ENVIRONMENTAL INFLUENCES ON THE BEHAVIOUR OF LABORATORY RATS AND SOME PHARMACOLOGICAL APPLICATIONS

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ABSTRACT

Increased knowledge of social and spatial influences on the behaviour of laboratory rats is important for both psychological and pharmacological research. This thesis investigates some housing parameters and demonstrates ways in which these variables can affect the results of behavioural tests and their interpretation in both general psychology and psychopharmacology. Popular single-subject behavioural procedures used in housing studies are adapted to elucidate the effects of the cage environment on both individual and group behaviour. In the psychopharmacological context control of, and elaboration upon, social and spatial characteristics of three environments (cage, post-injection, test) may promote a more realistic approach to the study of psychotropic drug effects on animal, and ultimately, human behaviour.

CONTENTS

Note to reader: Pages are numbered chapter by chapter; chapters are separated by a blue sheet of paper; tables and figures appear at the end of each chapter.

CHAPTER 8 CONSPECTUS

Sources of dissatisfaction with the housing studies of Part 1, facilities, methods, frustrations, measures, general limitations of single-animal tests, solutions.

CHAPTER 9 INTRODUCTION TO PART TWO

Desirability of social measures in psychopharmacology.

CHAPTER 10 EFFECTS OF LITHIUM CHLORIDE ON THE ACTIVITY OF RATS TESTED ALONE OR IN PAIRS

Evaluation of social variables and the response to lithium chloride, effects of social isolation in the post-injection period, depressant qualities of lithium salts.

CHAPTER 11 INFLUENCE OF SEX, NOVELTY OF THE TEST ENVIRONMENT AND LITHIUM CHLORIDE ON SOCIABILITY IN RATS

Effects of lithium on aggressive responses, problems in the analysis of complex social behaviour, presentation of a new method for measuring simple social behaviour (sociability), sex differences in the response to lithium salts, problems with the sociability measure, the shape of the test arena, general problems in establishing the effects of drugs on social behaviour.

CHAPTER 12 EFFECTS OF CHLORPROMAZINE AND METHAMPHETAMINE ON SOCIABILITY IN RATS

The autonomic arousal-affiliation hypothesis, use of a round arena for measuring sociability, testing Ss in their cage groups.

CHAPTER 13 GROUP INSTABILITY AND THE SOCIAL RESPONSE TO METHAMPHETAMINE

Modification of the social response to methamphetamine by treating rats of identical social caging history but with either familiar or unfamiliar test companions, possible implications of such manipulations for drug screening.

CHAPTER 14 GENERAL REVIEW

Future developments in the photographic technique, environmental characteristics of the test arena, problems in the analysis, the degree of reliability which may be expected.

CHAPTER 15 CONCLUSION

Concluding remarks.

CHAPTER ONE

INTRODUCTION

C H A P T E R O N E

I N T R O D U C T I O N

Over the past decade the social environment of the laboratory animal has caught the attention of many people concerned with the search for optimal cage conditions. "Experimental animals .. present a complex of varied problems. But in one respect they are all alike. Theirs is a man-made ecology. Their numbers, distribution, and environmental adventures are not an intrinsic problem, as those of wild animals remain to some extent, but a problem in human sociology; for they are determined by human needs and decisions" (Russell & Burch, 1959, pp. 32-33).

These human needs have dictated the emergence of large-scale industries which are devoted entirely to the breeding and caging of animals for human use. But "human" need not be confused with "humane." Economising on space in the animal house seems to be the main criterion for determining cage dimensions. Most cage recommendations, for instance, state only that adequate movement of the animal must be allowed for. Porter, Scott & Walker (1970), in a review of existing caging standards for rats and mice, found no reports of critical investigations of area requirements for either animal. But before this review several studies had indicated that social conditions within the cage environment could alter

the behaviour of laboratory rats and mice in, for example, the open field.

The common practice of keeping one animal in a cage and isolating it from normal social contact with others was criticised, on both physiological and behavioural grounds, by such people as King, Puh Lee & Visscher (1955); Yen, Stanger & Millman (1958); Weltman et al (1968); and Hatch et al (1965) with such strong statements as : " - the routine practice of housing animals singly may readily nullify or modify anticipated experimental conclusions" (Weltman, Sackler, Schwartz & Owens, 1968). Yet few studies, especially those concerned with developmental stimulation effects (e.g. Levine, 1967) state housing conditions as a possible artifact in their experimental results, while it has been established that the isolated animal behaves in a more "emotional" or "frightened" manner than does the group-housed animal.

Although a number of experimental studies have, in fact, investigated the effects of different housing conditions on the behaviour and physiology of laboratory rodents, these have usually been concerned with manipulating "population density" in order to generalise findings to, or from, the field situation (for reviews, see Thiessen, 1964b; Archer, 1970). Unfortunately the nature of the cage environment generally precludes such generalisations. Whereas housing studies involve small single-sex group dynamics, pen (e.g. Calhoun, 1949) and field (e.g. Christian, 1950) studies embrace true

populations in which reproduction can occur freely. Only field studies impose no spatial constraint, allowing emigration of subjects from the area examined. A distinction between these three types of investigation is provided by Barnett (1964) in a comprehensive discussion of "social stress" emanating primarily from the work of Selye (1946) and Christian (1950).

Acceptance of the domesticated rat as a useful subject for behavioural research (Boice, 1972) permits housing studies to assume an alternative methodological role. This thesis not only investigates some housing parameters but also attempts to show how these relate to behavioural methodology in psychopharmacology.

The distinction between the proximate and developmental environment of laboratory animals (e.g. Russell & Burch, 1959, p. 115) illustrates the potential influence of caging and experimental procedures on results obtained in drug studies. The developmental environment directly interacts with genetic factors, while the proximate environment acts upon the combined system of phenotype and dramatype; the latter being the pattern of performance in a single physiological response of short duration relative to the animal's life-time e.g. the reaction of the whole organism to a drug. Thus, in order to fully control the variability of physiological -and, to some extent, behavioural - responses, one should first control the phenotype by breeding methods together with influencing the environmental conditions in which the

animals are reared; and second, control the environmental conditions in which the animals are tested.

The studies reported in this thesis are concerned with the "proximate" environment and have been influenced primarily by the experimental approach and results of Chance (1956). This work was effectively the first challenge to the prevalent assumption "-that provided conditions are kept constant (and are not grossly unhealthy) it does not matter what the conditions are: the physiological responses of the animals will tend to be uniform because they are in a uniform environment" (Russell & Burch, 1959, pp. 123-124).

In his study of the assay response of immature female rats to serum gonadotrophin Chance found that the coefficient of variation in ovary weight (the test response) was affected, independently of the effect on the mean, by a number of different environmental variations: changing the subjects' cages, changing the cage-group composition (i.e. social disruption), in the size of the cage and in the number of animals within the cage. Chance thus postulated that "the size of the variance is related to the exact nature of the conditions and is sometimes unaffected by differences in the conditions." This last phrase was prompted by the finding that change in some environmental factors (e.g. the number of visits to, and disturbances of, the subject by the experimenter) had no appreciable effect on the mean of this response, while others (such as cage change) did have an effect.

As early as 1953 Lane-Petter complained about our ignorance of laboratory animal behaviour, and warned of the serious consequences this could have in experimentation. In fact there was a tendency to disregard this factor altogether. "According to this fallacy, if the animal does not grow the diet is at fault; if it does not breed there is an endocrine disorder; if it will not keep still while it is being inoculated it must be forcibly restrained." Even now, the systematic study of the social behaviour of the more common laboratory animals has hardly begun (Chance, 1957; Dimond, 1971; Crook, 1970). But there is a resurgence of interest in this area as it affects both the caging of such animals and psychopharmacological research (Chance, 1957). Perhaps, eventually, a rationale will exist for the optimal caging of laboratory animals with a consequent refinement and re-evaluation of popular experimental techniques.

At this point it is appropriate to discuss some of the central concepts relevant to the studies described in this thesis.

"Social stress"

In the present context it is considered sufficient to use the term "social stress" as a broad and convenient description of the physiological concomitants of social disruption. One attempt was made to obtain an index of such "stress" by dissecting out the adrenal glands from socially stressed rats (Ch. 3).

All this respectable effort achieved was a closer perusal of the literature regarding the usefulness of such gross measures of adreno-cortical activity (Angervall, 1959; Angervall & Carlstrŏm, 1963; Barnett, 1964) and a healthy scepticism towards perpetuating the "adrenal weight" fallacy amongst psychologists who seldom consider the wider implications of placing these endocrinological mysteries into the literature to bemuse the uncritical and amuse the physiologist.

The Open Field

A recent critical review of open-field studies as tests for emotionality in rats and mice (Archer, 1973) illustrates the lack of standardisation achieved in the use of this apparatus. One reason for this situation could be the variety of housing conditions imposed upon laboratory rodents which results in differing degrees of social disruption occuring in the transition between cage and test environment.

The open field was conceived by Hall (1934) as a measure of individual temperament in laboratory rats; where "temperament" is defined (Hall, 1941) "-as consisting of the emotional nature, the basic-needs structure, and the activity level of an organism." But the open field is no more than an enclosed arena of varying size and shape marked in such a way to facilitate a record of the S's activities within it. The dubious and often inappropriate use of the term "emotionality" or "temperament" particularly in

developmental studies (e.g. Denenberg, 1969) and for animals other than laboratory rodents (e.g. Candland & Nagy, 1969; Kilgour, 1972) leads this author to use the concept with caution, as several other authors advise (e.g. Candland & Nagy, 1969; Archer, 1973). Where the term is used it is to enable the comparison of results obtained with other studies using the concept; that is, in the studies described in Part 1 of this thesis - all of which use rats placed alone in a novel test situation.

Further comments concerning the use of the open field as a group-distribution apparatus are presented in Chapter 14.

Housing Studies

For the purposes of this thesis "housing studies" are defined as those concerned with the consequences of social and spatial manipulations of the homecage environment on the behaviour of laboratory rats and mice in novel test situations.

Part 1 of this thesis is concerned with the consideration of a number of variables operating in the cage environment. Responses studied measure either locomotor or non-specific general activity in a novel environment, and variables manipulated include: cage size, open-field size, sex, and the number of animals in the cage. All testing is performed with individual animals. Since the results of these studies suggest that this is an unsatisfactory approach to the study of housing parameters in that even if the Ss are group housed in a

stable social environment some degree of social disruption must confound the effects obtained in the experimental setting, Part 2 of this thesis extends the approach of Part 1 to pharmacological methodology, where individual measures of activity play an important role (Kinnard & Watzman, 1966). Measures of sociability within a group-testing situation are introduced. Thus the work described in the second part of this thesis attempts to develop a method which minimizes the effects of social disruption on the behaviour of laboratory rats treated with three drugs which have previously been studied in a social context: methamphetamine, chlorpromazine, and lithium chloride.

