P2V computer program):

* Interaction Effect of Structure x Moveability, p=.011
** Interaction Effect of Developmental Stage x Structure, p=.034
*** Interaction Effect of Developmental Stage x Moveability, p=.004

TABLE 8

TOTAL TIME (sec) ENGAGED IN LOCOMOTOR ACTIVITY DURING THE LITTER PERIOD (In Quadrants 2 + 3)

A. Excluding Time In/On Structure

	BOX				TUBE			
	MOV		N-MOV		MOV		N-MOV	
	Mn	SD	Mn	SD	Mn	SD	Mn	SD
1*	21.3	19.3	30.8	26.1	35.6	28.5	23.5	21.8

2**	MOV		N-MOV	
Developmental Stage	Mn	SD	Mn	SD
1	29.4	35.7	12.8	8.3
2	21.9	19.4	16.7	16.1
3	27.5	18.8	37.8	27.6
4	47.5	34.2	31.7	31.9
5	27.5	21.1	40.6	25.1

Using Analysis of Variance (BMD P2V computer program):

* Interaction Effect of Structure x Moveability, p=.004

** Interaction Effect of Developmental Stage x Moveability, p=.007

TABLE 8 (CONT'D)

TOTAL TIME (sec) ENGAGED IN LOCOMOTOR ACTIVITY DURING THE LITTER PERIOD (In Quadrants 2 + 3)

B. Including Time In/On Structure

1 *

BOX				TUBE			
MOV		N-MOV		MOV		N-MOV	
Mn	SD	Mn	SD	Mn	SD	Mn	SD
36.7	24.8	50.4	35.6	58.2	43.6	44.6	39.5

2 **

	MOV		N-MOV	
Developmental Stage	Mn	SD	Mn	SD
1	41.3	33.8	27.2	22.7
2	36.3	27.0	29.4	18.6
3	50.6	32.8	60.0	35.5
4	53.8	33.2	54.4	42.5
5	48.1	31.0	67.2	44.3

Using Analysis of Variance (BMD P2V computer program):

* Interaction Effect of Structure x Moveability, p=.012

** Interaction Effect of Developmental Stage x Moveability, p=.050

TABLE 9

TOTAL TIME (sec) ENGAGED IN LOCOMOTORY ACTIVITY DURING THE LITTER PERIOD (In Quadrants 1 + 4)

A. Excluding Time On Feeding Can

1 *	N-Mov-Reared Pups		Mov-Reared Pups	
	Mn	SD	Mn	SD
	46.7	35.2	36.1	28.3

2 **	BOX		TUBE	
Developmental Stage	Mn	SD	Mn	SD
1	35.0	31.4	25.6	34.3
2	25.0	28.3	40.0	31.4
3	65.6	25.3	31.7	24.6
4	48.1	33.3	53.3	37.6
5	51.3	33.6	42.8	26.3

Using Analysis of Variance (BMD P2V computer program):

* Main Effect of Environmental Moveability, p=.036

** Interaction Effect of Developmental Stage x Structure, p=.007

TABLE 9 (CONT'D)

TOTAL TIME (sec) ENGAGED IN LOCOMOTOR ACTIVITY DURING THE LITTER PERIOD (In Quadrants 1 + 4)

B. Including Time On Feeding Can

1 *	BOX		TUBE	
Developmental Stage	Mn	SD	Mn	SD
1	45.6	31.6	30.6	29.0
2	36.9	31.8	50.6	31.9
3	85.6	27.8	42.8	25.4
4	63.1	37.0	68.3	43.1
5	72.5	45.5	61.7	34.2

2 **	MOV		N-MOV	
Developmental Stage	Mn	SD	Mn	SD
1	36.3	31.2	38.9	31.2
2	43.1	34.2	45.0	31.0
3	59.4	32.3	66.1	36.0
4	75.0	30.6	57.8	46.0
5	46.9	28.9	85.0	40.5

Using Analysis of Variance (BMD P2V computer program):

* Interaction Effect of Developmental Stage x Structure, p=.008
** Interaction Effect of Developmental Stage x Moveability, p=.018

however, did stimulate a difference in responsiveness between box-reared and tube-reared animals which was sufficiently pervasive to determine the outcome of the developmental analysis for total locomotion (see Tables 9 A-2 and 7-b).

Locomotion, like interindividual activity (considered previously), occurred more in quadrants 1 and 4 than in quadrants 2 and 3 for most experimental groups over their development.

In general, more locomotion occurred within and upon the plastic structures than upon the feeding can, a result likewise consistent with the use of these items during social interactions.

II. The Weaning Observation

In order to assess the influence of the environmental factors of "sheltering" structure and moveability on the responsiveness of pups to newly encountered inanimate stimuli, each weanling was observed in an environment in which both the structures and substrates representing these two factors were simultaneously presented (see Figure 3). Data were obtained to determine if pups responded to items as a function of their experience with them. In addition, the results obtained could also reveal if the stimulus properties of any item were approach-eliciting to Acomys cahirinus as a species, regardless of experience.

A. General Procedures

1. Subjects

All experimental young were weaned 22 days post-partum (see Methods) and were individually placed in the apparatus (see below).

2. Apparatus

The observation environment upon weaning consisted of an aquarium (40.6 cm x 30.5 cm x 30.5 cm) with unpainted walls. The aquarium floor was covered with both sand and balsa arranged lengthwise as 2 equal strips. In addition, a plastic box and plastic T-tube were placed at opposite ends of the aquarium (see Fig. 3). Illumination was provided by a single Lumiline 30 W incandescent tube suspended longitudinally .78 m above the aquarium floor.

The maintenance or home cage for each weanling was a 19 liter aquarium (35.6 cm x 21.6 cm x 25.4 cm) prepared as a scaled down replica of the litter aquarium in which it was

WEANING ENVIRONMENT

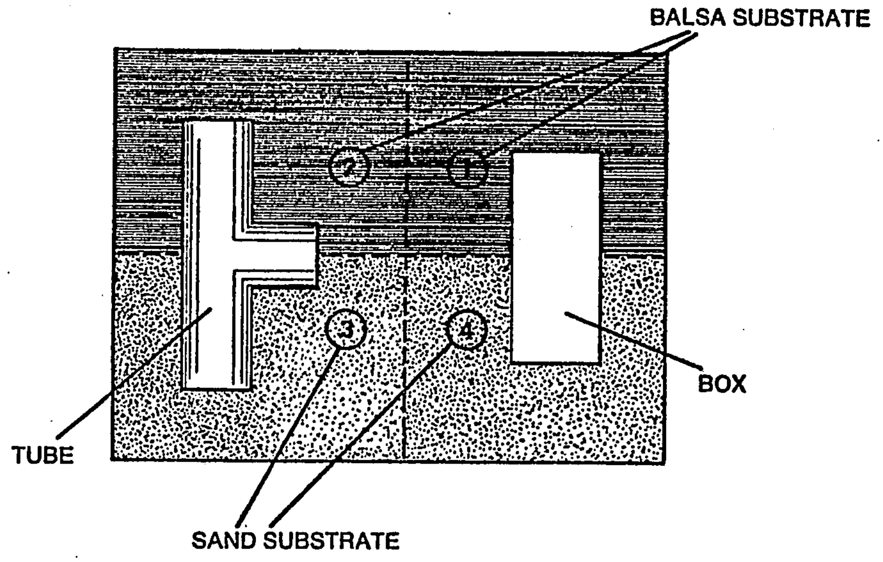
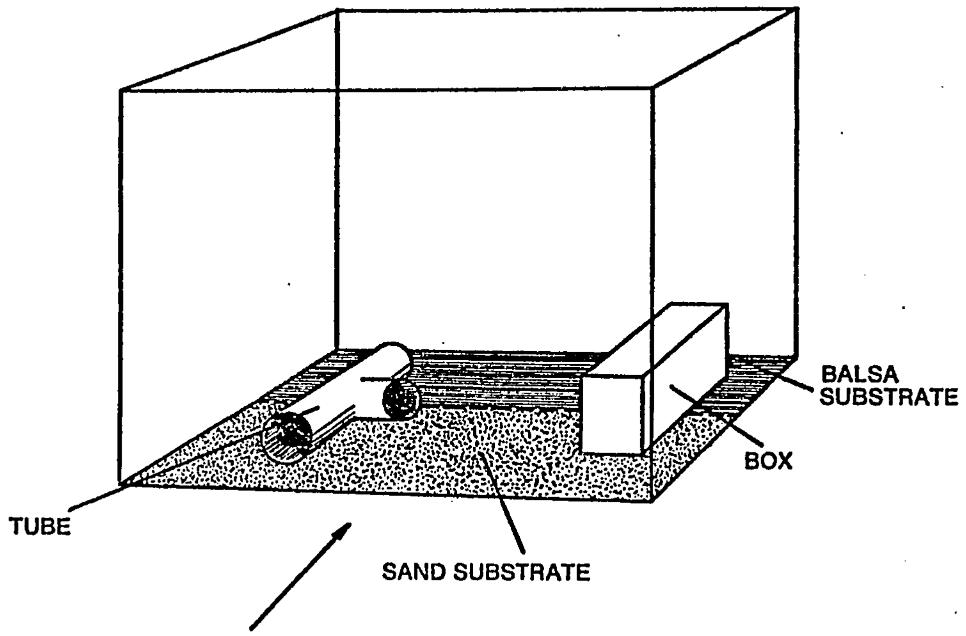


Figure 3. The weaning environment as viewed from above (top) and from the corner of Quadrant 4 (bottom). The arrow indicates the orientation of the observer.



reared (see Fig. 4). Straw was not added to sand-bottomed maintenance aquaria.

3. Maintenance

All maintenance aquaria were kept side by side upon shelving in a room containing the environmental chamber. Visual contact between adjacent environments was precluded by the painted sides of each aquarium. The animals received a reversed lighting cycle of 12D/12L and "white" noise of 35 db from a ventilation fan. Temperatures ranged from 27° C to 33° C with an RH averaging 60%.

4. Procedures

On day 22 the female was removed from her litter and returned to the colony. Each pup was then individually cup-captured, weighed and placed into the center of the observation environment, and its behavior was observed for fifteen minutes. The pup was then removed to its appropriate maintenance cage. The observation environment was disassembled and cleaned before each individual observation.

5. Data Recorded

Appendix A gives a general list of behavior items recorded during the weaning observation. Three major categories of data were taken: the first included all locomotor activity, all activities involving both structures and self-grooming of all body surfaces. In order to measure responses to specific characteristics of the environment, a second category of data dealt with discrete behaviors directed at or upon the box, tube, sand, and balsa of the observation environment.

MAINTENANCE ENVIRONMENTS

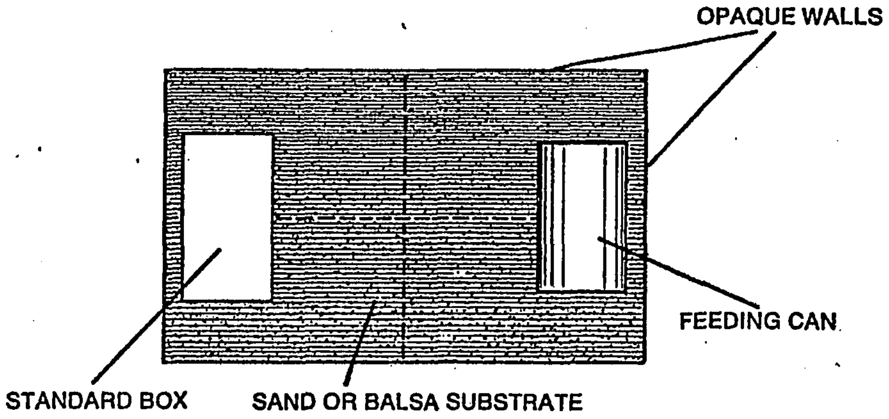
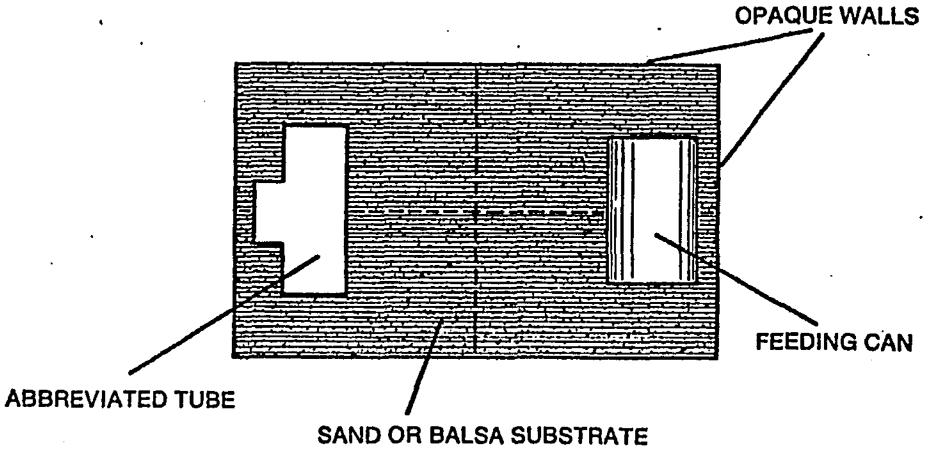


Figure 4. Maintenance environments viewed from above to demonstrate proportion.



The third category specified the time spent within or upon the box or the tube.

6. Data Analysis

An anlysis or variance of three main factors in a 2 (structure: Box;Tube) x 2 (moveability: Mov; N-Mov) x 2 (sex: male; female) design revealed the statistical significance of differences in response durations, occurring between and among sub-groups of the experimental population, for each behavior recorded. Studentized "t" and Newman-Keuls tests were then employed to establish the direction of the ANOVA differences.

B. Results

1. Combined Activity Measures

The effects of being reared in an environment with non-moveable objects and substrates was clearly reflected in two of the three measures of this category (see Table 10 A - 1, 2 and 3; Table 10 A - 4). Groups reared in a non-moveable environment spent more time (Mn=230.8 sec) locomoting than those reared in a moveable one (Mn=218.5 sec; Studentized "t" $p < .05$, d.f. = 30). The source of this difference was primarily related to tube-reared male activity: Tube-N-Mov males locomoted more (Mn=249.6 sec) than Tube-Mov males (Mn=180.5 sec) at $p < .05$ (Newman-Keuls paired comparisons).