Pharmacological Methodology

While there is some literature pertaining to the influence of social variables on the response to drugs (for review, see Kinnard & Watzman, 1966) only one study has been concerned with the problems of social disruption occuring in the transfer of Ss between the cage and test environment (Wilson & Mapes, 1964a,b). Most studies investigating the effects of psychotropic drugs on social behaviour have adopted an "ethological" approach (e.g. Silverman, 1965; Krsiak & Borgesova, 1971) using familiar or unfamiliar rats or mice and providing a verbal description of the social interaction between pairs of treated and untreated Ss. However this procedure involves the separation of "partners" for periods of up to 24 hours, thus ensuring the disruption necessary to

produce observable "social behaviour." Other methods using social variables either observe the behaviour of treated rats in unstable groups (e.g. Schiørring & Randrup, 1971) or use group-housed rats but neglect to state whether familiar animals are used in the test setting (e.g. Tikal & Benesova, 1972).

Thus one may conclude that it is difficult to place the experiments described in Part 2 of this thesis in an established pharmacological literature, since little exists for the methodology in question. Although the development of a photographic method for analysing the spatial distribution of treated rats in a stable social setting is presented, even this method is not as well developed as the literature would suggest; i.e. this method is primarily derived from the work of Herron & Frobish (1969). However when the first author of this paper was approached for further information regarding the analytical procedure used (Herron, 1974, personal communication) he admitted that the work had not progressed beyond the "idea" stage. With the cooperation of Dr. W. Whittlestone a computer program is now being developed at the Ruakura Agricultural Research Centre by Mr. A. Pearson and Mr. S. Willson to analyse the spatial distribution of groups of animals. But, even at this stage, the underlying distribution of groups of animals (particularly, in the present context, the laboratory rat) is poorly understood and caution must be exercised in the extrapolation of results between species.

In view of the speculative nature of the experimental methodology presented, then, it is perhaps most satisfactory to view the experiments described in Part 2 of this thesis as illustrative ones only, in terms of the potential usefulness of the method. One further point deserves attention. Because of the time required for a manual analysis of data obtained in the photographs a "typical" drug dosage is usually employed. For example, 2 mg/kg i.p. methamphetamine was selected as a dosage sufficient to produce an increase in psychomotor activity but not stereotyped behaviour (Del Rio & Fuentes, 1969) which could mask social processes. It was decided that, once these "typical" dosages had been found to produce reliable results and the most suitable field shape had been determined, it would be most fruitful to concentrate on developing the potential of the method in a situation where the effectiveness of the experimental conditions had been demonstrated.

CHAPTER TWO

SOCIAL ISOLATION IN YOUNG RATS: EFFECTS OF CAGE SIZE ON OPEN-FIELD BEHAVIOUR[+]

[+] The results of Experiment 1 have been reported in Psychonomic Science, 1972, 29, 25-26.

C H A P T E R T W O

Introduction

For some time it has been recognised that the convenience of housing laboratory animals alone must be balanced against the risk of producing abnormal subjects for both behavioural and physiological research (Hatch et al, 1963; Weltman et al, 1968). Isolation of laboratory rodents often produces "nervous" and aggressive behaviour associated with increased adrenocortical activity (Hatch et al, 1965). However, while some studies report that isolation reduces activity in a novel test situation (Archer, 1969; Moyer & Korn, 1965; Stern et al, 1960; Thiessen, Zolman & Rodgers, 1962), others describe increases in activity (Essman, 1966; Weltman, Sackler & Sparber, 1966).

Essman (1966) has suggested that these contradictory results may have been due to the different ages at which differential housing was introduced, the different methods used to assess activity, the different lengths of time spent in selective housing conditions, or the varying sizes and types of cage used.

The present study was designed to investigate the possibility that open-field behaviour in rats is related to cage dimensions. This has been suggested by Morrison (1968) who found rats housed individually in large cages (18 x 14.5 x 9 in) to be less emotional than those housed individually in small cages (6.7 x 9.5 x 6.7 in). However the difference was not statistically significant. There was a significant

difference between the animals caged singly or in pairs in large cages, the former being the more emotional in the field. Unfortunately there was no paired condition in the small cages.

The behavioural difference between the isolates housed in small and large cages may reflect a spatial effect due to the similarity in dimensions between the large cage and the open field (45 x 45 x 24 in). This explanation is proposed by Morrison (1968), who might have obtained a significant result if the dimensions of his large cage and field were the same. Experiment 1 tests this hypothesis, using young isolated rats.

EXPERIMENT 1

Subjects

The Ss were 15 male Sprague-Dawley rats, group housed since weaning at 25 days of age. These were individually housed at 35 days of age in wooden cages measuring 15 x 15 x 10 cm (small), 30 x 30 x 20 cm (medium), or 60 x 60 x 40 cm (large). These cages had wire-netting lids and were painted brown. Food and water were provided ad libitum and the animals were maintained on a reversed light-dark schedule from 7pm to 7am. Cages were cleaned once a week and the Ss were not otherwise handled.

Apparatus

The apparatus was a wooden open field measuring 60 x 60 x 40 cm and painted brown. White-painted lines

divided the floor into 15 x 15 cm squares. Illumination was provided by a 22-W fluorescent lamp suspended 75 cm above the apparatus, and approximately 40 db of white noise provided an auditory masking background during testing.

Procedure

When the Ss were 50 days old they were each observed for 5 min in the apparatus by means of closed-circuit television. The receiver and observer were situated in an adjacent room to the apparatus. Television was used here since it was thought that the presence of the observer looking over the high walls of the field might disturb the S's behaviour. However a later refinement, consisting of a mirror held at an angle over the field overcame this problem. Since the television was cumbersome, time-consuming and difficult to set up with the camera in a vertical position at a sufficient height above the field, the simpler experimental procedure was adopted for later studies.

Each rat was removed from its home cage and placed in a corner of the field. Every 3 sec its position in a corner, wall or inner 15 x 15 cm square was noted, and if it was ambulating, rearing up on its hind legs or remaining immobile. In addition, total numbers of squares entered and faecal boli deposited were recorded.

Results

Kruskal-Wallis one-way analyses of variance followed by Mann-Whitney U tests were applied to the data. The results, summarised in Table 2.1 show that, as cage size increased, there were higher frequencies of ambulation (time spent walking), square entries (distance travelled), and rearing accompanied by greater tendencies to move away from corner squares towards wall and inner ones. Even though all Ss appeared "nervous" when picked up, there was no significant effect of cage size on defaecation which is commonly regarded as an index of emotional reactivity in rats (Hall, 1934, 1936).

Discussion

These findings support those of Morrison (1968) and suggest that, if the open field and large cages had been of similar dimensions in his study, a significant difference between his two isolated cage conditions might have been obtained.

It is possible that isolation in small cages, being the closest approximation to immobilisation (Stern et al, 1960), was more stressful than isolation in larger cages. But the significant differences between rats from medium and large cages (neither of which could be regarded as immobilising) and the lack of an effect on defaecation would argue against this. However, this still does not entirely rule out the possibility that differences in emotional reactivity may

have been in some way related to the results, although further work is required to ascertain this.

The findings do have considerable relevance to housing studies in which both group size and living space appear to be significant determinants of behaviour. Bell et al (1971) distinguish between studies using a crowded-group paradigm (CG) in which different size groups are placed in a cage of constant size and those using a density-group paradigm (DG) in which cage floor space is proportional to group size. Studies using CG have found isolated mice to be more active (Essman, 1966) and to have heavier adrenals than aggregated animals (Thiessen, 1964a), while those using DG have found the opposite (Bailey, 1966; Christian, 1955). Even though many such investigations are not directly comparable for reasons mentioned earlier (Essman, 1966), it is nevertheless true that different cage sizes have often been used for isolated animals when comparing them with animals from both DG and CG groups of varying numbers. Most DG isolates have typically been caged in small areas, while CG isolates are caged in much larger areas to enable one to progressively increase numbers of Ss within a fixed area. But, as Experiment 1 shows, this may produce a difference in activity between the two isolated conditions even before comparison with appropriate grouped Ss.

EXPERIMENT 2

Introduction

Latané & Walton (1972) suggest that socially deprived animals are more responsive to their environment than socially satiated, or grouped, animals. However, studies concerned with the effects of social isolation on the behaviour of rats in novel test situations such as the open field have shown that socially deprived Ss explore less than group-housed animals (Stern et al, 1960; Myers & Fox, 1963; Hahn, 1965; Moyer & Korn, 1965; Archer, 1969).

In Experiment 1 locomotor activity in the open field, exhibited by young socially isolated male rats, was found to be positively related to cage size, as was the tendency to move away from corner squares towards wall and inner ones. The relationship was a proportional one and the results could not be interpreted in terms of a change in emotional reactivity as cage size increased.

If the correlation between cage size and movement in the open field does not occur when animals are group housed, Latané & Walton's hypothesis may be supported and the housing studies re-interpreted. However a positive result would pose awkward questions for all studies utilizing emotionality explanations for the effects of social conditions in the cage environment. Experiment 2 investigates whether open-field behaviour by young male rats caged in pairs is affected by cage dimensions.

Subjects and Apparatus

The Ss were 18 male hooded rats (N.Z.B.W.S.) pair-housed at weaning at 25 days of age in the same small, medium and large wooden cages as used in Experiment 1. When the animals were 40 days old they were each observed for 10 min in the open field. This was the same apparatus as used previously and testing was carried out under the same conditions.

Procedure

This was the same as that used in Experiment 1 except that the time-sample was every 5 sec over the 10-min test period.

Results

Kruskal-Wallis one-way analyses of variance followed by Mann-Whitney U tests were applied to the data. The results, summarised in Table 2.2 show no significant relationship between locomotor behaviour in the field and cage dimensions. In fact, the only significant difference appears on the immobility scores in the opposite direction to that predicted from the results of the first experiment with individually-housed rats. Pair-housed Ss from small cages were less immobile than those from the other two conditions.

Discussion

The results of Experiment 2 differ from those in Experiment 1, thus confirming the predictions of

Latanē & Walton (1972). Socially isolated rats do appear to be more responsive, or sensitive, to their cage environment than pair-housed animals. However the explanation of these results awaits further investigation.

General Discussion

There are several methodological differences between these two experiments: strain and age of Ss, length of the time-sample and thus the test period, group size, and the area per S in the cage environment. Also, the lack of space, cages and Ss prevented the inclusion of both housing conditions in the same study and consequently inter-group comparison. Even so, it appears that the weak spatial effect reported by Morrison (1968) for isolated rats may have been due to the differing cage and field sizes. If this is the correct interpretation the cage-field size effect would be masked in most open-field studies in which either circular or square fields much larger than the usual cage dimensions of individually-housed Ss are used.

Experimental procedures for the two studies are not really equivalent in that the second procedure confounds social and spatial variables. However if size familiarity accounts for the results of Experiment 1, it should still hold in the second case, the field being less novel for the Ss from the large cages.

This question is further explored in Chapter 6, using an apparatus designed to provide a choice for

Ss from the different cage conditions to move between these three spaces.

TABLE 2.1

Median 3-sec observations seen in corner, wall and inner squares; median scores on the four activity measures; results of Kruskal-Wallis H and Mann-Whitney U tests.