The same difference between N-Mov and Mov groups was found for the measure combining all structure-involved activity (see Table 10 A - 4). Mice reared in N-Mov environments were more active with structures (Mn=419.1 sec) than those

TABLE 10 A
Observations of *A. cahirinus* at Weaning
Combined Activity Measures

1. Total Duration of Locomotion (Sec)
Source of Main Effect: Environmental Moveability [a.] p=.057

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
N	9	9	10	10	6	7	11	5
Mean	210.1	211.7	218.8	227.0	180.5	246.7	249.6	234.6
S. D.	28.1	37.7	30.6	34.2	73.5	44.8	39.2	48.1

2. Duration of Locomotion in Quadrant 1 (Sec)
Source of Main Effect: Environmental Moveability p=.001

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
N	9	9	10	10	6	7	11	5
Mean	33.4	38.2	41.7	39.2	27.5	41.0	49.9	41.1
S. D.	9.2	7.4	12.0	5.5	7.8	8.4	9.4	11.9

3. Duration of Locomotion in Quadrant 2 (Sec)
Source of Main Effect: Environmental Moveability p=.005

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
N	9	9	10	10	6	7	11	5
Mean	44.4	50.9	53.3	46.7	38.0	51.1	64.9	51.6
S. D.	9.1	11.7	14.2	7.2	12.2	8.3	10.0	13.6

a. Analysis of Variance (BMD P2V computer program) d. f. = 1,59

TABLE 10 A

Observations of *A. cahirinus* at Weaning
Combined Activity Measures (Cont'd)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
4. Total Duration of Structure-Involved Activities (Sec) Source of Main Effect: Environmental Moveability p=.015								
N	9	9	10	10	6	7	11	5
Mean	363.7	367.4	419.2	410.0	345.3	395.3	435.5	392.0
S. D.	61.8	41.0	71.4	74.7	149.4	56.6	62.7	28.1
5. Duration of Self-Grooming in Quadrant 1 (Sec) Source of Main Effect: Structure p=.027								
N	9	9	10	10	6	7	11	5
Mean	10.1	16.3	8.6	7.6	4.7	7.7	6.8	2.8
S. D.	7.8	13.9	9.9	8.0	5.8	12.7	4.6	1.3

reared in moveable ones (Mn=373.6 sec; Studentized "t", $p < .01$, d.f. = 30).

Grooming differences reflected the type of structure found in the rearing environment rather than moveability (see Table 10 A - 5). In quadrant #1 which contained the box on the balsa substrate, box-reared pups groomed more reliably (Mn=10.5 sec) than tube-reared pups (Mn=5.9 sec; Studentized "t", $p < .025$, d.f. = 28).

2. Specific Behavior Items with Substrates and Structures

Nosing and rising responses reflected differences in rearing experiences. The possibility that the factors of familiarity and unfamiliarity were operating was seen in the direction of these responses. For that reason the following results will be considered in light of the findings of the other non-social observations mentioned in the General Discussion section.

Time spent nosing sand in quadrants 3 and 4 combined (see Table 10 B - 1) was greater for the N-Mov group (Mn=25.8 sec) than for the Mov group (Mn=20.3 sec; Studentized "t", $p < .05$, d.f. = 30). This could have been related to the novelty of sand for these balsa-reared animals. An active response to the unfamiliar was revealed when the nosing of structures was analyzed. For example, the ANOVA for total nosing of box (a measure including nosing this structure from within as well as from outside) indicated a difference related to the structure reared with (see Table 10 B - 5). It was found that tube-reared animals nosed the box more than

TABLE 10 B

Observations of *A. cahirinus* at Weaning
Specific Behavior Items with Substrates and Structures

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
1. Total Duration Nosing Sand (Sec)								
Source of Main Effect: Environmental Moveability [a]					p=.015			
Source of Interactive Effect: Environmental Moveability X Sex						p=.003		
N	9	9	10	10	6	7	11	5
Mean	27.8	16.3	24.2	28.2	21.7	14.6	21.9	32.6
S. D.	17.6	8.1	11.2	8.2	9.1	2.4	6.7	14.3
2. Duration Nosing Sand in Quadrant 3 (Sec)								
Source of Main Effect: Environmental Moveability					p=.062			
Source of Interactive Effect: Environmental Moveability X Sex						p=.034		
N	9	9	10	10	6	7	11	5
Mean	16.0	9.1	15.0	14.2	10.3	8.0	10.4	17.6
S. D.	12.7	6.1	9.0	4.5	2.6	3.1	4.9	6.1
3. Duration Rising Upon Balsa in Quadrant 1 (Sec)								
Source of Main Effect: Sex					p=.074			
N	9	9	10	10	6	7	11	5
Mean	14.9	19.8	15.4	17.1	11.8	15.1	15.5	16.6
S. D.	7.1	6.9	4.6	7.0	4.5	4.4	4.6	7.8

---

[a] Analysis of Variance (BMD P2V computer program) d. f. = 1,59

TABLE 10 B

Observations of <u>A. cahirinus</u> at Weaning
Specific Behavioral Items with Substrates and Structures (Cont'd)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
4. Duration Rising Upon Sand in Quadrant 3 (Sec) Source of Main Effect: Structure					p=.056			
N	9	9	10	10	6	7	11	5
Mean	11.8	18.1	13.3	12.0	9.3	11.4	10.6	11.6
S. D.	5.6	9.2	4.4	5.7	5.8	6.6	5.3	6.3
5. Total Duration Nosing Box (Sec) Source of Main Effect: Structure					p=.042			
N	9	9	10	10	6	7	11	5
Mean	29.1	34.6	31.1	35.0	34.2	37.3	47.9	41.8
S. D.	11.7	17.9	12.8	14.9	16.9	10.5	15.4	22.2
6. Total Duration Nosing Tube (Sec) Source of Main Effect: Structure					p=.001			
N	9	9	10	10	6	7	11	5
Mean	51.6	49.6	62.9	58.5	38.6	31.7	42.1	31.0
S. D.	20.9	18.0	25.9	22.4	13.2	17.1	11.6	9.6

box-reared animals (41.1 sec and 32.1 sec respectively; Studentized "t", $p < .025$, d.f. = 28). In contrast, the total nosing of tube was greater for box-reared pups (ANOVA "p" = .001; see Table 10 B - 6).

The response to the unfamiliar was also seen in rising against structures. Rising against the box in quadrants 1 and 4 combined was greater in tube-reared pups than in box-reared ones (see Table 10 B - 7) with means 21.3 sec and 13.2 sec respectively (Studentized "t", $p < .01$, d.f. = 28). Again, the opposite was found in regards to the tube with box-reared pups rising against the tube in quadrant 3 more than tube-reared pups (see Table 10 B - 8; means = 9.92 and 4.76 sec respectively (d.f. = 28).

In one respect, it would appear that previous experience with the structures was more valent in the bahavior. Rising upon the tube required that the animal balance upon the top surface of a curved structure. The results obtained (see Table 10 B - 9) indicated that familiarity with this activity made it more likely to occur: tube-reared mean = 21.3 sec, box-reared mean = 15.7 sec (Studentized "t", $p < .05$, d.f. = 28).

3. Location Measures (In/On Structures)

For time spent in the box, a significant effect of the unfamiliar was indicated again (see Table 10 C - 1) with a tube-reared mean of 42.7 sec and a box-reared mean of 33.9 sec (Studentized "t", $p < .05$, d.f. = 28).

TABLE 10 B

Observations of *A. cahirinus* at Weaning
Specific Behavior Items with Substrates and Structures (Cont'd)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
7. Duration Rising Against Box from Quadrants 1 and 4 Combined (Sec) Source of Main Effect: Structure [a]					p=.016			
N	9	9	10	10	6	7	11	5
Mean	9.7	11.4	19.8	11.2	14.2	36.0	26.6	20.4
S. D.	6.8	5.8	14.3	7.5	5.7	46.8	16.1	8.2
8. Duration Rising Against Tube from Quadrant 3 (Sec) Source of Main Effect: Structure					p=.004			
N	9	9	10	10	6	7	11	5
Mean	10.4	8.3	12.4	8.4	4.5	3.6	5.0	6.2
S. D.	12.6	5.8	7.2	5.9	2.6	2.4	3.1	5.8
9. Duration Rising on Tube Source of Main Effect: Structure					p=.036			
N	9	9	10	10	6	7	11	5
Mean	23.7	12.9	10.1	16.8	15.0	28.3	18.5	26.4
S. D.	13.9	7.4	5.7	6.5	10.2	14.3	13.7	18.0

a. Analysis of Variance (BMD P2V computer program) d. f. = 1,59

TABLE 10 C

Observations of *A. cahirinus* at Weaning
Location Measures - In/On Structures

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
	1. Duration Spent in Box (Sec) Source of Main Effect: Structure [a]				p=.080			
N	9	9	10	10	6	7	11	5
Mean	30.6	31.7	31.2	42.2	49.5	41.3	42.2	37.6
S. D.	15.2	13.5	11.4	22.2	40.0	12.9	16.8	19.4

a. Analysis of Variance (BMD P2V computer program) d. f. = 1,59

III. Observations With a Novel Environment

The results of the weaning observations warranted a further investigation of the "familiarity" factor. Accordingly, approximately one-third of the animals were observed in an environment where discrete items, equally unfamiliar to all, were presented (see Figure 5). If these subjects approached and contacted items based solely on their unfamiliarity with them, no differences should be expected among experimental groups.

A. General Procedures

1. Subjects

One-third of the total experimental population representing females and males of the four experimental groups were observed 11 days post-weaning in the situation described below. The remaining two-thirds of the animals were only handled (see 4 below). Behavioral data were recorded for a sub-population of these (see III, A, 4, 5, and 6 below).

2. Apparatus

The novelty environment used the large aquarium described for weaning (see II, A, 2 above) with a sheet of clear plastic in place of balsa and mica, sifted to uniformity, in place of sand. A stainless steel "box" (15.9 cm x 8.40 cm x 8.9 cm) was placed opposite the aquarium from a stainless steel arch (16.0 cm x 12.7 cm x 5.7 cm). In addition five 2.5 cm lengths of thin, amber plastic rod and two 2 cm^3 styrofoam blocks were placed across both substrates at the environment's center (see Figure 5). These materials were introduced as analogs of straw and food respectively which characterize the weaning-

NOVELTY ENVIRONMENT

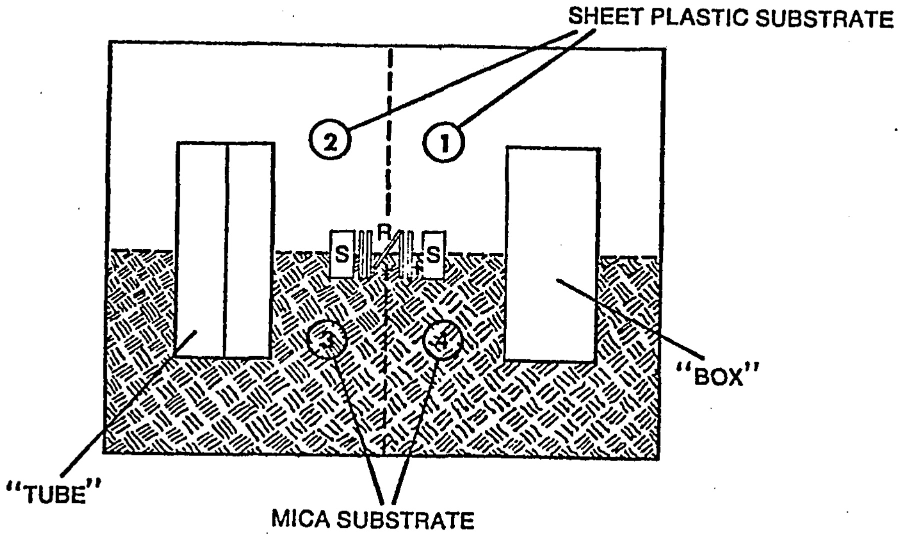
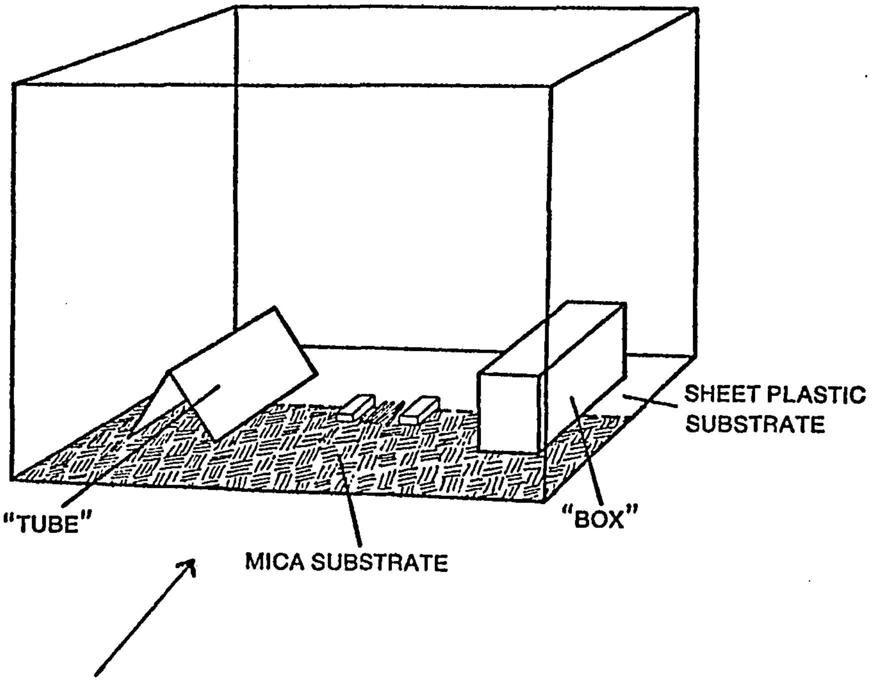


Figure 5. The novelty environment as viewed from above (top) showing location of styrofoam blocks (S) and plastic rods (R); also viewed from the corner of Quadrant 4 (bottom) with arrow indicating the orientation of the observer.



like environment (see IV below). Illumination was as II.A.2 above.

3. Maintenance

See II.A.3 above.

4. Procedures

After removal from its maintenance (home) aquarium, the subject was examined for evidence of bodily maturation (i.e., pelage changes; enlargement of nipples (females); enlargement of genitalia). It was then placed into the environment described in III.A.2 above and observed. After 15 minutes it was removed to the maintenance environment which was returned to its original shelf position. Before subsequent use the observation environment was disassembled and cleaned.

The remaining members of the experimental population were handled and inspected but not placed into the observation situation described above. Instead each was returned to its maintenance aquarium which had been placed beneath the observation light used for the novel environment observation. Data were collected on some subjects under these conditions (see Methods; 5 and 6 below). After 15 minutes the maintenance aquarium was returned to its original shelf position.

5. Data Recorded

For subjects experiencing the novel environment data were recorded as per Appendix A. For subjects observed within their maintenance aquaria (see Figure 4) three measures, locomotion, structure-involved activity and grooming were employed (see Table 11).

TABLE 11

RESPONSIVENESS TO NOVEL ENVIRONMENT AND MAINTENANCE AQUARIUM COMPARED

TOTAL STRUCTURE-INVOLVED ACTIVITY (Mn sec)

	B-MOV		B-N-MOV		T-MOV		T-N-MOV	
	NOVELTY	HOME CAGE	NOVELTY	HOME CAGE	NOVELTY	HOME CAGE	NOVELTY	HOME CAGE
N	7	6	8	7	5	6	8	7
MN	242.00	368.83	223.50	398.29	276.20	641.83	205.25	464.00
SD	45.67	91.63	51.52	145.94	116.71	171.93	56.12	102.85
			TOTAL SELF-GROOMING (Mn sec)					
MN	17.71	46.00	16.88	73.00	18.20	61.50	18.00	72.29
SD	14.06	35.39	9.09	49.93	10.13	56.72	9.50	67.46
			TOTAL LOCOMOTION (Mn sec)					
MN	254.71	213.67	260.13	137.00	262.00	213.67	238.38	253.86
SD	24.48	66.48	20.22	91.72	43.19	222.63	44.97	90.08

6. Data Analysis

The data from subjects experiencing the novel environment were analyzed in the manner used for the weaning observations (see II.A.6) with the addition of one major category of data, i.e., special measures of moveability. This category included activities associated with the portable plastic rods and styrofoam blocks of the novel apparatus (see III.A.2 and Figure 5).

To obtain adequate sample sizes for each of the four experimental groups, i.e., Box-Mov, Box-N-Mov, Tube-Mov, Tube-N-Mov, the data for males and females were combined. Therefore, all ANOVA values reported for the novelty observation were based on 2 main factors in a 2 (structure: box; tube) x 2 (moveability: Mov; N-Mov) design.

A Mann-Whitney U test was employed to compare group "novelty" and "maintenance" means for each of the three measures listed in III.A.5 above (see also Table 11). The statistical results obtained were viewed against a one-tailed level of significance of $p = .10$.

B. Results

The effects of both rearing structure and moveability were seen in the responses made by Acomys to the structures and substrates of the novel environment. That this environmental configuration was effectively unfamiliar to each of the experimental groups was demonstrated by the differences found between the responses recorded in the novel environment, and those observed in the home environment (see Table 11).

1. Results Obtained in the Novel Environment

a. Combined Activity Measures

No significant differences among the experimental groups were found for any of the three general measures of total locomotor, structure-involved, and grooming activity.

b. Specific Behavior Items with Substrates and Structures

Differences in snout and forepaw responses to both substrates were related to environmental moveability during rearing. Mov-reared mice spent more time than N-Mov-reared manipulating mica (ANOVA "p" = .014, d.f. = 1,24; see Table 12 A - 2). The source of this difference was between Box-Mov animals (Mn=19.4 sec) and Box-N-Mov animals (Mn=1.9 sec) ($p < .025$, d.f. = 24, Newman-Keuls test). This result indicated that a moveable, novel substrate is attractive to animals reared on sand. Their consequent manipulatory response appears to be a function of their previous experience with moveability.

A difference, also related to rearing moveability, was found for nosing of the sheet plastic substrate, in quadrant 2 of the novel environment (ANOVA "p" = .003; see Table 12 A - 1). Box-Mov animals spent more time (Mn=16.7 sec) nosing this substrate than Box-N-Mov ones (Mn=9.0 sec) (Newman-Keuls test, $p < .025$, d.f. = 24).

All measures of rising upon substrates without structural contact which distinguished the groups from each other, did so primarily as a function of type of rearing structure. Box-reared *Acomys* rose upon both plastic and

TABLE 12 A

Observations of *A. cahirinus* in the Novel Environment
Specific Behavior Items with Substrates and Structures

Structure:	BOX		TUBE	
Moveability:	YES	NO	YES	NO
1. Duration Nosing Plastic Substrate in Quadrant 2 (Sec) Source of Main Effect: Environmental Moveability [a]			p=.003	
N	7	8	5	8
Mean	16.7	9.0	12.8	11.9
S. D.	4.3	3.2	2.2	3.3
2. Total Duration Manipulating Mica (Sec) Source of Main Effect: Environmental Moveability			p=.014	
N	7	8	5	8
Mean	19.4	1.8	8.4	4.5
S. D.	18.1	1.2	10.1	6.3
3. Duration Rising Upon Plastic in Quadrant 1 (Sec) Source of Main Effect: Structure			p=.001	
N	7	8	5	8
Mean	24.3	17.5	12.6	13.4
S. D.	6.2	4.6	5.0	4.0

[a] Analysis of Variance (BMD P2V computer program) d. f. = 1,24

mica substrates, treated separately or combined for statistical analysis, more than tube-reared ones (ANOVA combined "p" = .007, d.f. = 1,24; see Table 12 A - 3; see also Table 12 A - 4, 5 and 6). In quadrant 1 the significant paired comparison for rising upon plastic was between Box-Mov (Mn=24.3 sec) and Tube-Mov (Mn=12.6 sec). The same relationship existed for quadrant 2 with the means being 21.3 and 13.6 sec respectively ($p < .05$, d.f. = 24). As with behaviors discussed above, those activities directed upon environmental structures differed as a function of rearing moveability. Mov-reared animals spent more time than N-Mov nosing the "tube," a measure including nosing this analog structure from within as well as from outside (ANOVA "p" = .021, d.f. = 1,24; see Table 12 A - 7).

When acting upon the box, however, the direction of the differences changed. N-Mov-reared animals rose against the "box" for greater amounts of time (Mn=20.9 sec) than Mov-reared animals (Mn=14.3 sec) (Studentized "t" test, $p < .01$, d.f. = 11) with Box-N-Mov animals (Mn=22.9 sec) and Box-Mov animals (Mn=12.7 sec) ($p < .025$, d.f. = 24; see Table 12 A - 12).

c. Location Measures (In/On Structures)

The differences found for two location measures, i.e., time spent on "box" and in "tube," were related to cage structures during rearing. It was found that box-reared Acomys spent more time on the "box" than did tube-reared ones (ANOVA "p" = .018, d.f. = 1,24; see Table 12 B - 1),

TABLE 12 A

Observations of A. cahirinus in the Novel Environment Specific Behavior Items with Substrates and Structures (Cont'd)

Structure:	BOX		TUBE	
Moveability:	YES	NO	YES	NO
4. Duration Rising Upon Plastic in Quadrant 2 (Sec) Source of Main Effect: Structure			p=.003	
N	7	8	5	8
Mean	21.3	17.1	13.6	15.0
S. D.	4.3	3.5	4.7	3.4
5. Duration Rising Upon Mica in Quadrant 3 (Sec) Source of Main Effect: Structure			p=.056	
N	7	8	5	8
Mean	13.0	10.9	9.0	9.5
S. D.	2.2	2.0	6.6	3.0
6. Total Duration Rising Upon Substrates (Sec) Source of Main Effect: Structure			p=.007	
N	7	8	5	8
Mean	117.7	96.6	82.8	71.3
S. D.	23.6	20.2	47.7	15.0

TABLE 12 A

Observations of A. cahirinus in the Novel Environment
Specific Behavior Items with Substrates and Structures (Cont'd)

Structure:	BOX		TUBE	
Moveability:	YES	NO	YES	NO
7. Total Duration Nosing Tube (Sec) Source of Main Effect: Environmental Moveability			p=.021	
N	7	8	5	8
Mean	26.0	16.1	23.4	19.0
S. D.	7.5	5.6	9.1	8.1
8. Duration Nosing Tube in Quadrant 2 (Sec) Source of Main Effect: Structure			p=.064	
N	7	8	5	8
Mean	6.0	5.0	10.6	7.4
S. D.	3.7	1.4	6.7	5.9
9. Duration Nosing Tube in Quadrant 3 (Sec) Source of Main Effect: Structure			p=.065	
N	7	8	5	8
Mean	5.6	4.1	3.4	3.0
S. D.	1.6	2.3	2.1	2.6

TABLE 12 A

Observations of *A. cahirinus* in the Novel Environment
Specific Behavior Items with Substrates and Structures (Cont'd)

Structure:	BOX		TUBE	
Moveability:	YES	NO	YES	NO

10. Duration Rising Against Box in Quadrant 1 (Sec)
Source of Main Effect: Environmental Moveability p=.095

	BOX YES	BOX NO	TUBE YES	TUBE NO
N	7	8	5	8
Mean	9.0	13.9	12.4	13.4
S. D.	2.6	4.5	4.8	5.1

11. Duration Rising Against Box in Quadrant 4 (Sec)
Source of Main Effect: Environmental Moveability p=.043

	BOX YES	BOX NO	TUBE YES	TUBE NO
N	7	8	5	8
Mean	3.7	9.0	4.2	5.6
S. D.	2.2	6.6	1.6	2.8

12. Total Duration Rising Against Box from Quadrants 1 and 4 Combined
Source of Main Effect: Environmental Moveability p=.036

	BOX YES	BOX NO	TUBE YES	TUBE NO
N	7	8	5	8
Mean	12.7	22.9	16.6	17.8
S. D.	3.7	7.8	6.1	7.4

TABLE 12 B

Observations of A. cahirinus in the Novel Environment
Location Measures

Structure:	BOX		TUBE	
Moveability:	YES	NO	YES	NO
1. Duration Spent On Box (Sec) Source of Main Effect: Structure [a]			p=.018	
N	7	8	5	8
Mean	64.0	46.0	29.2	31.6
S. D.	25.4	30.3	23.7	19.0
2. Duration Spent in Tube (Sec) Source of Main Effect: Structure			p=.048	
N	7	8	5	8
Mean	93.0	66.8	115.8	111.9
S. D.	45.2	26.5	43.4	51.3

a. Analysis of Variance (BMD P2V computer program) d. f. = 1,24

while tube-reared *Acomys* spent more time within the novel "tube" than did those box-reared (see Table 12 B - 2; Studentized "t", $p < .05$, tube-reared mean = 113.4 sec, box-reared mean = 79.0 sec, d.f. = 12). Both of these results implied a positive response to similarities between these structural analogs and the rearing structures they were supposed to represent.

d. Special Measures of Moveability

Differences related to both rearing structure and moveability were found for the mouthing and manipulating of special portable items. N-Mov mice responded more (Mn=51.1 sec) than Mov-reared ones (Mn=23.0) to styrofoam blocks (see Table 12 C -1; Studentized "t", $p < .05$, d.f. = 1,24; see Table 12 C - 2).

2. Comparison of Results Obtained with Novel and Maintenance (Home) Situations

For two measures, i.e., structural contact and self-grooming all experimental groups showed a significantly greater duration of activity in the maintenance (home) situation than in the novel environment (see Table 11). The two box-reared groups locomoted more in response to novelty (Box-Mov mean = 254.7 sec, Box-N-Mov mean = 260.1) than at "home" (213.7 sec and 137.0 sec respectively). For tube-reared pups, however, there was no significant difference in locomotion between the two situations.

Although experimental subjects had no experience with the actual novel items prior to this observation, their

TABLE 12 C

Observations of A. cahirinus in the Novel Environment
Specific Behaviors with Portable Items

Structure:	BOX		TUBE	
Moveability:	YES	NO	YES	NO
1. Duration Mouthing and Manipulating Styrofoam Blocks (Sec) Source of Main Effect: Environmental Moveability [a]			p=.106	
N	7	8	5	8
Mean	10.6	57.1	37.2	46.5
S. D.	13.1	53.3	49.3	45.1
2. Duration Mouthing and Manipulating Plastic Rods (Sec)			p=.020	
N	7	8	5	8
Mean	17.0	34.5	54.2	63.5
S. D.	9.1	20.6	41.3	51.4

a. Analysis of Variance (BMD P2V computer program) d. f. = 1,24

experience with similar objects and substrates during rearing did affect their responses to "novelty." In some cases, therefore, pups demonstrated dexterity with freshly encountered items due to their previous "training," while in other cases a reduced responsiveness resulted, which reflected an inadequate discrepancy between novel and previously experienced items. The significance of these findings to the total study will be considered in the General Discussion (pp. 108-128).

IV. Weaning-Like Observation: Portable Objects Typically Provided in Colony Maintenance Cages Added to Situation Used in the Weaning Observation

This observation was essentially a replication of the weaning experiment to provide behavioral data at an intermediate (juvenile) stage of development. It differed, however, in its inclusion of two portable items (i.e., straw and loose food pellets) which were always in the Mov litter cages of this study and were typically provided to colony maintenance cages. Since pups reared in N-Mov environments were not exposed to these items previously, information as to their responses to the unfamiliar was obtainable. The weaning-like observation could also be used to determine whether experimental _Acomys cahirinus_ which experienced the "Novel" environment developed differently from those which did not.

A. General Procedures

1. Subjects

Each member of the experimental population was observed in a special environment 22 days post-weaning (see Methods).

2. Apparatus

The environment (including illumination) used was identical to that described for the weaning observation (II.A.2) except for the addition of two 2 cm^3 food pellets and three 5 cm strands of straw placed across both substrates at the environment's center.

3. Maintenance

See II.B.3 above.

4. Procedures

Observational procedures used in II.A.4 and III.A.4 were used with the environment described above. All equipment was cleaned between subjects.

5. Data Recorded

Appendix A lists the behavior items recorded.

6. Data Analysis

As for both the observation at weaning and that within the novel environment, time spent in locomotion, with structures, and in self-grooming provided the data for comparing general activity among the experimental groups. These same measures were used to determine if animals previously experiencing the "Novel" environment developed differently from those which did not (see III.A.4 above). The Mann-Whitney U procedure for small samples was employed for this comparison.

The other major categories of data including Specific Activities with Substrates and Structures, Location Measures and Special Measures of Moveability were again employed as data categories.

B. Results

No statistical differences were found between animals having the "Novel" experience and those not (see II.A.6 above). Although the subjects were not sexually mature when observed in the "weaning-like" environment, sex differences were observed for the first time. This was true for a number of the responses, particularly those combined measures of structure-involved activity and self-grooming. The effects of both rearing structure and moveability were seen more specifically in the response of *Acomys* to the structures, substrates and portable items provided in this environment.

1. Combined Activity Measures

An ANOVA value of .002 confirmed the result that males spent more time engaged in structure-involved activities than females (d.f. = 1,62; see Table 13 A - 2). However, females groomed more than males regardless of specific location (ANOVA "p" = .050, d.f. = 1,62; see Table 13 A - 3). As in the observation at the time of weaning, box-reared animals spent more time (Mn=8.6 sec) grooming in quadrant 1 (containing the box on balsa) than tube-reared ones (Mn=5.8 sec) (Studentized "t", $p < .01$, d.f. = 32).