Measure	Cage Size			H	p
	Small (N=5)	Medium (N=5)	Large (N=5)		
Corner	73+	64+	46+	9.6	0.009
Wall	26	28	43+	9.4	0.009
Inner	0+	8	11	7.2	0.01
Squares entered	49+	72+	101+	10.1	0.009
Ambulation	30+	41	43	8.3	0.009
Immobility	58+	40+	19+	12.0	0.009
Rearing	11+	21+	30+	10.1	0.009

+ : differs significantly from all groups ($p < 0.05$, Mann-Whitney U test). Other comparisons not significant.

TABLE 2.2

Median 5-sec observations seen in corner, wall and inner squares; median scores on the four activity measures; results of Kruskal-Wallis H and Mann-Whitney U tests.

Measure	Cage Size			H	p
	Small (N=6)	Medium (N=6)	Large (N=6)		
Corner	62	54	58	3.1	NS
Wall	46	48	49	0.8	NS
Inner	11	15	12	2.5	NS
Squares entered	169	167	143	2.1	NS
Ambulation	52	60	59	4.8	NS
Immobility	12+	20	17	7.4	0.05
Rearing	46	38	41	1.2	NS

+ : differs significantly from all groups ($p < 0.05$, Mann-Whitney U test). Other comparisons not significant.

CHAPTER THREE

SOCIAL ISOLATION AT WEANING: SOME EFFECTS ON TWO MEASURES OF ACTIVITY[+]

[+]The results of this study are reported in Animal Learning and Behavior, 1973 (in press).

C H A P T E R T H R E E

Introduction

The study described here investigates another aspect of the housing literature reviewed in the previous chapter: the age at which housing conditions are introduced. Bronfenbrenner (1968) suggests that the effects of stimulus deprivation are negatively related to the age at which such deprivation occurs. The present experiment was designed primarily to determine the effect of imposing different housing conditions at weaning rather than at some later time.

In contrast to Archer (1969) who isolated female rats at 40 days of age and compared their activity with that of grouped animals 24 weeks later, this study uses female rats isolated at weaning and tests them after the same period in comparison with control-grouped and crowded Ss. Adrenal weights, as a supplementary index of social stress (Schnürer, 1963; Barnett, 1964) were obtained after three and six months. Two measures of activity are used. Locomotor activity was observed in the open field while non-specific general activity was measured on an activity platform. This provides a test of the prevalent assumption (Baumeister, Hawkins & Cromwell, 1964) that the different methods can be regarded as equivalent when comparisons of activity studies are made.

Subjects

The Ss were 74 female hooded rats (N.Z.B.W.S.) weaned and differentially housed at 23 days of age. Twenty-six rats were isolated in cages measuring 18 x 18 x 18 cm, while six groups of 8 Ss each were housed in cages measuring 75 x 45 x 33 cm high. Food and water were freely available and the animals were maintained on a reversed light-dark schedule from 7 pm to 7 am. Cages were cleaned once a week and the animals were not otherwise handled.

Apparatus

Two measures of activity were obtained in this study: locomotor and non-specific general activity. The first measure was obtained in an open field of dimensions 60 x 60 x 20 cm. The floor of this was marked out into 15 x 15 cm squares. Illumination was provided by a 22-W fluorescent lamp suspended 75 cm above the field. The other measure of activity was obtained using a similarly illuminated Lafayette A501 activity platform. A wooden box painted brown and measuring 30 x 30 x 20 cm high was placed on the platform, the area of which was 30 x 30 cm. A wire gauze lid fitted the top of the box. This was painted white on the underside and black on the top of the gauze to minimize distraction from the experimenter when entering the room. The platform was suspended on its four corners by rubber mounts which transferred gross activity to the centre of

the platform where a photo sensing unit produced an output proportional to animal movement. An amplifier, with a sensitivity control set throughout the testing at 5 (the middle of the range) was of integrated circuit design. The output from this operated a relay, the contacts of which were used to operate a Lafayette activity counter, which was situated 2 m from the apparatus. All testing occurred between 9 am and 4.30 pm, and approximately 40 db of white noise provided an auditory masking background during this time.

Procedure

At 120 days of age (about 14 weeks after differential caging) 6 Ss from each cage condition were weighed, sacrificed and their adrenal glands were removed and weighed to the nearest mg. Because it was considered desirable to test all Ss directly from their home cage to avoid socially isolating the group-housed animals before testing, the grouped Ss were re-housed in easily transportable cages at this stage. Although this meant that some of the grouped animals were placed in the room for a short time before testing, this was thought preferable to the social isolation of each group member in a small strange holding cage, where this did not occur for the "real" isolates. It was considered that either all or none of the Ss should be subjected to the chosen procedure. Three groups of 7 Ss each were caged in crowded conditions in cages measuring 30 x 30 x 20 cm high and another two groups of 7 Ss were housed in cages

measuring 50 x 35 x 30 cm high (control). Re-housing of Ss thus necessitated the removal of 7 animals from the experiment.

When the Ss were 190 days old, and had been in their respective cage conditions for a further 10 weeks, six isolated and six crowded animals were weighed, then sacrificed and the adrenal glands were removed and weighed to the nearest mg. One crowded S was discarded from the experiment at this point. It was not considered necessary to sample control adrenal weights at this stage since there is no evidence to suggest that the isolate-control adrenal weight relation would be dissimilar at 24 weeks to that found at 14 weeks of differential housing (Hatch et al, 1965; Sigg, Day & Colombo, 1966).

Adrenal weight has been reported to increase as a function of population density (Christian, 1959). Thus it was of interest for the present study to determine whether a reduction of living space per animal would reduce the expected adrenal-weight difference at 14 weeks. Activity measures were obtained for these "crowded" Ss to determine the effect of this space manipulation.

Three groups of 7 Ss from the three cage conditions (isolated, control-grouped, and crowded) were tested in the open field, the number of squares crossed by the hind legs of each rat during a 10-min period being recorded. The other, as yet untested, three groups of Ss (isolated, control-grouped, and crowded) were tested on the activity platform for 5 min each.

Results

Kruskal-Wallis one-way analyses of variance followed by Mann-Whitney U tests were applied to the behavioural data. The results for the two activity measures obtained by the three groups of Ss in the open field (number of squares crossed) and on the activity platform are summarised in Table 3.1 and the relationships between these in Figure 3.1.

In the open field both isolated and crowded Ss crossed significantly more squares during the 10-min test period than did the control-grouped animals, while there was no significant difference between the two groups. Using the activity platform the crowded rats were significantly more active than the control-grouped Ss but were not significantly more active than the isolates. There was no significant difference between the isolated and control-grouped animals on this activity measure.

Table 3.2 shows the body and adrenal weights measured when the Ss were aged 120 and 190 days. The t' test for unequal population variances (Winer, 1962) was used for these physical measures, because of the marked differences in the standard errors and small sample sizes. After 14 weeks of differential housing the mean relative weight (i.e. the ratio of organ weight to body weight) of the adrenals of the isolated Ss was significantly heavier than that of the control group-housed Ss, as was also the absolute weight of these organs.

Ten weeks later the isolated rats still had heavier adrenals (relative and absolute weights) than those of the grouped-crowded animals, although the difference was not a significant one. There was no significant change in the absolute weights of these organs between the two periods for either isolated or grouped-crowded Ss. After 14 weeks of differential housing the mean body weight of the isolated Ss was significantly greater than that of the group-housed control Ss. After 24 weeks differential housing (10 weeks for crowded rats) there were no significant differences in the body weights of the isolated and grouped-crowded Ss.

Discussion

The results show that the introduction of differential housing conditions at weaning rather than at 40 days of age produces activity differences in the opposite direction to those found by Archer (1969); isolated female rats were more active than control-grouped animals in the open field. In that isolated rats are supposed to show greater emotionality and diminished exploratory behaviour in such a novel test situation (Archer 1970) this is an interesting result. There may be another explanation; that it takes a far longer time for social isolation to affect the activity of rats as opposed to mice. For example, Sigg, Day & Colombo (1966) have found that isolation-induced aggressiveness (which is a behavioural manifestation of the "isolation syndrome" described by Hatch et al, 1965)

develops in mice and rats housed individually for three weeks and three to six months respectively. Previous studies finding isolates to be more active than group-housed animals have all used mice as Ss (e.g. Essman, 1966; Weltman, Sackler & Sparber, 1966). This question is further investigated in the next chapter.

When animals from the control-grouped and isolated housing conditions were tested on the activity platform this activity difference between isolated and control-grouped Ss did not occur, suggesting that locomotor rather than spontaneous or "restless" motor activity was affected by the lack of stimulation afforded by social isolation. But this argument does not account for activity changes resulting from increasing social density within the cage environment. Rather it emphasizes the methodological limitations of directly comparing two disparate measures of activity in socially-stressed groups which may be interpreted in entirely different ways.

The adrenal weight differences illustrate the differing susceptibility of female rats to isolation (Hatch et al, 1965) and grouping (Thiessen, 1964b). Although the grouped-crowded Ss did not show a significant adrenal response over the last 10 weeks these animals exhibited a high degree of "restless" activity. Syme (1971) has shown that crowded female rats consistently reared more and were immobile less often than isolated or control-grouped Ss in the open field. In accordance with Prescott (1970) this behaviour pattern could

produce a relatively higher level of restless activity using the activity platform. Therefore which measure is chosen for housing studies, spontaneous activity (e.g. Essman, 1966) or locomotor activity (e.g. Archer, 1969) may influence the results obtained.

At this point the possibility of disturbed oestrus function must be raised since, as Figure 3.1 shows, both activity measures were high for the grouped-crowded Ss. Pseudopregnancy (the temporary suspension of oestrus) may be density dependent (for review, see Thiessen, 1964b, pp. 289-292) and would be manifest by high activity levels (Munn, 1950).

The significance of the adrenal measures may be questioned because of the positive relationship between body and adrenal weights (Angervall, 1959; Angervall & Carlström, 1963). However it is interesting to note that Hatch et al (1965) found the body weights of isolated female rats (13 weeks) to be significantly less than those of grouped animals while relative adrenal weights were significantly greater. No reason can be given for the direction of the weight difference found in the present study, although this has been reported for isolated and group-housed male rats (24 weeks) by Sigg, Day & Colombo (1966).

Hahn (1965) suggests that such weight differences as observed by Hatch et al (1965) may be an artifact of differences in food intake rather than a measure of differential physiological adaptation to a stressful condition in that Harlow (1932) observed rats fed in a

group to ingest significantly more food than rats fed alone. This would explain the observation by Hatch et al (1965) that the individually caged rat grows more slowly than the group-housed animal.

The crucial factor may be the distribution of food in the cage environment. Hoyenga & Aeschleman (1969) suggest that food pellets placed on the floor of the cage may become contaminated by faecal boli and urine and thus unpalatable to the group-housed Ss. In the present study food was distributed in this manner and isolated Ss were found to be heavier than group-housed animals. No information is provided about food provision methods in the studies previously cited (Hatch et al, 1965; Sigg, Day & Colombo, 1966). However, Hoyenga & Aeschleman (1969) placed food in bins on the outside of cages and found social facilitation of feeding activity under ad libitum conditions, whereas Shelley (1965), using identical conditions apart from the scattering of food on the cage floor, reported social inhibition of feeding.