2. Specific Behavior Items with Substrates and Structures

Differences related to both rearing structure and moveability were found for nosing balsa (see Table 13 B - 1, 2 and 3). In quadrant 1 box-reared *Acomys* nosed the substrate more than tube-reared ones (ANOVA "p" = .008, d.f. = 1,62; see Table 13 B - 2). The source of this difference was between Box-Mov males (Mn=20.5 sec) and Tube-Mov males

TABLE 13 A

Observations of *A. cahirinus* in the Weaning-Like Environment
Combined Activity Measures

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
1. Duration of Locomotion in Quadrant 3 (Sec) Source of Main Effect: Environmental Moveability [a] p=.046								
N	8	9	10	10	6	10	12	5
Mean	36.5	34.7	31.2	27.7	36.2	34.8	26.5	32.8
S. D.	9.9	8.3	10.8	9.6	19.1	16.6	10.0	7.0
2. Total Duration of Structure-Involved Activities (Sec) Source of Main Effect: Sex p=.002								
N	8	9	10	10	6	10	12	5
Mean	383.8	360.3	459.8	386.4	463.7	353.9	446.9	359.8
S. D.	60.0	46.1	117.6	81.8	218.9	49.0	62.1	21.2
3. Total Duration of Self-Grooming (Sec) Source of Main Effect: Sex p=.050								
N	8	9	10	10	6	10	12	5
Mean	25.1	35.0	18.0	26.6	19.8	35.4	22.9	26.4
S. D.	12.3	26.9	12.4	13.5	8.8	20.3	13.1	39.6

[a] Analysis of Variance (BMD P2V computer program) d. f. = 1,62

TABLE 13 B

Observations of *A. cahirinus* in the Weaning-Like Environment
Specific Behavior Items with Substrates and Structures

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
1. Total Duration Nosing Balsa (Sec) Sources of Main Effects: Environmental Moveability and Structure [a]							p=.041; .037	
N	8	9	10	10	6	10	12	5
Mean	39.4	30.3	23.4	25.6	24.2	24.6	21.6	22.4
S. D.	15.4	14.2	12.5	6.1	12.9	11.4	12.3	13.2
2. Duration Nosing Balsa in Quadrant 1 (Sec) Source of Main Effect: Structure							p=.008	
N	8	9	10	10	6	10	12	5
Mean	20.5	14.3	11.5	15.4	9.0	12.3	10.9	9.6
S. D.	11.4	7.2	7.4	5.3	4.7	7.5	6.8	4.6
3. Duration Nosing Balsa in Quadrant 2 (Sec) Source of Main Effect: Environmental Moveability							p=.025	
N	8	9	10	10	6	10	12	5
Mean	16.6	15.5	11.4	9.9	14.8	12.0	10.7	11.8
S. D.	6.6	7.6	6.9	4.9	7.9	6.4	6.4	7.9

[a] Analysis of Variance (BMD P2V computer program) d. f. = 1,62

(Mn=9.0 sec) (Newman - Keuls, $p < .025$, d.f. = 62). In quadrant 2 (see Table 13 B - 3) the difference found for nosing balsa was related to rearing moveability with Mov-reared animals nosing more (Mn=14.6 sec) than N-Mov-reared (Mn=10.7) (Studentized "t", $p < .025$, d.f. = 32). Differences related to both rearing structure and moveability were found for manipulating sand (see Table 13 B - 4). Tube-reared animals manipulated sand more (Mn=15.9 sec) than box-reared (Mn=5.2 sec) (Studentized "t", $p < .05$, d.f. = 32) while Mov-reared mice did so more (Mn=16.5 sec) than N-Mov ones (Mn=5.4 sec) ($p < .05$, d.f. = 24). As with the manipulation of mica (see III.B.1.b), this latter result demonstrated that an animal's familiarity with sand since birth increased the likelihood of its manipulating a clean, moveable substrate when available. This outcome will be considered again in the General Discussion.

Box-reared animals nosed and rose against the tube more than tube-reared animals as they had done during the weaning observation. Box-reared mice nosed the tube (in total) more than tube-reared ones (ANOVA "p" = .039, d.f. = 1,62; see Table 13 B - 8). For rising against the tube (from quadrants 2 and 3 combined; see Table 13 B - 9) box-reared animals were more active (Mn=15.6 sec) than tube-reared ones (Mn=10.8 sec) (Studentized "t", $p < .025$, d.f. = 32). Therefore, despite a previous exposure to this structure, box-reared animals seemed attracted to the tube as if it were still unfamiliar to them. In contrast, tube-reared mice were not

TABLE 13 B

Observations of *A. cahirinus* in the Weaning-Like Environment
Specific Behavior Items with Substrates and Structures (Cont'd)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
4. Total Duration Manipulating Sand (Sec) Sources of Main Effects: Environmental Moveability and Structure						p=.056; .046		
N	8	9	10	10	6	10	12	15
Mean	6.9	9.0	5.9	2.6	38.0	18.1	4.2	12.8
S. D.	8.9	10.9	7.6	2.8	70.9	27.6	8.3	16.3
5. Duration Rising Upon Balsa in Quadrant 2 (Sec) Source of Main Effect: Sex						p=.017		
N	8	9	10	10	6	10	12	15
Mean	9.4	15.0	11.7	14.7	8.3	14.8	11.8	15.8
S. D.	4.3	6.4	4.3	15.3	5.2	4.8	6.5	7.2
6. Duration Rising Upon Sand in Quadrant 3 (Sec) Sources of Main Effects: Structure and Sex						p=.064; 061		
N	8	9	10	10	6	10	12	15
Mean	8.3	13.0	9.2	8.7	6.3	9.7	5.7	7.8
S. D.	5.7	2.8	4.5	6.7	4.5	7.5	3.7	2.2

TABLE 13 B

Observations of <u>A. cahirinus</u> in the Weaning-Like Environment
Specific Behavior Items with Substrates and Structures (Cont'd)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
7. Duration Nosing Box in Quadrant 4 (Sec) Source of Main Effect: Sex					p=.031			
N	8	9	10	10	6	10	12	15
Mean	4.8	5.8	3.8	4.1	4.2	7.5	4.3	6.6
S. D.	3.7	2.2	1.8	2.5	3.2	4.6	2.7	4.8
8. Total Duration Nosing Tube (Sec) Source of Main Effect: Structure					p=.039			
N	8	9	10	10	6	10	12	5
Mean	46.6	44.0	53.9	47.1	43.3	39.6	43.1	21.8
S. D.	15.6	17.0	36.4	22.1	14.6	18.6	14.1	8.5
9. Duration Rising Against Tube in Quadrants 2 and 3 Combined (Sec) Source of Main Effect: Structure					p=.036			
N	8	9	10	10	6	10	12	5
Mean	11.9	17.0	14.8	18.0	8.3	10.6	12.9	8.8
S. D.	5.3	7.2	8.7	16.1	6.7	7.2	10.4	9.0

specially attracted to the box.

A difference based on rearing structure was found for rising upon the box (see Table 13 B - 10) with box-reared Acomys more active (Mn=34.7 sec) than tube-reared ones (Mn= 27.9 sec) (Studentized "t", $p < .05$, d.f. = 32). Extensive familiarity with the box as a platform for rising above the environment's substrate may have accounted for this difference.

3. Location measures (In/On Structures)

When the total time spent on the box was analyzed a difference based on rearing moveability was found (see Table 13 C - 2) with N-Mov-reared animals more active (Mn=105.8 sec) for this measure than Mov-reared (Mn=89.0) (Studentized "t" $p < .05$, d.f. = 24).

4. Special Measures of Moveability

Both straw and pellet food were mouthed and manipulated more by N-Mov-reared animals than by Mov-reared. For straw an ANOVA value of p = .001 assured this difference (d.f. = 1,62; see Table 13 D - 1) while for food a Studentized "t" test confirmed this result ($p < .025$, N-Mov mean = 16.9 sec, Mov mean = 5.8 sec; see Table 13 D - 2). These results are examined further in the General Discussion section (pp. 108-128).

Maturation and development between the time of weaning and the weaning-like observation are indicated when the results of these two situations are compared. An obvious outcome of these ongoing processes is the emergence of response differences related to sex which reveal that non-social behavior does distinguish the sexes prior to the development of adult

TABLE 13 B

Observations of <u>A. cahirinus</u> in the Weaning-Like Environment
Specific Behavior Items with Substrates and Structures (Cont'd)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
10. Duration Rising Upon Box (Sec) Source of Main Effect: Structure					p=.039			
N	8	9	10	10	6	10	12	5
Mean	39.6	39.8	32.7	28.2	19.2	27.2	32.3	29.6
S. D.	15.5	20.2	14.2	18.0	14.3	8.8	15.5	10.9

TABLE 13 C

Observations of *A. cahirinus* in the Weaning-Like Environment

Location Measures - In/On Structures

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
1. Duration Spent in Tube (Sec)[a.] Source of Main Effect: Sex p=.049								
N	8	9	10	10	6	10	12	5
Mean	92.6	86.8	150.4	122.9	225.7	101.0	128.5	69.6
S. D.	20.6	28.1	138.5	46.5	312.8	34.4	53.8	12.3
2. Duration Spent On Box (Sec) Source of Main Effect: Environmental Moveability p=.045								
N	8	9	10	10	6	10	12	5
Mean	103.0	100.7	104.3	94.7	71.7	83.6	113.8	111.6
S. D.	25.3	38.7	37.4	18.2	39.2	21.7	41.2	19.2

a. Analysis of Variance (BMD P2V computer program) d. f. = 1,62

TABLE 13 D

Observations of *A. cahirinus* in the Weaning-Like Environment
Specific Behaviors with Portable Items

1. Duration Mouthing and Manipulating Straw (Sec)
Source of Main Effect: Environmental Moveability [a] p=.001

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
N	8	9	10	10	6	10	12	5
Mean	12.9	5.2	14.0	30.9	7.3	7.8	30.0	34.0
S. D.	19.8	5.3	16.0	36.3	7.0	11.1	27.1	35.1

a. Analysis of Variance (BMD P2V computer program) d.f. = 1,62

TABLE 13 D

Observations of *A. cahirinus* in the Weaning-Like Environment
Specific Behaviors with Portable Items

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
2. Duration Mouthing and Manipulating Food (Sec) Source of Main Effect: Environmental Moveability [a] p=.053								
N	8	9	10	10	6	10	12	5
Mean	7.4	1.3	16.8	36.0	10.2	7.5	5.6	9.2
S. D.	14.2	.5	22.0	39.0	22.0	16.8	14.4	14.3

[a] Analysis of Variance (BMD P2V computer program) d. f. = 1,62

sexual activity.

V. Observations of Limited Social Contact at Early Sexual Maturity

This observation was made to determine if differentially reared A. cahirinus responded differently to conspecifics of either sex when encountered in an environment containing objects and substrates of varying familiarity.

A. General Procedures

1. Subjects

Forty-four days post-weaning, sixty-three animals from the previously tested population representing females and males of the four experimental groups were permitted limited contact with colony-reared adult conspecifics. Complete records were obtained for 14 females and 13 males observed with their own sex as well as 14 females and 12 males observed with the opposite sex.

2. Apparatus

The environment for the observation of social contact employed a 2.3 m x .68 m table elevated .90 m above the floor. The table supported nine contiguous compartments each 37.8 cm x 16.8 cm, which provided all experimental variables both in contact with and at equal distances from three singly caged resident adults (see Figure 6). This was designed to test for the existence of a direct relationship between the degree of familiarity with environmental items and the amount of social interaction occurring in their proximity. In addition it also provided experimental subjects with many options for increasing or decreasing the space between themselves and the resident

LIMITED SOCIAL CONTACT ENVIRONMENT

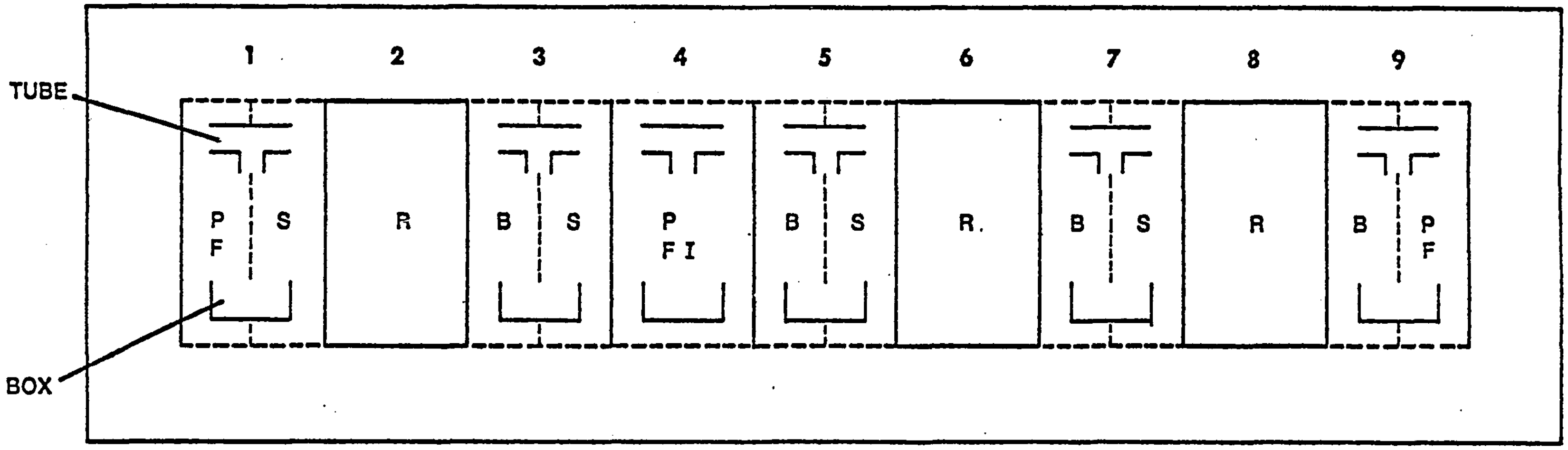


Figure 6. The limited social contact environment as viewed from above showing the position of boxes and tubes on substrates of balsa (B), sand (S) and sheet plastic (P) in relation to residents' cages (R). Food pellets and straw were provided at three locations (f). The experimental animal was introduced at location I.

conspecifics. The apparatus was illuminated by three 30 W Lumiline tubes suspended end to end .78 m above the table.

3. Maintenance

See II.B.3 above.

4. Procedure

A 30 minute observation was made after the subject was placed within the compartment indicated in Figure 6. After each use the apparatus was completely disassembled for cleaning.

5. Data Recorded

The subject's changes of location within the large environment were recorded. Contact behavior with resident conspecifics was of particular interest. Appendix A lists the items considered.

6. Data Analysis

In this section of the study, an analysis of variance for four main factors in a 2 (female; male) by 2 (box;tube) by 2 (Mov; N-Mov) by 2 (female resident; male resident) design was used to determine the statistical significance of behavioral differences among experimental groups. The cage mesh between experimental and resident animals permitted only nosing contact and this was the measure of direct social interaction used for analysis.

B. Results

In most cases, the presence of adult conspecifics affected the behavior of young, sexually mature, animals. The sex of the conspecific resident relative to the experimental animal often influenced the kind and intensity of the latter's behavior. For example, among measures of general activity, total locomotion and time spent "on box" were strongly affected by the residents' sex (see Tables 14 A - 1; 14 B - 1). Here most male experimental animals were more likely to engage in these activities in the presence of male residents than when exposed to female residents, while female subjects responded more in the presence of conspecific females than conspecific males. The direction of this outcome (i.e., same sex > opposite sex) for both activity measures was confirmed by Studentized "t" tests at $p < .05$ (d.f. = 25).

Even in cases where a different factor was primarily responsibly for the differences observed, the sex of the residents influenced the more outstanding comparisons. For example, time spent self-grooming was mainly related to structure of rearing with tube-reared spiny mice responding more (Mn=23.0 sec) than box-reared ones (Mn=15.9 sec) (see Table 14 A - 2; Studentized "t", $p < .05$, d.f. = 22). Among groups, Tube-N-Mov males showed a distinguishably high self-grooming level (Mn=36.5 sec) when observed with conspecific females. When observed with resident males the response of these same animals was the lowest recorded (Mn=8.0 sec) among all sub-groups (male or female) having the "same sex" experience. In notable contrast was the self-grooming response of Box-N-Mov females; they collectively showed the highest level (Mn=20.0 sec) among box sub-groups when observed with residents of the same sex but the lowest (Mn=5.3 sec) of all experimental sub-groups when with male conspecifics. Table 14 A - 2 provides all sub-group means used in these comparisons.