Replication of the present study would obviously be desirable, with the addition of appropriate controls at 14 and 24 weeks (see Table 3.2) and male Ss. However, even with these preliminary results, it seems reasonable to conclude that unless social density studies impose housing conditions at an identical age and use the same measure of activity direct comparison between results obtained should not be considered.

TABLE 3.1

Median activity scores for isolated, control and crowded female rats in both the open field (number of squares crossed) and the activity platform; results of Kruskal-Wallis H and Mann-Whitney U tests.

	Density				
	Isolated (N=7)	Control (N=7)	Crowded (N=7)	H	p
Open field	182+	130	181+	4.0	NS
Activity platform	800	764	890+	7.1	0.05

+ : differs significantly from the control group ($p < 0.05$, Mann-Whitney U test); other comparisons not significant.

TABLE 3.2

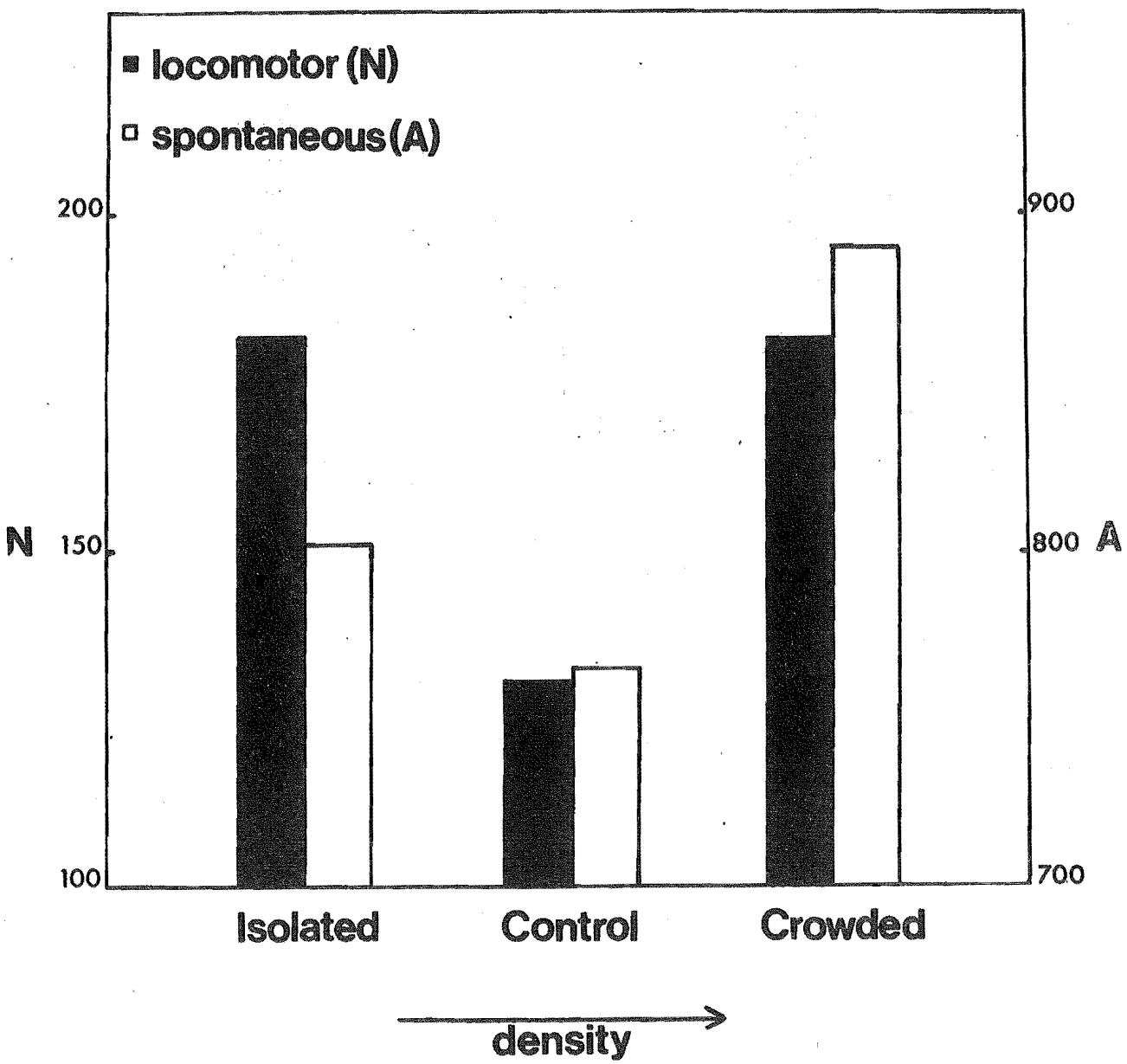
Mean body and adrenal (absolute and relative) weights obtained after 14 weeks and 24 weeks in the different cage conditions (10 weeks for the crowded subjects).

Measure	Cage groups			p
	Isolated (N=6)	Control (N=6)	Crowded (N=6)	
Body (g) ± S.E.				
14 weeks	162±2.95	149±2.38		0.05
24 weeks	181±4.63		179±2.57	NS
Adrenal (mg) ± S.E.				
14 weeks	48.16±2.18	39.66±1.69		0.01
24 weeks	45.17±1.62		40.16±2.09	NS
Adrenal (mg/100g body wt. ±S.E.)				
14 weeks	31.62±1.56	27.42±0.85		0.05
24 weeks	25.07±1.23		22.40±3.34	NS

Differences established by the t' test.

FIGURE 3.1

Relationship between locomotor (N) and non-specific general "spontaneous" activity (A) exhibited by Ss in the open field and on the activity platform.



CHAPTER FOUR

SPURIOUS SPECIES COMPARISONS IN HOUSING STUDIES USING LABORATORY RATS AND MICE[+]

[+]The results of this study are reported in Psychological Reports, 1973, 33, 507-510.

C H A P T E R F O U R

Introduction

Although the differing open-field behaviour of laboratory rats and mice has been documented (Collins, 1966; Candland & Nagy, 1969) this appears to be overlooked in many studies concerned with the effects of social and spatial characteristics of the cage environment on the activity of the two species in novel test situations. Whereas socially isolated mice have been found more active than group-housed animals within one day of weaning (Essman, 1966) the results of Chapter 3 suggest that it may take from three to six months for rats to be similarly affected. Physiological evidence (Sigg, Day & Colombo, 1966) provides support for this hypothesis.

In a recent review of this literature Archer (1970) states that "most of the laboratory investigations have compared small fixed-number groups of rats or mice with isolates. The typical procedure is to house the animals differentially for a period of time and then to test their activity levels, usually in an open-field situation. Conflicting results have been reported." While some studies show that social isolation reduces activity (Stern et al, 1960; Thiessen, 1964a; Moyer & Korn, 1965; Archer, 1969) others describe increases in activity (Essman, 1966; Weltman, Sackler & Sparber, 1966). In a review of studies concerned with population density and behaviour Thiessen (1964b) also comments on these discrepant findings, saying that "it is not always clear

whether the change due to grouping reflects an increase or decrease in .. emotional and aggressive responses." He quotes studies by Stern et al (1960) who used rats. and by Thiessen & Rodgers (1961), Thiessen, Zolman & Rodgers (1962), Thiessen (1963) and Thiessen (1964a) who used mice as Ss.

Discussing these "discrepant findings regarding the differential effects of isolation and aggregation upon activity levels in rodents" and quoting studies with rats by Stern et al (1960), Myers & Fox (1963), Zimbardo & Montgomery (1957) and Woods (1959), and some with mice by Gunn & Gurd (1940), Chance (1946, 1947), Essman (1966) suggests a number of possible contributing variables, all of which have, since his study, been investigated. These are quoted in the introduction to Chapter 2. However the question has still not been resolved and the "conflict" appears to provide a legitimate problem for further study.

When the literature is classified into studies using rats and those using mice a species difference in the behavioural response to social isolation emerges. Whereas isolated mice are either more or less active than their group-housed counterparts, only with six months isolation have rats ever been found to be more active than group-housed Ss (Chapter 3). Also, since these animals were female the activity difference could well have been due to the state of oestrus produced by the unfavourable housing conditions (Thiessen, 1964b)

The present study was concerned with the possibility that accepted species comparisons in studies investigating the effects of housing conditions on later activity are, in fact, spurious.

Investigations of repeated measures of open-field activity in young rats and mice (21 - 50 days) show differing trends. While the activity of rats increases (Bronstein, 1972), although a drop in activity on the second trial has been reported (Valle, 1971), that of mice decreases (Candland & Nagy, 1969; Dixon & DeFries, 1971). Defaecation, which is supposed to bear an inverse relation to activity in open-field measures of "emotionality" (Hall, 1934) also shows an opposite trend over repeated trials, increasing for mice and decreasing for rats (Candland & Nagy, 1969).

One study which obtained repeated locomotor activity measures in young mice and found isolated Ss to be more active than those housed in groups of five (Essman, 1966) also reported a decreased trend in activity for aggregated mice while the isolates maintained a level within the range shown in the first few trials. Thus this measure of activity showed a similar trend to the longitudinal open-field studies with mice, discussed previously.

If the housing variable produces general activity differences any apparatus measuring activity should demonstrate these over comparable time periods. If this is not the case a closer examination is required of the specific behavioural consequences of differential

housing. In Chapter 3 isolated and grouped rats were used, and the activity platform apparatus was found to yield a more conservative activity difference for the two conditions than the open-field measure, i.e. Type I errors were minimised. Accordingly the present study employed this same apparatus for isolated and pair-housed rats to test the generality of (1) repeated open-field measures of activity in young rats, and (2) previous studies with rats finding group-housed Ss to be more active in the open field than isolates, when a measure of non-specific general activity is used over a number of consecutive trials.

Subjects

The Ss were 12 male hooded rats (N.Z.B.W.S.) weaned at 25 days of age and then housed individually or in pairs (not littermates) in cages measuring 18 x 18 x 18 cm. These were cleaned once a week and the animals were not otherwise handled. Food and water were freely available and the Ss were maintained on a reversed light-dark schedule from 7 pm to 7 am, as they had been since parturition.

Apparatus

This was the activity platform described in the previous chapter. The apparatus was situated 50 cm from a 22-W fluorescent lamp providing a low ambient level of illumination.

Procedure

At 26 days of age and for 13 consecutive days thereafter each S was placed on the activity platform for 5 min. Testing was carried out between 9 am and 12 am; approximately 40 db of white noise provided an auditory masking background during this time. Ss from the two housing conditions were tested alternately to control for time-of-day effects.

Results

The mean activity counts recorded per day for the isolated and paired rats are shown for each of the 14 testing days in Figure 4.1. A repeated-measures analysis of variance confirmed the effect of the different cage conditions upon activity; pair-housed Ss were always more active than isolates (F = 188.8; df = 1/10; $p < 0.001$). The trend of increasing activity over the 14 testing days was also significant (F = 7.4; df = 13/130; $p < 0.01$) as was the interaction between days and caging (F = 6.5; df = 13/130; $p < 0.01$). This showed that activity increased with repeated testing.

Discussion

Several methodological differences appear to preclude generalisation from these results to those of Essman (1966): group size, weaning age, the number of days testing, and the activity measure used. However the present findings are consistent with previous studies using (1) repeated activity measures with young rats, and

(2) rats housed in groups of 5 (Archer, 1969) to 15 animals (Stern et al, 1960) which have shown grouped rats to be more active than isolates. Conversely, pair-housed mice have been found less active than isolates (Weltman et al, 1966).

The early activity drop from an initially high level has also been noted by Valle (1971) and Essman (1966). This may be a reaction to the novelty of the test apparatus or perhaps, as Essman suggests, related to the recent change in housing conditions at weaning; though this does not apply for Valle's study.

Comparisons between activity measures obtained in three experimental settings (Essman's activity box, open field, activity platform) seem justified when similar trends are observed with repeated testing. The present findings do concur with those reported for young rats in the open field. Moreover, repeated open-field tests with mice confirm the negative trend in Essman's data (Dixon & DeFries, 1968).

General Conclusion

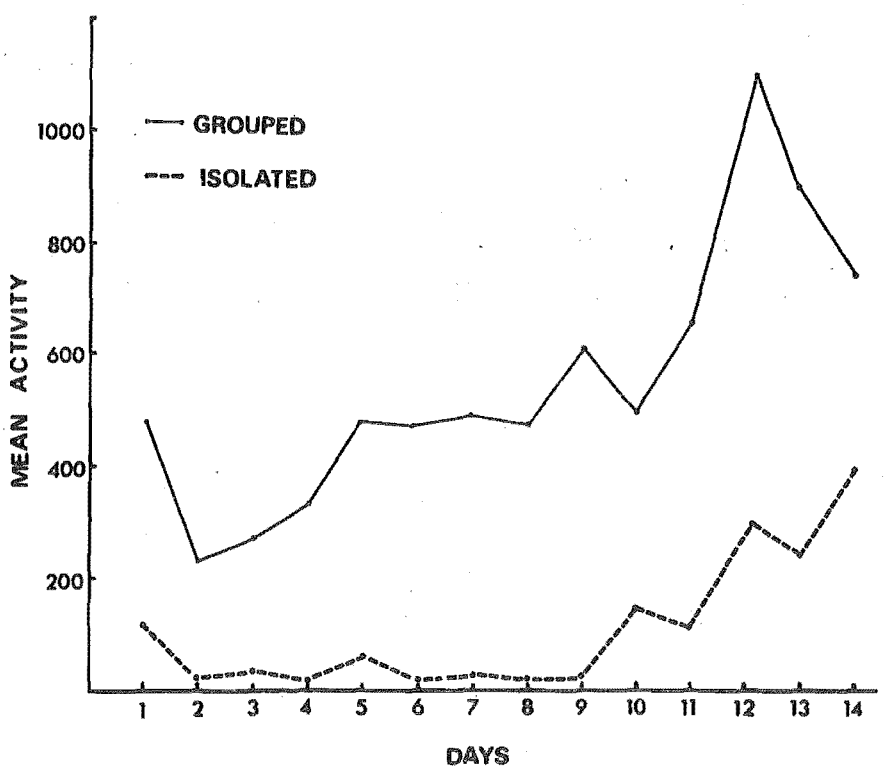
This study was not planned to demonstrate a qualitative difference in the response to social isolation by laboratory rats and mice. Rather, future knowledge of such housing effects may be evaluated more coherently if, meanwhile, the two species are considered separately.

The real purpose of the study was to provide some respectable "experimental padding" to a methodological point which is not made clear in the literature.

Since it took this author a considerable period to clarify the question of species specificity in the behavioural response to social isolation, it seemed reasonable to warn other prospective investigators of the ambiguous nature of much of the housing literature.

FIGURE 4.1

Mean activity counts recorded per day for isolated and pair-housed rats.



C H A P T E R F I V E

S Y N O P S I S

C H A P T E R F I V E

The evidence from the first three studies suggests that there are a number of deficiencies within the existing housing literature. Chapter 2 illustrates the relevance of spatial variables for both housing and open-field studies. Chapter 3 demonstrates the importance of equating age and activity measures before comparing studies, while Chapter 4 extends this methodological point to the practice of generalising not only between different housing conditions, sexes, ages, and measures but between studies using laboratory rats and mice.

All these results show that methodological, procedural, statistical, genetic and social standardisation (and validation) have not, so far, been achieved. Such factors could well account for the high proportion of contradictory findings in this area. A cautionary note should be sounded by these considerations for those authors (e.g. Thiessen, 1964b) who have tried to extrapolate from cage studies, such as those reported here, to theories of population dynamics. Such environmental extrapolation may be as misleading as inappropriate species comparisons. The unisexual group of domesticated rats is no more nor less than this and it may be more helpful to fully explore the effects of common laboratory environmental manipulations before propounding grand theories.

The last two chapters in Part 1 represent an attempt to apply the principles of housing studies to two established areas of investigation: exploration (e.g. Berlyne, 1950) and activity restriction (e.g. Lore, 1968). A further discussion of these studies will be presented in Chapter 8.

C H A P T E R S I X

S P A T I A L C H O I C E

C H A P T E R S I X

Introduction

Chapter 2 demonstrates one way in which cage dimensions can influence the behaviour of young socially-isolated male rats. In this situation the open field may be viewed as providing a choice to the Ss moving within the confined space, in that the animals can either restrict movement to a familiar range (as did the isolates) or move over the whole area irrespective of their home-cage dimensions (as with the pair-housed Ss).

If the rats were given the opportunity to move between a familiar and unfamiliar space, current theories of exploratory behaviour would predict (1) some positive relationship between area and time-spent-exploring (Montgomery, 1951; Broadhurst, 1957) and (2) Ss to spend more time in the more novel space (Berlyne, 1950) - this effect disappearing for animals habituated to the apparatus before testing.

Morrison (1968) found rats housed individually in large cages (18.0 x 14.5 x 9.0 in) to be less emotional than those housed individually in small cages (6.7 x 9.5 x 6.7 in). The difference, however, was not statistically significant. Although there was no paired condition in the small cages, animals caged alone in large cages were more emotional than those housed in pairs. It was suggested that this behavioural difference between the isolates housed in small and large cages could reflect a spatial effect due to the similarity in dimensions

between the large cage and the open field (45 x 45 x 24 in).

The experiment described in Chapter 2 was designed to test this hypothesis using small (15 x 15 x 10 cm), medium (30 x 30 x 20 cm) and large (60 x 60 x 40 cm) cages and an open field of identical dimensions and construction to the large cages. Whereas a positive relationship was found between cage size and movement for socially isolated Ss, this did not occur for pair-housed rats.

If these Ss were habituated to the open field before testing, theories of exploration would predict no behavioural difference between isolated rats reared in the small, medium and large cages, as was the case for the non-habituated pair-housed Ss. Accordingly the present study utilized two groups of isolated rats which were either habituated or not habituated to the experimental spatial-choice apparatus, and a control group of non-habituated Ss which had previously (Chapter 2) shown no spatial-choice behaviour.

The experiment described here was designed to distinguish between two interpretations of spatial-choice behaviour: preference for novelty (Berlyne, 1950) or preference for familiarity (Morrison, 1968).

Subjects

The Ss were 60 male hooded rats (N.Z.B.W.S.) weaned and housed differentially at 25 days of age. The cages used were of identical construction to those

described in Chapter 2 and measured 15 x 15 x 10 cm (small), 30 x 30 x 20 cm (medium), or 60 x 60 x 40 cm (large). Fourteen Ss were placed alone in the small cages, while three pairs were housed similarly. The same procedure was followed for Ss in the medium and large cages. Food and water were freely available and the animals were maintained on a reversed light-dark schedule from 7 pm to 7 am. Cages were cleaned once a week and the Ss were not otherwise handled.

Apparatus

The apparatus consisted of three boxes of identical size, construction and colour as the cages housing the Ss (S - small, M - medium, L - large). However in opposite walls of each of these a 5 x 5 cm square was cut out in the middle of the bottom edge, so that a rat could run through adjacent boxes. The squares of wood removed were retained so that the boxes could be fitted together in three combinations: A (S - M - L); B (S - L - M); and C (M - S - L). These combinations are shown in Figure 6.1.

Wire gauze lids could be placed over the top of these boxes during testing. These were painted white underneath and black on top to minimize external distraction. Two 22-W fluorescent lamps were suspended 1 m above the apparatus to illuminate the three boxes equally. The observer sat on a high stool looking over and down on the apparatus and manipulated two stop clocks - one for each of the outside boxes. Time spent in the middle box was obtained from the total time registered on each clock

and the time left in the 600-sec test period.

Procedure

Before testing began each S in one individually-housed group was habituated for 10 min in the three combinations of the apparatus: A, B, and C. Thus the three treatment groups in this study were: (1) individually-housed and habituated to the apparatus, (2) individually-housed but not habituated to the apparatus, and (3) pair-housed and not habituated to the apparatus. The rationale for this choice of Ss is presented in the introduction. The order of testing was arranged in an incomplete block design (Cox, 1958). This ensured that, over each of the three testing days, each S was tested in a different apparatus combination.

When the Ss were 40 days old they were each observed, as described above, in each condition for a 10-min test period. Nine "time" measures were thus obtained for each S, three for each box size in each order. The Ss were placed straight from their home cage into the middle box of the apparatus for all testing.

Results

Table 6.1a,b,c shows the means and variability of times spent by the three groups of Ss in the three apparatus combinations - A,B,C - giving a total of 81 scores.

The areas of the three boxes were in the ratio of 1 : 4 : 16, so that the expected occupancy in terms

of area alone may be expressed as S = 29 sec, M = 114 sec, and L = 457 sec. Underlined means in Table 6.1 refer to those occasions on which observed values were less than, or equal to, those expected. For both small and medium boxes the times are always greater than expected on the area basis while, for the large box, the values are always less. It thus seemed reasonable, for the purpose of further analysis, to treat the choice between the three apparatus components as occuring with equal probability ($p = \frac{1}{3}$).

For every S in each condition a preference was defined as that size box occupied for the longest time. The resultant frequencies were subjected to a series of Chi square tests. Table 6.2a,b,c shows the composition and results of these tests, while Table 6.3 shows the relative frequencies of preferences made when the apparatus combination presented contained the S's home-cage size as the middle component in the box order e.g. combination (S - M - L) for Ss from medium cages. Only the small box was chosen significantly more often (that is, the S spent significantly more time in it) when in this position.

In all cases Ss spent significantly less time in the medium box than in the other two components; in six of the nine possible test conditions this was statistically significant. On two of the remaining conditions there was a nonsignificant tendency for this to occur. In the remaining case a significant Chi square value was caused by a tendency for the large-

cage pair-housed Ss to prefer the large component. Overall, there was a very high preference against the medium box; irrespective of the significance of the individual Chi squares, this occurred over all nine conditions with a probability $\underline{p} = \frac{1}{3}^{9}$.