TABLE 14 A

Observations of <u>A. cahirinus</u> Under Condition of Limited Social Contact

Combined Activity Measures

Structure:		BOX				TUBE			
Moveability:		YES		NO		YES		NO	
Sex:		♂	♀	♂	♀	♂	♀	♂	♀
		1. Total Duration of Locomotion (Sec) Source of Main Effect: Sex of Resident [a]					p=.086		
SS	N	5	3	3	4	2	4	4	3
	Mean	285.2	260.3	229.6	271.3	255.0	305.3	262.5	312.3
	S. D.	80.5	80.0	118.5	55.7	84.9	155.2	118.1	151.2
OS	N	2	3	5	3	3	5	2	3
	Mean	194.0	302.7	254.4	188.0	152.0	253.6	184.5	248.3
	S. D.	45.3	169.6	79.3	23.0	32.2	104.6	50.2	57.7

SS = with residents of same sex
OS = with residents of the opposite sex

a = Analysis of Variance (BMD P2V computer program) d. f. = 1,38

TABLE 14 A (cont'd)
Observations of A. cahirinus Under Conditions of Limited Social Contact

Combined Activity Measures

2. Total Duration of Self-Grooming (Sec)
Source of Main Effect: Structure[a] p=.060

Structure:		BOX				TUBE			
Moveability:		YES		NO		YES		NO	
Sex:		♂	♀	♂	♀	♂	♀	♂	♀
	N	5	3	3	4	2	4	4	3
SS	Mean	19.0	12.3	14.3	20.0	25.0	24.8	8.0	21.7
	S. D.	7.3	14.0	4.7	15.2	9.9	11.4	4.8	14.6
	N	2	3	5	3	3	5	2	3
OS	Mean	22.0	12.4	18.4	5.3	32.0	22.8	36.5	13.3
	S. D.	9.9	10.0	11.5	7.5	21.0	20.4	33.2	9.1

SS = with residents of same sex
OS = with residents of the opposite sex

a = Analysis of Variance (BMD P2V computer program) d. f. = 1,38

TABLE 14 B
Observations of *A. cahirinus* Under Conditions of Limited Social Contact

Location Measures (In/On Structures)

Structure:		BOX				TUBE			
Moveability:		YES		NO		YES		NO	
Sex:		♂	♀	♂	♀	♂	♀	♂	♀
		1. Duration Spent on Box (Sec) Sources of Main Effect: Structure and Sex of Resident [a]						p=.095; p=.081	
	N	5	3	3	4	2	4	3	2
SS	Mean	17.2	19.0	15.7	20.8	12.0	3.0	20.3	18.5
	S. D.	17.0	16.7	15.9	23.4	14.1	4.0	11.9	3.5
	N	2	3	5	3	3	5	2	3
OS	Mean	29.5	7.7	14.2	1.0	1.0	1.0	1.0	3.0
	S. D.	37.5	10.7	29.5	0.0	0.0	0.0	0.0	3.5

SS = with residents of the same sex
OS = with residents of the opposite sex

a = Analysis of Variance (BMD P2V computer program) d. f. = 1,38

Although the difference in time spent within the tubes of the limited social contact environment was primarily related to structure of rearing, the influence of sex of resident was again found. The overall difference shows tube-reared animals spending more time "in tubes" (Mn=335.4 sec) than box-reared ones (Mn=144.4 sec) (see Table 14 B - 2; Studentized "t", $p < .009$, d.f. = 23). One notable finding was the low response of Tube-N-Mov males (Mn=106.5 sec) observed with females when contrasted to their "in tube" mean (473.0 sec) with resident males which was the highest recorded for this measure. On the other hand, Tube-Mov males spent more time within the tube, when observed with the opposite sex, than any other sub-group; their same-sex mean was not outstanding. Table 14 B - 2 provides all sub-group means referred to.

Since paired comparisons using the Newman-Keuls method (see Table 14 C - 1; $p < .025$, d.f. = 38) indicated that Tube-N-Mov males contacted females, by nosing, more (Mn=145.0 sec) than did Tube-Mov males (Mn=64.0 sec), a relationship between this measure and the time that these groups spent "in tubes" (see above) presented itself. Indeed, Table 15 which lists all sub-group means for the measures "in box," "in tube" and "contact nosing" taking place with same and opposite sexes, suggests that such a relationship exists across sub-groups. This is described in the General Discussion section (pp. 108-128).

As seen for plastic boxes, little evidence exists for the influence of either the balsa or sand substrates upon the incidence of social contact. Their impact upon _Acomys cahirinus_ is probably

TABLE 14 B (Cont'd)
Observations of _A. cahirinus_ Under Conditions of Limited Social Contact

Location Measures (In/On Structures)

2. Duration Spent in Tube (Sec)
Source of Main Effect: Structure [a] p=.016

Structure:		BOX				TUBE			
Moveability:		YES		NO		YES		NO	
Sex:		♂	♀	♂	♀	♂	♀	♂	♀
	N	5	3	3	4	2	4	3	2
SS	Mean	58.4	57.7	256.0	130.3	349.0	467.8	473.0	136.5
	S. D.	38.5	15.0	365.5	114.3	72.1	437.0	488.7	120.9
	N	2	3	5	3	3	5	2	3
OS	Mean	75.5	77.3	157.6	372.3	441.7	300.4	106.5	249.7
	S. D.	78.5	18.7	151.7	137.6	130.9	254.1	70.0	153.8

SS = with residents of the same sex
OS = with residents of the opposite sex

a = Analysis of Variance (BMD P2V computer program) d. f. = 1,38

TABLE 14 C
Observations of *A. cahirinus* Under Conditions of Limited Social Contact

Behaviors Involving Actual Contact

Structure:		BOX				TUBE			
Moveability:		YES		NO		YES		NO	
Sex:		♂	♀	♂	♀	♂	♀	♂	♀

1. Duration of Nosing Contact (Sec)
Source of Main Effect: Sex[a] p=.031

		BOX YES ♂	BOX YES ♀	BOX NO ♂	BOX NO ♀	TUBE YES ♂	TUBE YES ♀	TUBE NO ♂	TUBE NO ♀
	N	5	3	3	4	2	4	4	3
SS	Mean	27.8	30.7	22.7	17.5	55.5	48.8	54.8	13.3
	S. D.	38.5	20.1	37.5	31.7	40.3	94.8	54.7	19.7
	N	2	3	5	3	3	5	2	3
OS	Mean	43.5	21.3	34.8	40.3	64.0	23.0	145.0	28.7
	S. D.	60.1	14.8	37.3	5.9	27.9	16.0	103.2	9.8

SS = with residents of the same sex
OS = with residents of the opposite sex

a = Analysis of Variance (BMD P2V computer program) d. f. = 1, 38

TABLE 15

LISTING OF "IN STRUCTURE" AND "NOSING CONTACT" SCORES (Mean sec) BY SUB-GROUP AND SEX OF RESIDENT

	In Box		In Tube		Nosing Contact	
	SS	OS	SS	OS	SS	OS
Box-Mov ♀	4.7	5.3	57.7	77.3	30.7	21.3
Box-Mov ♂	6.4	8.5	58.4	75.5	27.8	43.5
Box-N-Mov ♀	19.8	12.0	130.3	372.3	17.5	40.3
Box-N-Mov ♂	9.3	15.6	256.0	157.6	22.7	34.8
Tube-Mov ♀	8.3	4.2	467.8	300.4	48.8	23.0
Tube-Mov ♂	6.0	8.3	349.0	441.7	55.5	64.0
Tube-N-Mov ♀	13.0	7.0	136.5	249.7	13.3	28.7
Tube-N-Mov ♂	7.3	4.5	473.0	106.5	54.8	145.0

SS = with residents of the same sex
OS = with residents of the opposite sex

diminished by the complexity of the experimental situation (see Figure 6) and its potential for social contact.

VI. Responses to Unimpeded Contact with Conspecifics (Pairing)

This observation was designed to examine the effects of differential rearing on the initial responses of sexually mature, experimental males and females to mature, opposite-sexed conspecifics, when encountered in a familiar environment.

A. General Procedures

1. Subjects

Fifty-one days post-weaning 37 animals (see Table 2) from the experimental population representing females and males of the four experimental groups were used. These were each paired with a colony-reared, like-aged, conspecific of the opposite sex which demonstrated typical sexual behavior.

2. Apparatus

For experimental males the pairing took place in their own maintenance environment. For each colony male scheduled for pairing with an experimental female an environment like hers was prepared.

3. Maintenance

See II.B.3 above.

4. Procedure

Each experimental male subject was weighed and examined and was returned to its maintenance environment, now placed beneath the observation light (see II.B.2 above). The colony female, weighed, examined and in addition tail-stained for identification was then placed into the center of the male's aquarium.

Each female subject, after being weighed and examined was placed into the maintenance environment occupied by a tail-stained colony male. The procedure of introducing females to males has been found to maximize the success of pairings in daily colony routine. For that reason it was employed here. In addition colony experience also shows that A. cahirinus pairs demonstrate their sexual responsiveness within 30 minutes of introduction. Therefore each observation was terminated after one-half hour.

5. Data Recorded

Based on years of successful colony breedings, the following patterns were observed to indicate that reproductive success was predictable.

a. Males follow and nose females intermittently, especially around the ano-genital region. When females are introduced into male home cages the male is not chased by the introduced female.

b. Females do not follow but do nose the male ano-genital region during periods of interaction. Female behavior should result in following and ano-genital nosing by males. Chasing by the male is typical.

The keyboard used for pairing, therefore, emphasized these details of social contact (see Appendix A). Among contact behaviors recorded (i.e., simple body proximity, undifferentiated body nosing and ano-genital nosing) the last was the most direct measure of sexual response. The duration of this intermittently occurring behavior was used for subsequent analysis since its frequency was found to be correlated.

6. Data Analysis

Analysis of variance of three main factors in a 2 (structure: box; tube) x 2 (moveability: Mov; N-Mov) x 2 (sex of subject: female; male) design was used to determine the statistical significance of behavioral differences among experimental groups. Where appropriate, further analyses were performed using Studentized "t" and Newman-Keuls tests.

B. Results

The best indicator of typical sexual contact, ano-genital nosing, revealed a difference based on rearing moveability with N-Mov-reared animals spending more time (Mn=15.6 sec) nosing the ano-genital region of their "mates" than Mov-reared (Mn=9.7 sec) (see Table 16 b; Studentized "t", $p < .10$, d.f. =31). This was particularly seen in the box-reared animals with N-Mov males and females showing an active interest in the ano-genital region of the opposite sex. In contrast only Tube-N-Mov males showed a high response whereas Tube-N-Mov females demonstrated the lowest activity among all sub-groups (i.e., Mov and N-Mov). Tables 17 and 18 provide the individual responses of experimental animals by rearing group. These tables reveal that the Mov/N-Mov difference described above is particularly notable between the male groups. Here, the highest duration of ano-genital nosing recorded for Mov-reared males was 12 seconds and was achieved by only 1 of the 7 animals in this group. In contrast 8 of the 14 N-Mov males surpassed this level.

TABLE 16

Observations of A. cahirinus Under Conditions of Unimpeded Social Contact (Pairing)

Behaviors Involving Actual Contact

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
a. Duration Spent by Experimental Mice Body Nosing (Sec) Source of Main Effect: Sex[1] p=.001								
N	3	3	5	4	4	6	9	2
Mean	51.7	16.7	93.8	20.0	62.3	24.5	63.2	22.5
S. D.	15.5	14.6	26.6	10.9	58.9	12.7	46.0	9.2
b. Duration Spent by Experimental Mice Ano-Genital Nosing (Sec) Source of Main Effect: Environmental Moveability p=.080								
N	3	3	5	4	4	6	9	2
Mean	7.7	8.7	20.8	11.0	3.8	5.8	14.6	2.5
S. D.	4.5	10.0	14.1	7.3	4.9	4.1	9.6	2.1

[1] = Analysis of Variance (BMD P2V computer program) d. f. = 1,28

TABLE 17

Duration (sec) of Ano-Genital Nosing

Experimental Males ——→ Colony-reared Females

During Unimpeded Social Contact Observation

Box-Mov N=3	Box-N-Mov N=5	Tube-Mov N=4	Tube-N-Mov N=9
3	34	0	32
12	11	2	26
8	8	0	7
	38	11	14
	13		17
			11
			0
			8
			15

TABLE 18

Duration (Sec) of Ano-Genital Nosing

Experimental Females ⟶ Colony-reared Males

During Unimpeded Social Contact Observation

Box-Mov N=3	Box-N-Mov N=4	Tube-Mov N=6	Tube-N-Mov N=2
5	11	0	4
20	21	0	1
0	8	9	
	4	9	
		0	
		5	

The result of the analysis for body nosing indicates that this activity was primarily a male response to females (see Table 16 a). Although the means presented for each male group accurately indicated the duration of the nosing contact achieved by each, they do not imply that a male-to-female approach was prerequisite so that the means, for example, of Tube-Mov and Tube-N-Mov males, although equivalent, were the result of different behavioral patterns (see General Discussion).

Time spent within the structure during "pairing" differed primarily as a function of rearing structure, with tube-reared animals (male and female) spending more time (Mn=438.0 sec) in their structure (i.e., the tube) than box-reared (Mn=101.1 sec) in theirs (i.e., the box) (see Table 19 a). Further analysis showed that Tube-Mov males spent significantly more time than any comparable sub-group in their structure (Newman-Keuls; $p < .025$, d.f. = 28). A significant difference related to sex was also found for this measure with males demonstrating a higher response (Mn=384.5 sec) than females (Mn=176.0 sec) (Studentized "t", $p < .025$, d.f. = 14). When time spent in actual body contact within the structure was considered the effect of sex was not significant. For males, therefore, the structure was not a site for contact. Contrarily, the results suggest it provided them with a shelter from social interaction. The difference found however was related to structure again, with the resulting relationship (i.e., tube-reared $>$ box-reared) coinciding with the "in structure" outcome above (see Table 19 c). Further analysis indicated that Tube-Mov males spent more time in the structure contacting the opposite

TABLE 19

Observations of A. cahirinus Under Conditions of
Unimpeded Social Contact (Pairing)
Location Measures (In/On Structures)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
a. Duration Spent Within Structure (Sec) Sources of Main Effects: Structure and Sex [1] p=.001; p=.040								
N	3	3	5	4	4	6	9	2
Mean	159.7	62.3	132.2	46.8	897.8	275.8	371.2	305.5
S. D.	150.7	31.9	194.0	18.3	607.4	237.5	238.7	294.9
b. Duration Spent On Structures (Sec) Sources of Main Effect: Environmental Moveability p=.155								
N.	3	3	5	4	4	6	9	2
Mean	134.3	210.0	247.6	228.3	122.5	111.7	272.2	129.0
S. D.	154.0	30.8	114.7	167.5	91.7	59.5	198.3	42.4

[1] = Analysis of Variance (BMD P2V computer program) d. f. = 1,28

TABLE 19 (Cont'd)

Observations of A. cahirinus Under Conditions of Unimpeded Social Contact (Pairing)

Location Measures (In/On Structures)

Structure:	BOX				TUBE			
Moveability:	YES		NO		YES		NO	
Sex:	♂	♀	♂	♀	♂	♀	♂	♀
c. Duration Within Structure While In Contact (Sec) Source of Main Effect: Structure p=.002								
N	3	3	5	4	4	6	9	2
Mean	1.3	3.0	2.0	11.8	96.0	24.0	34.3	32.0
S. D.	1.0	3.5	1.0	7.9	88.1	19.2	24.6	43.8

sex than any other comparable sub-group (Newman-Keuls; $p < .025$, d.f. = 28). The reason for this seemingly anomalous result is dealt with in the General Discussion section. Although Box-N-Mov females spent the smallest amount of time (Mn=46.8 sec) of any sub-group within their structure, they spent the largest proportion of that time (among sub-groups) in contact with their "mate" (see Tables 19 a and 19 c).

By inspection of Table 20 one can see a clear difference between Box-Mov males (N=3) which were always chased and Box-N-Mov (N=5) and Tube-Mov males (N=4) which were never chased. The reason for differences in each case, however, is not the same. This is explained in the General Discussion section. Three (3) Tube-N-Mov males were chased among the 9 "paired."

A tabulation of the chasing responses of colony reared males to experimental females (see Table 21) shows that the highest frequencies of chasing were stimulated among the mates of Box-N-Mov females. In turn, Box-Mov females were somewhat more stimulatory than either Tube-reared groups. This outcome is examined further inthe General Discussion section.

TABLE 20

Frequency of Chasing

Colony-Reared Females ——→ Experimental Males

During Unimpeded Social Contact Observation

Box-Mov N=3	Box-N-Mov N=5	Tube-Mov N=4	Tube-N-Mov N=9
54	0	0	0
28	0	0	15
6	0	0	0
	0	0	0
	0		27
			41
			0
			0
			0

TABLE 21

Frequency of Chasing

Colony-Reared Males ——→ Experimental Females

During Unimpeded Social Contact Observation

Box-Mov N=3	Box-N-Mov N=4	Tube-Mov N=6	Tube-N-Mov N=2
7	14	0	0
0	1	0	0
0	31	0	
	0	0	
		9	
		0	

DISCUSSION

The Effects of Rearing Environments on Social Behavior

In the precocial species Acomys cahirinus, the range of behavioral responses to the environment is increased by the neonate's visual and locomotor capabilities so as to experience objects and surfaces beyond themselves, littermates, and the lactating female. Therefore A. cahirinus pups can and do selectively approach and investigate with their eyes, snouts, forepaws and mouths the substrates, walls and debris of the rearing environment, beyond the immediate vicinity of the "nest," obtaining feedback from those sources. In this way the integration of input derived from various inanimate elements can accompany processes of early socialization characteristic of the A. cahirinus litter period. Whether or not the quantity or quality of such "inanimate" input affects ongoing social development is an appropriate question, heretofore neglected in behavioral research.

The present study, in dealing with this question, provided four experimental environments which differed in two significant aspects: type of structure and moveability. The four experimental combinations produced by the two variations of each of these factors, differed in detail yet were comparable in their overall configuration. The structures used (i.e., box or tube) differed primarily in shape. Both provided height for climbing, and exterior surfaces to locomote upon and an inner space within which social contact could be encountered or avoided. "Moveability" was obtained through varying the substrates (i.e., balsa or sand) as well as immobilizing the structures upon them in the non-moveable situation (N-Mov) or not immobilizing them in the moveable situation (Mov). Loose straw and food were available in the sand-bottomed environment, whereas straw was lacking and food could not be moved away from the feeding site in the non-moveable situation.

The non-moveable environment, therefore, lacked the potential for as much environmental reorganization as was present in the moveable one. Beyond the bodily secretions and eliminatory products laid down during their daily activities, pups within the non-moveable environment could effect a limited number of perceptible changes upon the inanimate surroundings. These may have been primarily chemical in nature. They, however, like pups in the Mov situations could stimulate movement in the animate environment through social interaction and in this way obtain the kinesthetic, chemical, visual, tactile and auditory feedback associated with effecting change. It might appear, then, that this experience, common to both Mov and N-Mov-reared pups, could result in an equivalence in their social development. It is possible, however, that the experience of moving conspecifics upon a relatively static inanimate backdrop (i.e., the N-Mov environment) as opposed to one which can also be moved (i.e., the Mov environment) differentially affects the perceptual aspects of development in A. cahirinus in such a way as to influence their responses to conspecifics during rearing and later in life.

Indeed, the results obtained during the litter period support this possibility. It was found that the amount of pup interaction with littermates and the lactating female depended on environmental moveability. Specifically, the environment which permitted greater opportunity for change (i.e., the moveable one) stimulated more interindividual activity during the litter period. This relationship became understandable when considered in light of the effects of change upon an animal's ability to organize its environment. Since recognizable visual cues (i.e., depressions and mounds) and chemical deposits (i.e., excretory and secretory) were often eradicated by both casual and purposive manipulations of the sand by cagemates, environmental input was variable. Even the food container and plastic structure, which were stable in configuration, differed daily as to their contents. As has been shown by the work of Rosenzweig *et al.*, Mason, etc., some of the effects of a complex environment in contrast with a static or low-stimulus level environment are definable. In such an environment therefore, where inanimate references were frequently changed, young *A. cahirinus* may have depended on animate ones upon which to organize their life space. Through interindividual activity, therefore, they could maintain in proximity the recognizable odors, sounds, warmth and visual input from their littermates and dam.

In the N-Mov environment, pups could respond visually and olfactorily to fecal deposits which were gradually accumulated and infrequently disrupted. Urine discolorations and their associated odors absorbed by the porous balsa floor were also more stable than in the Mov environment. These chemical and visual landmarks provided the pups with information about the environment's total organization and about locations of particular attractiveness. Under these circumstances the pups received feedback from an inanimate environment which was relatively constant and fixed. In comparison, feedback from animate sources resulting from a pup's visual, tactile and olfactory investigations of its cagemates would be relatively unpredictable. According to one theory (Schneirla, 1959) this form of environmental unpredicability may present the pup with a sufficiently intense stimulus so that withdrawal from conspecifics tends to occur. The observable outcome is that the N-Mov-reared pups approached the animate elements of their environment less than Mov-reared pups.

A second possible explanation for the greater time spent by Mov-reared pups in interindividual activity during their early development may be related to the environment's moveability directly, instead of its changeability as discussed above. Both animate and inanimate elements of this environment provided the developing pup with feedback from effecting movement in entities other than self: in animate objects as a consequence of social interaction; in inanimate objects through manipulatory experiences. Since it may be assumed that the process of receiving and integrating such feedback starts immediately after birth for this precocial species, the variable experience of moving inanimate items may have familiarized the pups with the unpredictability of movement, characteristic of their developing social interactions. For N-Mov-reared pups, the relative stability of the inaimate environment may have provided less facilitation so that social interactions, normally resulting in conspecific movements, were less likely to occur. Besides the potent influence of environmental moveability upon the occurrence of interindividual activity during the litter period, the site of the behavior composing this measure was influenced by the type of structure in the rearing environment. It was found that the box stimulated social interaction more than the tube, possibly because of its suitability as a nursing site. Half of the time that box-reared animals spent together on the structure side of their environment was spent together in direct contact with the structure itself. The tube-reared pups, spent relatively less time interacting within or upon their structure. They did seem to be affected by its presence, however, and they engaged in a significant amount of social contact in its vicinity. The role served by the tube in producing this outcome is probably related to its good characteristics as a shelter, since an individual interacting nearby could easily discontinue social contact by withdrawing to it.

A more direct relationship between the tube as a buffer and social interaction was seen during the Limited Social Contact Observation 44 days post-weaning. It was generally found that the longer an animal stayed within a tube in the proximity of a resident conspecific, the more time it spent in social (nosing) contact. Making this relationship possible was the juxtaposition of tube openings and the mesh of the resident cages which permitted both nosing contact as well as instant and total withdrawal by the experimental animal at any time. The use of the tubes in this way probably was affected by familiarity with this structure. Tube-reared animals took greater advantage of the tubes as sheltered locations for nosing contact than did box-reared animals, especially under the condition of encountering same-sexed conspecifics. Among box-reared animals those from the moveable environment were found to spend, in comparison to all other experimental groups, a greater proportion of their brief "in tube" time nosing same-sexed conspecifics. For these animals, therefore, the tube served primarily as a site for social contact.

When <u>A. cahirinus</u> were observed with conspecifics of the opposite sex, the relationship between time spent in tube and nosing contact differed from that found during observations with same-sexed conspecifics. Box-N-Mov and Tube-N-Mov males both spent less time in the tube than they had done with same-sex residents. However, these two groups nosed the opposite sex more. For the Box-N-Mov males this difference in pattern was relatively conservative with instances of contact still related to the time they spent within the tube. Tube-N-Mov males spent more time in nosing contact than within the tube so that in this case the males were making additional social contact at other locations as well. This significantly different pattern of behavior, which included greater exposure to the surrounding environment and increased amounts of social contact reflected a heightened interest in females by these two male groups. In contrast both Box-Mov and Tube-Mov males maintained and increased in duration the pattern which they had employed with same-sexed conspecifics, engaging in proportionally <u>more</u> nosing contact while spending <u>more</u> time within the tube. For Box-Mov males this was a demonstration of withdrawal since, in this case, the tube became even more of a requirement for achieving social contact than it was with same-sexed residents. The increased "in tube" response by Tube-Mov males to females was greater than the moderate increase in nosing contact recorded, so that withdrawal was also indicated. Therefore, for both of these male groups the shelter of the tube was more attractive during encounters with females than with males. This finding suggests that a deficit exists in the behavioral responses of Box-Mov- and Tube-Mov-reared males to female conspecifics, a proposal which is further developed in a later section of this discussion.

The relationship between time spent in tube(s) and in nosing males was not consistent enough among female groups to be of inferential value. The time that females spent in nosing same- as compared to opposite-sexed residents, however, did reveal lawful differences in group responsiveness. Primarily, an important distinction based on rearing moveability was found. N-Mov-reared females surpassed their same-sex nosing response when experiencing resident males, and Mov-reared females responded less when males were presented. Therefore Mov-reared females, like the Mov-reared males discussed above, promoted less social contact with opposite-sexed conspecifics than did their N-Mov-reared counterparts as detectible under conditions of limited social contact.

Following Eisenberg's criteria for characterizing social systems in rodents (1967) Acomys cahirinus is a "socially tolerant" species in that its members "overcome (an intial) avoidance interaction by means of special behavioral mechanisms to insure contact and familiarity without (immediately) fighting." Included among these mechanisms for maintaining and promoting contact are naso-nasal and naso-anal investigation. Since these forms of contact are prerequisite to the maintenance of pre-copulatory, sexual arousal, the more these are exhibited the greater the likelihood for later stages of sexual behavior to occur. Using this comparison it can be assumed that when depressed levels of heterosexual social contact are observed a deficit in responsiveness is indicated. Such a deficit appears to occur in animals reared in the moveable environment and is probably related to aspects of the socialization process occurring there. As we have seen socialization in Mov-reared animals was characterized by extensive interindividual activity during the litter period, a condition which would seem conducive to the development of functional social responses. Since the reverse occurred, one could speculate that this may result from factors relative to the situation in which it was expressed or, it may be that greater amounts of litter period interaction (when compared with N-Mov-reared mice) in some way interfered with future attachments with unfamiliar conspecifics. That heterosexual relationships are particularly affected is possibly due to the additional stress of experiencing newly arising physiological reactions associated with their recently developed sexual responsiveness.

The possible effects of these factors were more directly seen in the Unimpeded Social Contact Observation, conducted 51 days post-weaning, where animals reared in the moveable environment responded less to available social stimuli than N-Mov-reared. This was particularly evident among experimental males where responses of approach to newly encountered females often determined the success or failure of the pairing. Years of experience in breeding A. cahirinus support the existence of a phenomenon by which often subtle, inappropriate responses by the male result in aggressive rejection by the female during which the male is chased and possibly bitten. In colony maintenance practice, if a male is actively rejected by the female, she is removed from his cage after, at most, 30 minutes of interaction. The tenor of any pairing becomes obvious by this time. Since in A. cahirinus copulation may not take place for hours after the initial introduction, the sexual responsiveness of males is evaluated by the amount of time they spend nosing the ano-genital region of their females. In general, successful males maintain intermittent contact with their females through ano-genital nosing and are infrequently, if ever, chased. Among experimental males observed under conditions of unimpeded social contact, those reared in the Box-N-Mov environment best fulfilled these two criteria for success. Their pattern was to follow the female closely from behind over all surfaces of their home environment, pausing at intervals upon the box before resuming this activity. These pauses, in particular, may have provided breaks in the social activity at critical times when continued pursuit would have precipitated scuffling. Tube-N-Mov-reared males demonstrated a similar persistence in their approach to females, employing a pattern which resulted in a level of ano-genital nosing nearing that of the previously mentioned group but which added the risk of being chased. Their pattern was to follow the female and nose her ano-genital region whenever possible, withdrawing temporarily to the inside of the tube when the ensuing interaction became either less attractive or directly repulsive (i.e., eliciting a neutral female response or eliciting chasing by the female).

When compared to males reared in the N-Mov environment, Mov-reared males responded inappropriately to females. Box-Mov males, although remaining conspicuous throughout "pairing," failed to demonstrate a consistent pattern of sexual approach via ano-genital nosing. Consequently their success at this mode of contact was sporadic and always resulted in chasing by the female. In contrast Tube-Mov-reared males remained hidden for long periods within their tubes, never initiating social contact. The exploratory movements of the female, however, provided the stationary male with the opportunity to nose her, despite his inactivity. Since Tube-Mov males never actively approached females they were never chased. For these males, therefore, this outcome, which in most cases is a criterion for pairing success, was the result of their inadequate heterosexual responsiveness.

The effect of rearing in a non-moveable environment was observed to increase the attractiveness of experimental females to colony-reared males, only when the box was the structure of rearing. Therefore, among females, the Box-N-Mov-reared group attracted the highest levels of chasing in the males with which they were observed. In turn, Box-Mov females attracted the next highest levels.

The success of box-reared females is primarily associated with the conspicuousness they had achieved by spending more time upon their structure than within it. In addition periodic nosing of the male ano-genital region, particularly by Box-N-Mov females, stimulated the male to resume his sexual approaches soon after breaks in these activities had occurred. In contrast tube-reared females spent more time within the tube than upon it. Although they engaged in some ano-genital nosing of their males the bouts recorded lacked the durations found for box-reared females. It appears, therefore, that tube-reared females were less stimulatory to their "mates" and consequently were chased less frequently by them.

Perceptual Characteristics of Rearing Environment

The body of evidence provided above indicates that the development of social behavior in A. cahirinus is influenced by the physical environment during rearing. To understand this apparent relationship it is necessary to examine the validity of the underlying assumption that the animals were detecting and distinguishing the different properties of the environmental items presented. Therefore, three observations of their responses to these items were made to test this basic assumption.