Discussion

Because the expected time/area relation is clearly not reflected in the data the simplest form of analysis was used. The symmetry of the apparatus required only two position preferences of Ss: in, or not in, the middle box - which, in turn, was the same or of different dimensions to the home cage. A more complex and informative sequential analysis would have been possible if an infinite chain of different sized boxes were used thus always providing two choices between components. In this way a probabilistic model of spatial choice could be developed. However, even the simple spatial model presented by this experiment raises important methodological questions.

The time - area relationship

The lack of a relationship between area and time spent in each novel box component is contrary to the predictions of several studies (Montgomery, 1951; Broadhurst, 1957). Assumption of equal choice probability simplifies the analysis, although with the present apparatus some bias still exists since the Ss in the middle box component are presented with two choices, while Ss in

the outside boxes are allowed only one.

Spatial preference

For each S in each condition a preference was defined for a particular component if the animal spent more time in it than in either of the other two boxes. Frequencies of these preferences were then subjected to a Chi square analysis with the assumption of a random distribution of the choices made. Significant values appear to be determined by the choice against the medium box (in either position) or, conversely, for the small and large boxes. This effect over-rides all others in the data, and is not predicted by any of the hypotheses advanced earlier.

There was little difference in the total number of preferences shown for small (75) and large (90) box components, while that for the medium box was considerably less (15).

Only one significant Chi square value seems to have been caused by a home-cage size effect. Pair-housed Ss from large cages preferred the large box. Even so, this result is contrary to the predictions of Chapter 2, where spatial-choice behaviour was only exhibited by individually-housed animals.

Habituation

As stated in the introduction to this study, habituation to the apparatus might be expected to lower the preference behaviour shown in the experimental situation (Berlyne, 1950). Reference to Table 6.2a and Table 6.2b

reveals little difference in the pattern of choice behaviour shown by individually-housed habituated and non-habituated Ss.

Novelty

This is partly an area problem, in that the largest area may provide to greatest amount of novel stimulation. To quote Broadhurst (1957) " - the larger arena .. caused an increase, rather than a decrease, in ambulation .. it is clear that we are dealing with an aspect of exploratory drive - a larger arena causing more ambulation. Montgomery's finding (1951) that the amount of exploration done by rats increased with the size of the maze, and is proportional to the total area, is comparable." Exploration theory does not generally include considerations of cage dimensions or social conditions. However in the present context Ss did not spend proportionately greater time in the largest area, in fact the opposite was true. On the basis of expected times, Ss spent the most time in the smallest space.

Small and large box components may perhaps be regarded as more "novel" than the medium enclosure in that Ss could touch the roof of the former and explore a very large area in the latter. Conversely, the medium box may present the ideal area; neither so small as to be confining nor so large as to be aversive. Whether the manifest behaviour in this apparatus should be regarded as preference or aversion remains to be answered.

It is of interest here that when the small box component was situated in the middle condition (C) the Ss

spent significantly more time in it than when it was situated on either side. A possible interpretation of this finding is that the two choices available to the S placed first in the small (middle) box may be aversive in terms of the relatively large spaces on either side of S. However a novelty interpretation would predict that the animal would spend the least time in the small centre box since the two choices presented incorporate the maximum quantity of novel stimuli.

TABLE 6.1a

Means and standard deviations of the times spent (sec) by the 60 Ss in the small, medium and large box components of the apparatus arranged in three combinations A (S - M - L), B (S - L - M) and C (M - S - L).

INDIVIDUALLY-HOUSED HABITUATED Ss

Apparatus Combination	Caging (N=7)	Apparatus Box Size: Small	Medium	Large
A	S	194.0±79.5	138.3±55.1	267.7±118.2
	M	234.6±84.3	161.6±44.1	203.6±65.1
	L	237.8±115.8	140.3±73.1	221.8±117.1
B	S	180.7±61.3	136.4±42.3	254.3±120.7
	M	248.1±105.8	124.7±28.9	200.5±62.1
	L	194.5±106.2	198.1±153.2	239.3±122.6
C	S	221.7±73.9	149.5±51.4	229.0±72.9
	M	220.0±82.1	156.4±41.5	220.4±62.8
	L	222.4±105.6	156.9±66.7	220.7±79.0

TABLE 6.1b

INDIVIDUALLY-HOUSED NON-HABITUATED Ss

Apparatus Combination	Caging (N=7)	Apparatus Box Size: Small	Medium	Large
A	S	217.8±17.3	206.3±19.5	175.8±27.6
	M	199.9±53.7	185.5±22.4	214.4±55.1
	L	199.3±53.1	197.3±16.7	203.4±59.4
B	S	193.8±47.6	162.3±33.6	243.8±34.3
	M	167.3±33.7	164.0±35.9	268.7±40.4
	L	190.7±27.6	161.3±21.9	248.0±17.4
C	S	209.0±66.5	154.5±25.3	236.4±48.7
	M	260.3±49.9	120.4±36.7	219.3±20.5
	L	325.7±67.7	181.1±94.8	142.3±63.5

TABLE 6.1c

PAIR-HOUSED NON-HABITUATED Ss

Apparatus Combination	Caging (N=6)	Apparatus Box Size: Small	Medium	Large
A	S	159.8±47.9	183.4±18.2	256.8±56.4
	M	200.2±53.3	194.0±38.8	205.3±28.2
	L	122.3±9.7	187.3±20.2	290.3±28.2
B	S	234.2±95.6	160.2±30.9	205.6±71.9
	M	257.6±60.2	153.0±30.4	189.3±39.7
	L	135.3±35.0	215.8±50.2	248.8±44.8
C	S	312.8±77.7	136.8±31.7	238.3±106.9
	M	226.3±79.1	144.8±41.9	228.8±63.1
	L	237.0±42.5	152.3±22.4	210.6±38.4

TABLE 6.2a

Number of preferences shown for each size box component over all experimental conditions and associated probabilities for each cage condition.
INDIVIDUALLY-HOUSED HABITUATED Ss (N=7 per cell)

Cage Size	Centre Area	Apparatus Box Size (Number of Preferences) Small	Medium	Large	χ^2 (df=2)
	M	1	1	5	
SMALL	L	2	-	5	
	S	4	1	2	
		7	2	12	7.10^{+}
	M	3	1	3	
MEDIUM	L	3	-	4	
	S	3	-	4	
		9	1	11	8.00^{++}
	M	3	1	3	
LARGE	L	5	1	1	
	S	3	1	3	
		11	3	7	4.33

+ : p<0.05
++ : p<0.02 (Chi square test)
+++: p<0.01

TABLE 6.2b

INDIVIDUALLY-HOUSED NON-HABITUATED Ss

Cage Size	Centre Area	Apparatus Box Size (Number of Preferences) Small	Medium	Large	χ^2 (df=2)
	M	4	2	1	
SMALL	L	2	-	5	
	S	2	-	5	
		8	2	11	6.00^{+}
	M	4	-	3	
MEDIUM	L	-	1	6	
	S	6	-	1	
		10	1	10	7.77^{+}
	M	3	1	3	
LARGE	L	1	-	6	
	S	7	-	-	
		11	1	9	8.00^{++}

Symbols as in Table 6.2a.

TABLE 6.2c

PAIR-HOUSED NON-HABITUATED Ss (N=6 per cell)

Cage Size	Centre Area	Apparatus Box Size (Number of Preferences) Small	Medium	Large	χ^2 (df=2)
	M	1	-	5	
SMALL	L	2	-	4	
	S	5	-	1	
		8	-	10	9.33^{+++}
	M	1	2	3	
MEDIUM	L	4	-	2	
	S	2	-	4	
		7	2	9	4.61
	M	-	-	6	
LARGE	L	-	3	3	
	S	4	-	2	
		4	3	11	6.33^{+}

Symbols as in Table 6.2a.

TABLE 6.3

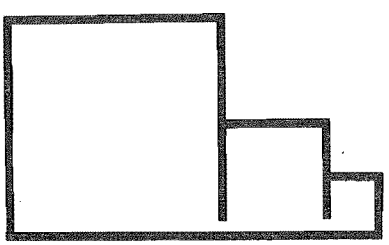
The relative frequencies of preferences made by all Ss when the box components were placed in the middlecondition versus to one side in the three combinations A, B and C.

Apparatus Component	Position		χ^2
	Centre	Side	(df=1)
Small	36	39	7.26^{++}
Medium	8	7	2.4
Large	36	54	1.8

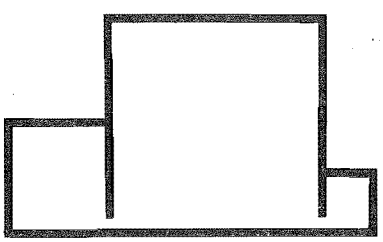
++ : $p < 0.01$ (Chi square test).

FIGURE 6.1

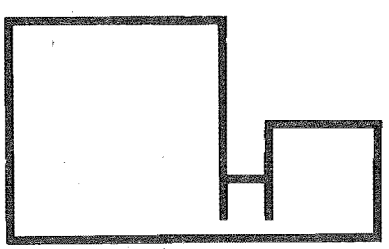
A diagrammatic representation of the three combinations of the box components (S - small, M - medium, L - large) of the spatial choice apparatus : A, B and C.



A



B



C

CHAPTER SEVEN

INFLUENCE OF AGE AND SEX ON SOME BEHAVIOURAL CONSEQUENCES OF SELECTIVE ACTIVITY RESTRICTION

C H A P T E R S E V E N

Introduction

"The important fact to be borne in mind is that the combined factors of developmental history and environmental context alone are often sufficient to reduce the range of behavioral potentials, a reduction that does not necessarily involve anatomico-physiological factors; it is a reduction of plasticity in the formation of new patterns without any need for reference to mythical pre-determined neural organization."

Kuo (1967) pp. 174 - 175

Although spatial behaviour has been investigated in Chapters 2 and 6 using only young male rats, this was a matter of circumstance rather than desire. The experiment described here uses both immature and mature rats of either sex to determine the effects of restricting a specific response (rearing up on the hind legs) both before and after its full development in the animals' behavioural repertoire.

Behavioural consequences of such activity restriction have considerable relevance to the practice of intensive animal husbandry (Ewbank, 1969). However few studies have systematically studied such effects, particularly within a developmental context. Laboratory restriction studies using domesticated rodents have generally been concerned either with justifying the existence of an autonomous drive or need for animals to be active (for reviews, see Baumeister, Hawkins & Cromwell, 1964; Lore, 1968), or with distinguishing between maturational versus learned components of exploratory

activity (e.g. Baron, Antonitis & Schell, 1962) or general ontogenetic development (for review, see Bronfenbrenner, 1968). Little experimental evidence is available concerning: the specific kinds of activity that are eliminated by a given confinement procedure, sex differences in the response to confinement, and the age at which confinement is imposed.

The rearing response is particularly suitable for examination of the effects of restriction since the experimental procedure (lowering the cage roof) allows the Ss to remain with their cagemates, thus avoiding the habitual confounding of social isolation and confinement (Lore, 1968). Restriction can also be imposed before and after the full development of the rearing response, permitting the investigation of two hypotheses proposed by Bronfenbrenner (1968): (1) early stimulus deprivation of a particular modality leads to impairment of function in that modality later in life, and (2) the later in life the stimulus deprivation occurs, the less severe the impairment of function. In this context initial sex differences in the prepotency of the rearing response (Hughes & Swanberg, 1970; Masur, 1972) are also of interest.