The weaning observation was the first employed. When Acomys pups were removed from the litter situation and placed into an environment containing the two experimental substrates (i.e., sand and balsa) and the two structures (i.e., box and tube), they distinguished between those items with which they were reared and those with which they were not. This was demonstrated in a number of behavior items (see Appendix B). Generally, both structures and substrates unfamiliar to a particular rearing group were found to attract the greater amount of nosing behavior. The response to balsa by N-Mov-reared animals was the only exception. Responsiveness to the unfamiliar was also most prevalent with "rising against" the box and tube, with pups of most subgroups spending more time supporting themselves against the unfamiliar than the familiar structure.

The use of the structures by pups as locations to be active within and upon was in the same direction. More time was spent by box-reared groups in the tube than in the box, while tube-reared groups spent more time upon the box than upon the tube. The tube was a difficult object for box-reared Acomys to mount and rise upon. This was probably due to the acute curvature of its upper surface. Their insufficient experience with such a surface, therefore, may have affected this response to the unfamiliar structure.

Differential rearing on the substrates also affected unsupported rising behavior, with Mov-reared groups spending more time "rising upon" the substrate (i.e., balsa) unfamiliar to them.

To investigate whether only the characteristic of unfamiliarity operated to produce the above findings or whether other patterns of responsiveness were affected by differential rearing, the pups were studied in the second observational environment. Here the young A. cahirinus were presented with a situation that was completely unfamiliar to all groups. If differential rearing affected their perception of environmental items only in terms of strangeness (unfamiliarity) then their responsiveness to a totally unfamiliar environment should not be related to their different rearing experiences. This is not the case.

The results obtained revealed lawful relationships among the experimental groups which indicated the potent effects of their rearing experiences. The one exception to this general finding was that mica, as opposed to plastic sheeting, stimulated more investigatory nosing in all experimental sub-groups. Generally the groups approached and acted upon the novel structures that were analogous to those in the rearing environment. This responsiveness to structural similarities was demonstrated by the tube-reared groups which spent more time "in tube" than "in box" and by box-reared groups which spent more time "on box" than "on tube." In addition box-reared pups rose more upon the "box" than upon the "tube." Responses to the substrate in terms of "analogous familiarity" was also seen in that N-Mov-reared groups spent more time "rising upon" plastic sheeting than on mica. This may have been a function of its stimulus properties, which are similar to the balsa of their rearing.

These responses are in contrast to those found in the weaning situation. In that observation, the environment contained familiar as well as unfamiliar items, with the responses to the unfamiliar being more dominant. Here the presence of familiar items may have reduced the stressfulness of the situation, which may have made it possible for the mice to attend to unfamiliar objects by approaching rather than withdrawing from them. For the "Novel" environment it may have been the stress of a totally new situation (Tobach and Schneirla, 1962) that brought about the approach to structures and substrates that were somewhat familiar.

Other behavior patterns were related to past experience as well as to the familiarity aspects of the situation. Although the styrofoam blocks and plastic rods should have been equally unfamiliar to both Mov and N-Mov groups, the latter spent more time mouthing and manipulating each of them. Apparently the stimulus characteristics of styrofoam blocks and plastic rods proved similar to those of the food pellets and strands of straw which Mov groups experienced throughout their rearing. These similarities, therefore, reduced the attractiveness of these analogs to the Mov-reared animals. This interpretation is supported by the results of the third (weaning-like) observation which took place in an environment patterned on that of the "weaning" observation but which included among the items presented loose food pellets and straw. Here again, those animals (i.e., N-Mov-reared) which never before experienced these portable items were attracted to them more than those animals (i.e., Mov-reared) which had experienced them previously.

For the most part, differentially reared groups made the same distinctions between environmental items in the weaning-like environment as they had previously made in the weaning environment, with the exception of two cases. Tube-reared A. cahirinus nosed the box less than the tube while N-Mov animals nosed balsa more than sand. In general, therefore, the environmental experience during the litter period and later had effects upon perception in experimental spiny mice. These effects were expressed in their responsiveness to different environmental items.

The responsiveness of the N-Mov groups to the styrofoam blocks and plastic rods might suggest that the lack of manipulable items in their previous environment in some way increased the attractiveness of the items ("deprivation effects" see Lorenz). However, in all three observational situations the Mov groups manipulated sand, mica and sand respectively more than did the N-Mov groups. This suggests that "deprivational effects" (Schneirla) may be too simplistic an explanation. Rather, other aspects of stimulus characteristics and experience may have been involved.

Theoretical Considerations

Essential to the significance of the findings discussed above is an understanding of the interrelationships existing between developing perceptual responsiveness in a mammal and developing social behavior. To T. C. Schneirla (1957) perception requires that an animal sense not only the quantitative aspects of the environment but the qualitative differences as well; in other words, the significance or "meaning" of the objects and situations. Therefore nothing is "perceived" unless its significance has been previously integrated in the history of the individual. The range and nature of developmental advances through early experience depend upon a species' capacity for integration. In addition, the development of adaptive behavioral patterns in an animal, through this process, requires the species-typical developmental setting. This includes species-typical patterns of self-stimulation as well as feedback from other inevitable animate and inanimate sources. For altricial mammals, such as the domestic cat and laboratory rat, this involves the regular presence of a complex of chemical and tactual stimuli from the nest environment along with maternal and litter associations (Tobach and Schneirla, 1962; Tobach, 1968; Rosenblatt et al., 1962). Deviations from this form of early experience lead to abnormalities in perceptual development which may later be refelcted in the way an animal responds to new situations, environmental objects and conspecifics.

The structures experienced by A. cahirinus during rearing were also perceived differently. Animals experiencing the box during the litter period apparently perceived this structure as a site for social contact while tube-reared A. cahirinus found their structure to be a shelter for withdrawal from social activity. The effect of this perceptual difference on social behavior was seen later when experimental females were provided an opportunity for unlimited social contact with males. In this situation, box-reared females were more responsive to males and in turn stimulated more contact promoting behavior in their "mates" than did tube-reared females. Again, as with moveability, the perceptual systems of the animals were differentially affected by an experimentally provided environmental factor. The effect, in this case, selectively advanced the perceptual systems of females to facilitate their species-typical responsiveness to members of the opposite sex.

In this study, both environmental fixity (i.e., non-moveability) and a rectangular shelter (i.e., the box) when experienced through rearing, have emerged as factors which promote appropriate sexual responsiveness in A. cahirinus. These results suggest that in some way both non-moveability and "boxness" have fulfilled perceptual requirements during development which lead ultimately to species continuance. Knowledge of the natural environment where species survival actually takes place, provides the information needed to understand the action of the experimental configuration upon Acomys cahirinus. All information to date (Missone, 1975; Happold, 1975; Tobach, personal communication) places this nocturnal rodent in a rocky environment where it finds daily shelter among crevices and shallow limestone caves, the mouths of which are generally oblong in shape. Some investigators have reported that individuals of this species are never found in the sandy areas surrounding their typical habitat (Happold, 1975; De Vos, 1975). In view of these descriptions from nature it becomes evident that these animals are adapted to living upon a fixed substrate of non-moveable, rocky debris and outcroppings and have access to shelters unlike the tubular burrows of subterranean rodents. Therefore, according to Schneirla, the "expectancy" of this adaption was fulfilled by the perceptual experiences provided in the experimental environments which were either non-moveable, had a rectangular structure or, as with females, both of these factors. In the case of animals so reared, a greater competency for normal sexual behavior and reproduction developed.

In addition to the explanatory hypothesis based on Schneirla's theory, two experimental and at least one other theoretical hypothsis might account in part for the results obtained:

1) The observational situation used for "pairing" affected the the species-typical pre-copulatory behavior in experimental animals. This statement which applies to the observations

of experimental males in moveable (Mov) situations and experimental females in tube situations during unimpeded contact infers that the physical environment was directly responsible for the experimental outcome. This is unlikely, however, since evidence obtained during the litter period as well as from observations of limited social contact shows that social responsiveness was not affected within either a moveable environment nor by the presence of a tube. The outcome of each of the three social situations observed, therefore, was influenced by the age of the responding animal and the observational situation, all of which changed over time. Analysis of the reactions of any animal to the physical characteristics of the cage in which it was paired cannot be carried out within the constraints of the present research.

2) The environment failed to facilitate the developing motor patterns so that species-typical coordination could not develop (King, 1968). This hypothesis infers that the environments within which groups demonstrating an atypical heterosexual responsiveness were reared, may have been deprivational. If this were so, however, Mov-reared animals having greater opportunity to develop coordination via locomotion upon a shifting substrate as well as though digging activities should have showed some accelerated motor development or some increased proficiency at later stages of development. Although no obvious differences in motor development were evident in this experiment, this hypothesis could be tested in further

experiments.

3) Lorenz (1965) theorized that inborn patterns of behavior underlie the adaptive responses of animals to their environments. Since variations in behavior within experimental groups of A. cahirinus with regard to their heterosexual responsiveness did exist, it is possible that inborn patterns were still emerging in some individuals although in a form modified by the experiences of rearing. The consequences of this in light of selection pressures within the Lorenzian model, however, could only be measured after allowing all members of the experimental population to copulate, reproduce and rear young. Although this is a testable hypothesis and the results would demonstrate some effects of differential rearing on reproductive fitness, it would not elucidate the "inborn" nature of the behavior.

The results of Riess' work (1951-1953) as interpreted by Schneirla (1952) provide an example particularly apropos to understanding the results of the present study. Riess had seen that female rats which had passed their early post-weaning life in isolation without ever having handled or carried objects of any kind were inferior to normal females during partirition, losing all their young promptly. Schneirla hypothesized that experimental females never having the opportunity to "sense with meaning" items common in a young rat's normal experience, failed to develop a "maternal behavior pattern." When normally reared with items to manipulate perception introduces an "expectancy" which is selective in function and which influences situational adjustments (i.e., promoting proper responses at parturition) and further learning (i.e., in response to the emerging social situation). Therefore, when an animal's perceptual systems are not sufficiently advanced to the stage demanded by a given situation, the behavioral responses will be inappropriate.

In the present study, striking differences in social behavior were recorded in a comparison of experimental groups of A. cahirinus reared in moveable as opposed to non-moveable environments when observed both pre-weaning and after sexual maturity. Earlier in this General Discussion (pp.109-112) mechanisms for these group differences in social responsiveness observed during the litter period were proposed, each based upon the underlying premise that animate and inanimate environmental items were perceptually compared by N-Mov-reared animals differently than by Mov-reared ones. The finding that sexually mature A. cahirinus reared in the N-Mov environment approached and contacted conspecifics, particularly of the opposite sex, more than did those Mov-reared can be considered in light of different perceptual organizations which developed earlier in these two groups. Assuming that less heterosexual social contact represents a behavioral deficit, rearing in a moveable environment has affected the species-typical behavior patterns in this murid species. Two possible mechanisms are, it did not provide the experimental information required to advance the perceptual systems of Acomys young to the level necessary for appropriate social responsiveness to unfamiliar conspecifics; it may have provided experiences that modified the species-typical conspecific response. It would appear that either or both effects may have operated during development. The disruption of social interaction during the litter period could have affected the relevant groups to produce the results.

For animals reared in the moveable environment, normal pre-reproductive behavior was clearly modified. Schneirla's statement (1957) that "receptivity of the sexually mature mammal to a species mate may represent the rearousal of a perceptual responsiveness established earlier in life during the litter period" is central to these results.

Summary

A relationship between the development of social behavior and the physical environment during rearing has been demonstrated. By providing variation in the rearing environment through object and substrate moveability, it was revealed that physical environments which permit daily changes through moveability tend to be disruptive to the development of normal social behavior in Acomys cahirinus. In addition, the shape of the rearing shelter was also found to influence this development. It was inferred that environmental stability and a particular shape to the shelter in the environment during rearing is associated with the development, in these animals, of those species-typical behaviors necessary to reproductive success in later life.

The effects of these elements in the physical environment of rearing on the development of social behavior become understandable when the natural environment of this species is considered. The developmental patterns in this species have evolved apparently around the availability of rocky habitats with their associated caves and crevices (see Tchernov, 1975). Certain perceptual characteristics of this environment undoubtedly were involved in the species-typical development of the individual. The availability of these environmental cues in the presence of a species-typical social setting during rearing apparently influenced, in turn, the ongoing development of social behavior. The present study has succeeded in demonstrating this relationship. It has provided evidence that the experienced perception of certain types of cues within the inanimate environment of Acomys cahirinus during rearing are related to the formation of species-typical social patterns in this animal.

APPENDIX A

A. Behavior Recorded	Data Taken For:
1. LOCOMOTING - coordinated movement of the entire body involving the use of all four legs resulting in the linear displacement of the animal	all observations
2. RISING - standing on hind legs only	all observations
3. INTERINDIVIDUAL ACTIVITY - the total of all those activities directed upon or occuring in contact with another animal or animals, including nursing and resting in proximity as well as each of the specific items listed below	litter observations only
The Following 4 Items Were Recorded To Include Oneself, Another, An Inanimate Object Or Substrate As The Object Of The Activity	
4. NOSING - touching the tip of the snout to... includes ano-genital nosing	all observations
5. MOUTHING - contacting opened mouth to... includes biting	all observations
6. MANIPULATING - applying forepaws to... includes digging	all observations
7. MOUTHING AND MANIPULATING - the coordinated use of both mouth and forepaws on... includes feeding and grooming	all observations
8. CHASING - locomoting rapidly in pursuit of another	litter and "pairing" observations
9. RISING AGAINST - while standing on hind legs placing the forepaws against an object or another animal for additional support	all observations

APPENDIX A (CONT'D)

B. Objects (Animate and Inanimate) and Substrates Experienced	Data Taken For:
1. lactating female	litter observations only
2. siblings	litter observations only
3. unrelated conspecific(s)	limited social contact and "pairing" observations
4. feeding can with wire mesh	litter and "pairing" observations
5. either plastic box or tube	litter and "pairing" observations
6. either sand or balsa	litter and "pairing" observations
7. both plastic box(es) and tube(s)	weaning, weaning-like and limited social contact observations
8. both sand and balsa	weaning, weaning-like and limited social contact observations
9. both steel "box" and steel "tube"	"novelty"observation only
10. mica	"novelty" observation only
11. sheet plastic	"novelty" and limited social contact observations
12. loose food pellets	litter*, weaning-like, limited social contact and "pairing"* observations
13. loose lettuce leaves	litter*, and "pairing"* observations

APPENDIX A (CONT'D)

14.	plastic rods	"novelty" observation only
15.	styrofoam blocks	"novelty" observation only
16.	wire mesh cages	limited social contact observation only
17.	plywood "runway"	limited social contact observation only

* moveable environments

APPENDIX A (CONT'D)

C. Locations Recorded (see figures 1, 2, 4, 5)	Data Taken For:
1. QUADRANT 1	All observations with the exception of limited social contact Δ
2. QUADRANT 2	
3. QUADRANT 3	
4. QUADRANT 4	
5. in plastic structures	all observations except "novelty"
6. on plastic structures	all observations except "novelty"
7. in and on steel structures	"novelty" observation only
8. plywood runway, wooden framework and mesh walls and tops	limited social contact observation only

Δ See figure 15

APPENDIX B

A. Evidence of Responsiveness to the Unfamiliar (Weaning Environment)

			Nosing Balsa (sec)		Nosing Sand (sec)	
			Mn	SD	Mn	SD
Box-Mov	♂	(N=9)	39.1	21.2	27.8	17.6
Box-Mov	♀	(N=9)	36.7	21.4	16.3	8.1
Tube-Mov	♂	(N=6)	27.5	8.3	21.7	9.1
Tube-Mov	♀	(N=7)	23.6	10.1	14.6	2.4

			Nosing Tube (sec)		Nosing Box (sec)	
			Mn	SD	Mn	SD
Tube-Mov	♂	(N=6)	38.6	13.2	34.2	16.9
Tube-Mov	♀	(N=7)	31.7	17.1	37.3	10.5
Tube-N-Mov	♂	(N=11)	42.1	11.6	47.9	15.4
Tube-N-Mov	♀	(N=5)	31.0	9.6	41.8	22.2
Box-Mov	♂	(N=9)	51.6	20.9	29.1	11.7
Box-Mov	♀	(N=9)	49.6	18.0	34.6	17.9
Box-N-Mov	♂	(N=10)	62.9	25.9	31.1	12.8
Box-N-Mov	♀	(N=10)	58.5	22.4	35.0	14.9

			Rise Against Tube (sec)		Rise Against Box (sec)	
			Mn	SD	Mn	SD
Tube-Mov	♂	(N=6)	17.5	6.2	14.2	5.7
Tube-Mov	♀	(N=7)	12.9	2.5	36.0	46.8
Tube-N-Mov	♂	(N=11)	17.7	6.1	26.6	16.1
Tube-N-Mov	♀	(N=5)	20.6	8.0	20.4	8.2
Box-Mov	♂	(N=9)	20.7	12.6	9.7	6.8
Box-Mov	♀	(N=9)	30.1	16.5	11.4	5.8
Box-N-Mov	♂	(N=10)	36.0	8.7	19.8	14.3
Box-N-Mov	♀	(N=10)	22.5	7.7	11.2	7.5

APPENDIX B

A. Weaning Environment (cont'd)

			In Tube (sec)		In Box (sec)	
			Mn	SD	Mn	SD
Box-Mov	♂	(N=9)	105.8	25.3	30.6	15.2
Box-Mov	♀	(N=9)	105.9	20.0	31.7	13.5
Box-N-Mov	♂	(N=10)	135.4	49.4	31.2	11.4
Box-N-Mov	♀	(N=10)	102.3	20.1	42.2	22.2

			On Tube (sec)		On Box (sec)	
			Mn	SD	Mn	SD
Tube-Mov	♂	(N=6)	59.0	41.7	78.2	30.1
Tube-Mov	♀	(N=7)	92.1	20.3	104.4	47.3
Tube-N-Mov	♂	(N=11)	83.4	26.0	101.0	50.1
Tube-N-Mov	♀	(N=5)	90.8	45.2	104.8	45.4

B. Evidence of Responsiveness to Similarities in Stimulus Characteristics (Novel Environment)

		In "Tube" (sec)		In "Box" (sec)	
		Mn	SD	Mn	SD
Tube-Mov	(N=5)	115.8	43.4	53.5	10.6
Tube-N-Mov	(N=8)	111.9	51.3	50.3	18.1

		On "Tube" (sec)		On "Box" (sec)	
Box-Mov	(N=7)	41.0	20.3	64.0	25.4

		Rise On Plastic (sec)		Rise On Mica (sec)	
		Mn	SD	Mn	SD
Box-N-Mov	(N=8)	17.1	3.5	10.9	2.0
Tube-N-Mov	(N=8)	15.0	3.4	9.5	3.0

APPENDIX B

C. Evidence of Maintained Responsiveness to the Unfamiliar (Weaning-Like Environment)

			Nosing Balsa (sec)		Nosing Sand (sec)	
			Mn	SD	Mn	SD
Box-Mov	♂	(N=8)	39.4	15.4	19.3	6.7
Box-Mov	♀	(N=9)	30.3	14.2	18.0	9.1
Tube-Mov	♂	(N=6)	24.2	12.9	15.1	6.0
Tube-Mov	♀	(N=10)	24.6	11.4	19.4	10.2

			Nosing Tube (sec)		Nosing Box (sec)	
			Mn	SD	Mn	SD
Box-Mov	♂	(N=8)	46.6	15.6	15.2	4.0
Box-Mov	♀	(N=9)	44.0	17.0	22.6	6.1
Box-N-Mov	♂	(N=10)	53.9	36.4	19.5	6.9
Box-N-Mov	♀	(N=10)	47.1	22.1	18.2	9.7

			Rise Against Tube (sec)		Rise Against Box (sec)	
			Mn	SD	Mn	SD
Box-Mov	♂	(N=8)	11.9	5.3	8.6	9.1
Box-Mov	♀	(N=9)	17.0	5.2	13.9	13.6
Box-N-Mov	♂	(N=10)	14.8	8.7	9.4	4.2
Box-N-Mov	♀	(N=10)	18.0	16.1	8.0	6.8
Tube-Mov	♂	(N=6)	8.3	6.7	8.5	5.9
Tube-Mov	♀	(N=10)	10.6	7.2	11.6	10.3
Tube-N-Mov	♂	(N=12)	12.9	10.4	13.5	5.2
Tube-N-Mov	♀	(N=5)	8.8	9.0	9.8	7.3

APPENDIX B

C. Weaning-Like Environment (Cont'd)

			In Tube (sec)		In Box (sec)	
			Mn	SD	Mn	SD
Box-Mov	♂	(N=8)	92.6	20.6	37.2	20.1
Box-Mov	♀	(N=9)	86.8	28.1	24.5	17.3
Box-N-Mov	♂	(N=10)	150.4	138.5	42.9	18.9
Box-N-Mov	♀	(N=10)	122.9	46.5	47.1	24.2

			On Tube (sec)		On Box (sec)	
			Mn	SD	Mn	SD
Tube-Mov	♂	(N=6)	80.3	47.9	71.7	39.2
Tube-Mov	♀	(N=10)	79.7	23.2	83.6	21.7
Tube-N-Mov	♂	(N=12)	107.8	24.9	113.8	41.2
Tube-N-Mov	♀	(N=5)	96.8	31.5	111.6	19.2

BIBLIOGRAPHY

Anderson, L. T. (1973) An analysis of habitat preference in mice as a function of prior experience. Behavior, 57, 302-339.

Denenberg, V. H., Wehner, F., Werboff, J., Zarrow, M. X. (1969) Effects of post-weaning enrichment and isolation upon emotionallity and brain weight in the mouse. Physiology and Behavior, 4, 403-406.

De Vos, A. (1975) Some observations on ecological adaptions of desert rodents and suggestions for further research work. In Prakash, I. and Ghosh, P. K. (eds.) Rodents in desert environments. The Hague: Dr. W. Junk b. v. Publishers, 185-188.

Dieterlen, F. (1961) Beitrage zur Biologie der Stachelmaus, Acomys cahirinus dimidiatus Cretzschmar. Z. Saugetierk., 26, 1-13.

Dieterlen, F. (1963) Zur Kennatnis der Kreta-Stachelmaus, Acomys (cahirinus) minous Bate. Z. Saugetierk., 28, 47-57.

Eisenberg, J. F. (1967) A comparative study in rodent ethnology with emphasis on evolution of social behavior, I. Proceedings of the United States National Museum, 122 (3597), 1-51.

Forgays, D. G., Read, J. M. (1962) Crucial periods of free-environment experience in the rat. Journal of Comparative and Physiological Psychology, 55, 816-818.

Gluck, J. P., Harlow, H. F., Schiltz, K. A. (1973) Differential effect of early enrichment and deprivation on learning in the rhesus monkey (Macaca mulatta). Journal of Comparative and Physiological Psychology, 84 (3), 598-604.

Happold, D. C. D. (1975) The ecology of rodents in the northern Sudan. In Prakesh, I. and Ghosh, P. K. (eds.) Rodents in desert environments. The Hague: Dr. W. Junk b.v. Publishers, 15-44.

Harlow, H. F., Schiltz, K. A., Harlow, M. K. (1969) Effects of social isolation on the learning performance of rhesus monkeys. Proceedings of the 2nd International Congress of Primatology, Base 1: Karger, p. 178.

Hebb, D. O. (1947) The effects of early experience on problem-solving ability at maturity. American Psychologist, 2, 306-307.

Henderson, N. D. (1976) Short exposure to enriched environments can increase genetic variability of behavior in mice. Developmental Psychobiology, 9 (6), 549-553.

Hinde, R. A., Spencer-Booth (1967) The effect of social comparisons on mother-infant relations in rhesus monkeys. In Morris, D. (ed.) Primate Ethnology. London, Morrison and Glibb Ltd. 267-286.

Hymovitch, B. (1952) The effect of experimental variations on problem-solving in the rat. Journal of Comparative Psychology, 45, 313-321.

Ivinskis, A., Ivinskis, V. (1976) Effects of environmental change on problem-solving ability in rats. Psychobiological Reports, 38, 19-22.

Jensen, G. D., Bobbitt, R. A., Gordon, B. N. (1968) Effects of environment on the relationship between mother and infant pigtailed monkeys (Macaca nemestrina). Comparative Physiological Psychology, 66 (2), 259-263.

King, J. A. (1967) Species specificity and early experience. In Newton, G., and Levine, S. (eds.) Early experience and behavior. Springfield: Charles C. Thomas, Publisher.

Lehrman, D. H. (1971) Experiential background for the induction of reproductive patterns by hormones. In Tobach, E., Aronson, L., and Shaw, E. (eds.) The biopsychology of development. New York: Academic Press. 297-302.

Lewontin, R. C. (1974) The genetic basis of evolutionary change. New York: Columbia University Press.

Lorenz, K. (1965) Evolution and modification of behavior. University of Chicago Press.

Manosevitz, M., Joel, V. (1973) Behavioral effects of environmental enrichment in randomly bred mice. Journal of Comparative and Physiological Psychology, 85 (3), 373-382.

Mason, W. A. (1968) Early social deprivation in the nonhuman primate: implications for human behavior. In Glass, D. C. (ed.) Biology and behavior: environmental influences. New York: Rockefeller University Press. 70.

Misonne, X. (1975) The rodents of the Iranian desert. In Prakesh, I. and Ghosh, P. K. (eds.) Rodents in desert environments. The Hague: Dr. W. Junk b.v. Publishers. 47-58.

Moltz, H., Leon, M. (1973) Stimulus control of the maternal pheromone in the lactating rat. Physiological Behavior 10, 69-71.

Reiss, B. F. (1954) The effect of altered environment and of age on mother-young relationships among animals. Annals of the New York Academy of Sciences, 57, 606-610.

Rosenblatt, J. S. (1962) The behaviour of cats. In Hafez, E. S. E. (ed.) The behaviour of domestic animals. London: Bailliere, Tindall & Cox Ltd.

Rosenblatt, J. S., Turkewitz, G., Schneirla, T. C. (1969) Development of home orientation in newly born kittens. Transactions of the New York Academy of Sciences, 31, 231-250.

Rosenblum, L. A. (1973) The ontogeny of mother-infant relations in macaques. In Moltz, H. (ed.) Ontogeny of vertebrate behavior. New York: Academic Press.

Rosenzweig, M. F., Bennet, E. L. (1969) Effects of differential environments on brain weights and enzyme activities in gerbils, rats and mice. Developmental Psychobiology 2 (2), 87-95.

Sackett, G. P. (1972) Exploratory behavior of rhesus monkeys as a function of rearing experiences and sex. Developmental Psychobiology 6, 260.

Sales, G., Pye, J. D. (1974) Ultrasound in rodents. In Ultrasonic communication by animals. London: Chapman and Hall. 149-201.

Schneirla, T. C. (1956) Interrelationships of the "innate" and the "acquired" in instinctive behavior. In P.-P. Grasse (ed.) L'Instinct dans le comportement des animaux et de l'homme. Paris: Masson. 387-452.

Schneirla, T. C. (1957) The concept of development in comparative psychology. In Harris, D. (ed.) The concept of development. Minneapolis: University of Minnesota Press. 78-108.

Schneirla, T. C. (1959) An evolutionary and developmental theory of biphasic processes underlying approach and withdrawal. In Janes, M. R. (ed.) Nebraska symposium on motivation. Lincoln: University of Nebraska Press. 1-42.

Schneirla, T. C. (1962) Psychology, Comparative. In Encyclopedia Britannica. Chicago: Encyclopedia Britannica.

Schneirla, T. C. (1965) Aspects of stimulation and organization in approach withdrawal processes underlying vertebrate behavioral development. In Lehrman, D. S., Hinde, R. and Shaw, E. (eds.)

Advances in the study of behavior, Vol. 1. New York: Academic Press.

Schweikert, G. R., Collins, G. (1966) The effects of differential postweaning environments on later behavior in the rat. Journal of Genetic Psychology 109, 255-263.

Seay, B., Hansen, E., Harlow, H. F. (1962) Mother-infant separation in monkeys. Journal of Child Psychology and Psychiatry 3, 123.

Shkolnik, A. (1966) Studies in the comparative biology of Israel's two species of spiny mice (genus Acomys) Ph.D. Thesis, Hebrew University of Jerusalem, 117.

Strasser, H. (1968) A breeding program for spontaneously diabetic experimental animals: Psammonys obesus (sand rat) and Acomys cahirinus (spiny mouse). Laboratory Animal Care 18, 328-337.

Tchernov, E. (1975) Rodent faunas and environmental changes in the Pleistocene of Israel. In Prakesh, I. and Ghosh, P. K. (eds.) Rodents in desert environments. The Hague: Dr. W. Junk b.v. Publishers, 331-361.

Tobach, E. and Schneirla, T. C. (1962) Eliminative responses in mice and rats and the problem of "emotionality." In Bliss, E. L. (ed.) Roots of behavior. New York: Harper & Row.

Tobach, E. and Schneirla, T. C. (1968) The biopsychology of social behavior in animals. In Cooke, R. E. (ed.) The biological basis of pediatric practice - infancy, childhood and adolescence. New York: McGraw-Hill. 1-46.

Tobach, E. (1972) The meaning of the cryptanthroparion. In Ehrman, L., Omenn, G., and Caspari, E. (eds.) Genetics, environment and behavior. New York: Academic Press.

Tobach, E. (1977) Developmental aspects of chemoception in the Wistar (DAB) rat: tonic processes. Annals of the New York Academy of Sciences 290, 226-269.

Topoff, H. (1973) The oldest race in history. In Tobach, E. (ed.) The four horsemen: racism, sexism, militarism and social darwinism. New York: Behavioral Publications.

Wecker, S. C. (1970) The role of early experience in habitat selection by the prarie deer mouse, *Peromyscus maniculatus bairdi*. In Klopfer, P. H. (ed.) Behavioral ecology. California: Dickenson Publishing Co. 2-41.

Wolf, A. M.D. (1943) Inhibition of functions in neurosis. Dept. of Neurology, College of Physicians and Surgeons. Columbia University. 27-37.

Wolfheim, J. H., Jensen, G. D., Bobbitt, R. A. (1970) Effects of group environment on the mother-young relationship in pigtailed monkeys (Macaca nemestrina). Primates 11, 119-124.