Subjects

The Ss were 28 male and 26 female hooded rats (N.Z.B.W.S.). For 14 animals of either sex experimental housing conditions were imposed at 50 days of age (7 rats per cage for each condition). The other 12 females and

14 male rats were housed selectively (6 or 7 Ss per cage for each condition) when weaned at 25 days of age. Food and water were provided ad lib. and the animals were maintained on a reversed light-dark schedule from 7 pm to 7 am. Cages were cleaned once a week and the animals were not otherwise handled. Control Ss were housed in cages measuring 75 x 45 x 33 cm high, while the restricted-rearing cages measured 75 x 45 x 8 cm high. These were constructed of wood with wire-mesh comprising the front wall and roof.

Apparatus

The open field used for testing the Ss measured 60 x 60 x 15 cm and the floor of this was marked out into 15 x 15 cm squares. The apparatus was painted black with the lines dividing the floor painted white. Illumination was provided by a 22-W fluorescent lamp suspended 75 cm above the centre of the field and white masking noise of approximately 40 db was used throughout testing.

Procedure

Two alternatives were available: either the Ss were kept for varying lengths of time in their respective cage conditions and tested at the same age, or they were kept the same time in their cage conditions and tested at different ages. The second alternative was chosen since there is no firm evidence showing rats aged between 80 and 110 days to behave differently in

the open field (Candland & Nagy, 1969). Thus after 8 weeks in their different cage conditions the Ss (aged either 81 or 106 days) were observed for 10 min in the open field.

Each rat was placed in a corner of the field and every 5th sec its position in a corner, wall or inner square was noted, and if it was ambulating (time spent walking), rearing up on the hind legs (with or without support from the walls of the apparatus), grooming, or remaining immobile. Total numbers of lines crossed by the hind legs of the S over the 10-min period was also recorded.

Results

Although it would have been consistent with the analysis employed in the open-field experiments of Chapter 2 to use non-parametric statistics, the complexity of the present design and the desirability of gaining information about interactions between variables prompted the adoption of factorial techniques.

Because of the unequal group sizes (faulty sexing resulted in three of the young restricted males being discarded from the experiment within two days of caging) a 2 x 2 x 2 unweighted-means analysis of variance (Winer, 1962) was performed on each behavioural category and on the position-preference measures. Significant main effects were found only on the grooming measure, while all first and second (except squares entered) order interaction terms were significant beyond the 0.01 level.

The large number of significant second-order interactions reflects the interdependence of the three factors: age at caging, sex, and housing. Consequently, to clarify the nature of these interactions, t-tests were used to provide an overall comparison between means.

Table 7.1 shows the mean scores and variability for all groups of Ss on the different measures, while Table 7.2 presents a summary of first and second-order interactions. Table 7.3 shows the calculated t-test values. Because of the inter-relationships between some measures (e.g. inner/corner-square occupancy, unsupported/supported rearing) not all possible individual tests were performed.

Table 7.3 reveals that the majority of significant t values occurred on four measures: inner-square occupancy, squares entered, total rearing and unsupported rearing. These effects are represented in Figures 7.1 to 7.4.

Effects of restriction on "emotionality"

Behavioural indices reported to reflect "emotionality" in the open-field test situation include low inner-square occupancy and a small number of squares crossed (Archer, 1973). Using these criteria the results of this experiment suggest that (1) restricted animals were more "emotional" than controls (Figures 7.1 and 7.2), (2) Ss restricted before the full development of the rearing response were more "emotional"

than Ss restricted at 50 days of age (e.g. Figure 7.1), and (3) females of both ages were more "emotional" than males in their response to restriction (Figures 7.1 and 7.2).

Effects of restriction on rearing behaviour

Figure 7.3 shows that both male and female rats deprived of rearing experience before the full development of the response reared significantly less than control Ss in the open field. This was also true for animals restricted at 50 days of age, but the difference was not significant.

Figure 7.4 illustrates a sex difference in the response to restriction. Whereas the mean unsupported rearing scores of restricted females were significantly lower than controls, this difference was not significant for the two male groups. As with the other measures (inner-square occupancy, squares crossed and total rearing) the effect appeared greater for the female Ss restricted at 25 days of age.

Discussion

Overall, from the observed position preferences and activity data, restricted Ss were more "emotional" than unrestricted animals. This accords with one interpretation of activity-restriction studies (Lore, 1968). However both the age (developmental stage) and sex of the Ss determined the extent of this reaction to confinement. This finding leads to a consideration of

Bronfenbrenner's hypothesis stated in the introduction to the present study. Early deprivation of rearing behaviour (25 days) resulted in the impairment of function later in life (81 days). Figures 7.3 and 7.4 show that this effect was less marked for the Ss deprived of rearing behaviour after the full development of this response (50 days) - which confirms the second hypothesis.

Sex differences in the response to confinement are of interest, since female rats have been shown to rear more than males (Hughes & Swanberg, 1970; Masur, 1972). The present findings suggest that female Ss were affected more than male Ss by the selective restriction procedure, in terms of both "emotionality" (e.g. Figure 7.2) and the incidence of later rearing behaviour (e.g. Figure 7.4).

The distinction between supported and unsupported rearing is important in this context. From the developmental point of view one might expect unsupported rearing to be affected more than supported rearing, since the former condition requires a greater degree of physical coordination and, perhaps, practice. Previous studies of rearing behaviour have not distinguished between these two rearing positions, using either climbing behaviour in restricted mice (Baron, Antonitis & Schell, 1962) or a rearing incentive (Russell & Pihl, 1973). One study has used perceptual restriction only to manipulate rearing behaviour (Holland, Gupta & Weldon, 1966) but with ambiguous results. Had a physical restriction procedure been adopted in a control group,

more useful information could have been obtained.

One finding of all three quoted studies, with respect to the nature of restriction effects, is that the physical manifestations are only temporary. Perhaps the simplest explanation is that animals restricted before they have had the opportunity to practise rearing behaviour find the unrestricted novel open-field environment more aversive than those Ss familiar with the rearing response before confinement. The influence on the unsupported rearing of the two groups of Ss (restricted pre-rearing or post-rearing) reinforces this interpretation. Figure 7.4 shows that the pre-rearing confined group reared considerably less than the post-rearing group, while this distinction does not appear for the total-rearing scores shown in Figure 7.3. In terms of Kuo's "behavioral potentials" (Kuo, 1967) one might say that the resultant rearing is lower since the original potential was lowered for the pre-rearing confined Ss (25 days). However, for the females, the rearing potential was originally higher and thus the "emotional" response to restriction greater. This approach contrasts with theories of drive suppression (e.g. Bronfenbrenner, 1968) which might predict a greater rearing response by females following restriction. After all, these Ss had ample opportunity to exercise in the restricted cage environment and should not have been physically deprived in terms of, for example, muscle development.

The main difference between the present study and Kuo's relates to our knowledge of the functional significance of the behaviour in question, the "potential"

of which is reduced by experimental manipulation. In Kuo's case, mynah birds were brought up in an environmental context which did not require a flying response. However many birds could fly when chased by a dog. This situation is most closely followed by Holland, Gupta & Weldon (1966) who obscured either the upper or lower portion of the cage setting with paper so that the S rats were obliged to either rear, or not rear, in order to obtain environmental "stimulation" outside the cage setting ie. to look out. However, knowledge of the development and function of rearing activity in laboratory rats is not as advanced as that of flying in free-range birds, and further speculation will be left to the reader.

FIGURE 7.1

Effects of selective housing conditions imposed pre-rearing (25 days of age) or post-rearing (50 days of age) on the mean inner square occupancy of restricted (■) and control (□) subjects. ($^{+}p < 0.05$, $^{++}p < 0.01$, t-test)

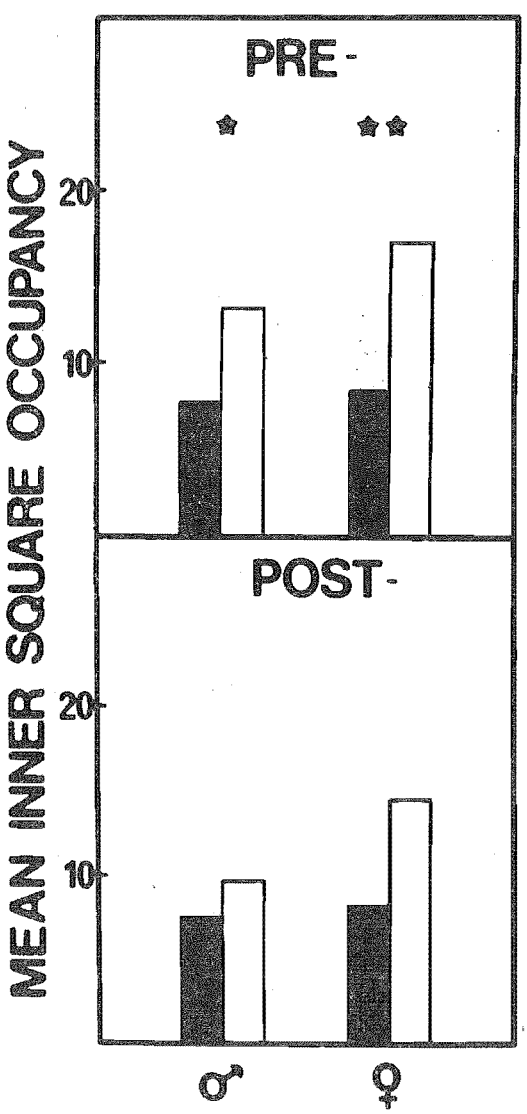


FIGURE 7.2

Effects of selective housing conditions imposed pre-rearing (25 days of age) or post-rearing (50 days of age) on the mean number of squares traversed in the open field by restricted (■) and control (□) subjects.
($^{+}p < 0.05$, $^{++}p < 0.01$, t-test)

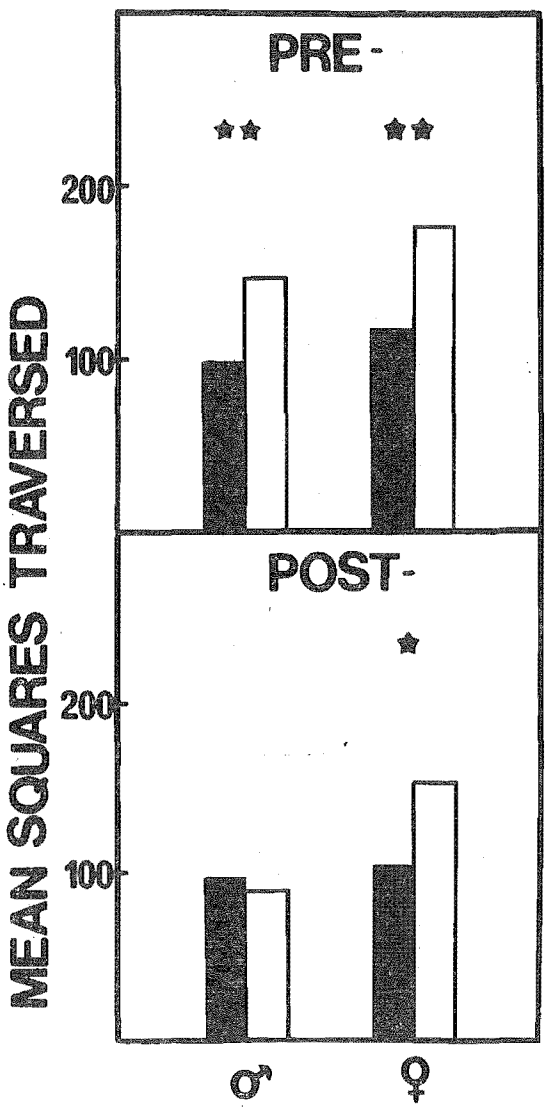


FIGURE 7.3

Effects of selective housing conditions imposed pre-rearing (25 days of age) or post-rearing (50 days of age) on the mean total rearing of restricted (■) and control (□) subjects. ($^{+}p < 0.05$, $^{++}p < 0.01$, t-test)

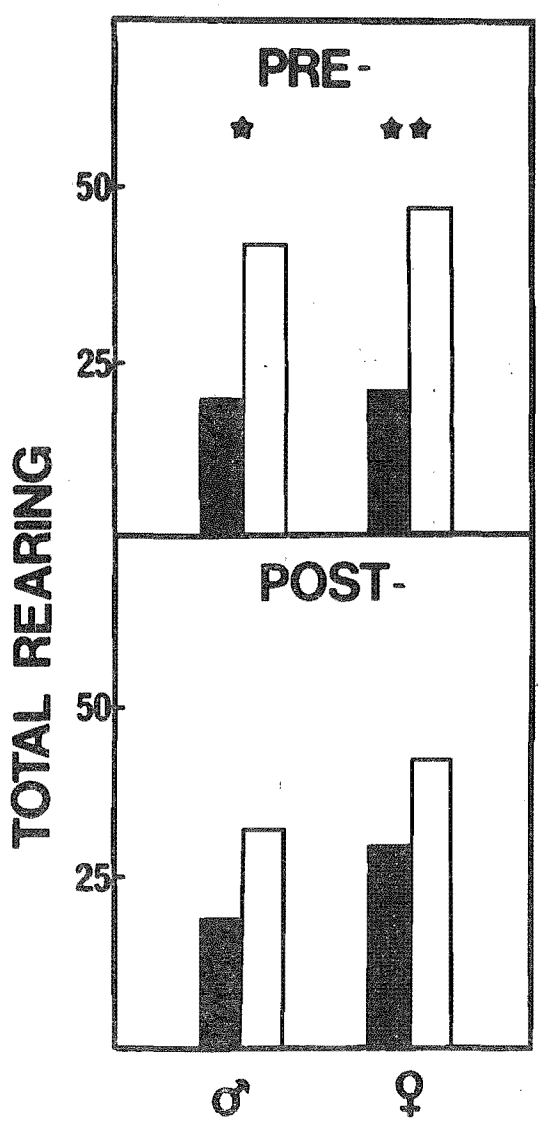


FIGURE 7.4

Effects of selective housing conditions imposed pre-rearing (25 days of age) or post-rearing (50 days of age) on the mean unsupported rearing of restricted (■) and control (□) subjects.
($^{+}p < 0.05$, $^{++}p < 0.01$, t-test)

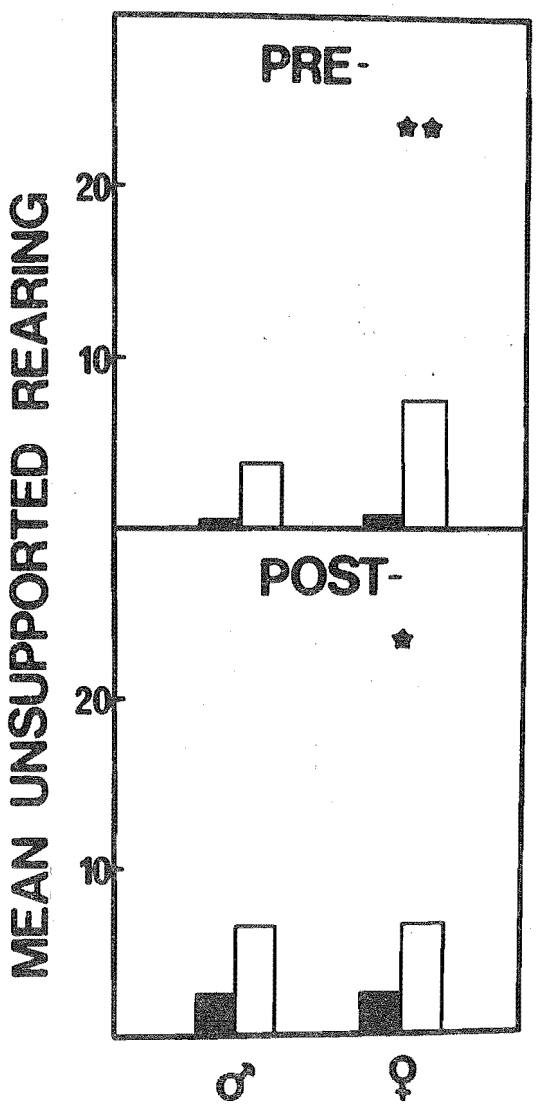


TABLE 7.1a

Mean scores (± S.E.) for all groups on each measure

Caging	Age at Caging	Sex	N	MEASURE			
				Inner Square Occupancy	Rearing Supported	Rearing Unsupported	Total Rearing
RESTRICTED	25 days	M	4	7.5±2.2	18.7±7.9	1.7±1.0	20.5±7.6
		F	6	8.2±1.5	20.3±5.2	2.0±0.9	22.3±5.3
	50 days	M	7	7.4±1.5	11.5±1.1	5.1±1.8	16.7±2.4
		F	7	8.0±1.4	25.0±5.0	4.4±1.9	29.3±5.1
UNRESTRICTED	25 days	M	7	13.1±2.4	34.8±3.9	7.7±2.0	42.6±4.4
		F	6	16.8±1.1	32.5±2.2	14.6±2.6	47.2±2.0
	50 days	M	7	9.7±1.7	18.5±3.4	13.0±3.7	31.5±8.2
		F	7	14.0±2.3	28.7±3.6	13.7±2.8	42.3±5.0

TABLE 7.1b

Mean scores (± S.E.) for all groups on each measure

Caging	Age at Caging	Sex	N	MEASURE			
				Squares Entered	Ambulation	Immobility	Grooming
RESTRICTED	25 days	M	4	99.0±13.2	37.5±6.5	53.5±14.1	8.5±2.1
		F	6	117.8±14.4	46.8±3.7	31.2±7.2	19.6±6.1
	50 days	M	7	92.0±10.1	47.7±5.4	38.7±4.7	16.8±3.1
		F	7	105.1±8.2	39.4±3.5	38.0±6.0	13.0±3.6
UNRESTRICTED	25 days	M	7	144.5±15.4	52.7±3.4	19.1±4.4	5.5±0.7
		F	6	175.6±7.2	57.1±4.3	9.0±1.2	6.6±3.0
	50 days	M	7	94.5±18.4	35.8±6.1	44.7±12.2	7.7±3.7
		F	7	150.1±12.9	49.0±3.4	21.5±6.0	7.0±2.0

TABLE 7.2

A summary of the analyses of variance for each measure. A - sex, B - age, C - caging. First and second order interactions are presented.

	F				
MEASURE	A x B	A x C	B x C	A x B x C	df
Corner Occupancy	149.6^{++}	152.5^{++}	153.6^{++}	318.6^{++}	1,43
Wall -	102.0^{++}	100.3^{++}	102.1^{++}	211.5^{++}	1,43
Inner -	43.3^{++}	44.6^{++}	44.0^{++}	95.8^{++}	1,43
Total Rearing	47.6^{++}	48.7^{++}	48.6^{++}	105.2^{++}	1,43
Supported -	36.7^{++}	34.7^{++}	35.6^{++}	76.8^{++}	1,43
Unsupported -	14.2^{++}	17.8^{++}	17.2^{++}	43.5^{++}	1,43
Squares Entered	7.8^{+}	7.7^{+}	7.7^{+}	2.6	1,43
Ambulation	7.7^{+}	7.6^{+}	7.6^{+}	15.4^{++}	1,43
Immobility	25.9^{++}	28.5^{++}	28.3^{++}	71.4^{++}	1,43
Grooming	116.5^{++}	113.0^{++}	146.6^{++}	526.5^{++}	1,43

$^{+}p < 0.01$, $^{++}p < 0.001$

TABLE 7.3

Values of *t* tests calculated between group means over the six behavioural measures. F - female, M - male, R - restricted, C - control/unrestricted, 25 or 50 - caged selectively at 25 or 50 days of age, $^{+}p < 0.05$, $^{++}p < 0.01$.

Comparisons Between Group Means	MEASURES					
	Inner Square Occupancy	Squares Entered	Ambulation	Total Rearing	Unsupported Rearing	Grooming
FR25 - MR25	0.23	0.84	1.37	0.21	0.23	1.71
FR50 - MR50	0.16	0.92	1.32	2.09	0.25	0.81
FC25 - MC25	1.22	3.56^{++}	0.83	0.87	2.03	0.36
FC50 - MC50	1.42	2.27^{+}	1.90	1.06	0.14	0.19
MR25 - MR50	0.02	0.44	1.36	0.60	1.42	2.18
MC25 - MC50	1.09	2.48^{+}	2.45^{+}	1.11	1.18	0.54
FR25 - FR50	0.09	0.76	1.50	0.81	1.02	0.99
FC25 - FC50	0.97	1.58	1.56	1.11	0.22	0.09
MC25 - MR25	2.50^{+}	3.50^{++}	2.30^{+}	2.79^{+}	0.88	1.96
FC25 - FR25	3.97^{++}	3.34^{++}	1.84	4.09^{++}	4.34^{++}	1.94
MC50 - MR50	0.42	0.11	1.47	1.64	1.76	1.94
FC50 - FR50	2.09	2.78^{+}	1.96	1.71	2.58^{+}	1.49
MR25 - FC25	3.72^{++}	5.06^{++}	2.72^{+}	3.60^{++}	3.31^{++}	0.46
FR25 - MC25	1.56	1.19	1.20	2.81^{+}	0.97	2.57^{+}
MR50 - FC50	0.93	1.40	0.21	4.34^{++}	2.46^{+}	2.70^{+}
FR50 - MC50	0.76	0.49	0.52	0.22	1.91	1.04

C H A P T E R E I G H T

C O N S P E C T U S

C H A P T E R E I G H T

Perhaps the best way to view the experiments described in Chapters 2 to 7 is as a series of ideas, each with a common theme but independently conceived. While useful results were obtained the primary outcome was dissatisfaction. Several sources of this will be discussed.

(1) Facilities

It may be noted, in the experiments previously described, that both the numbers and strains of Ss used vary widely, as do also the age of these at weaning and their sex. Under ideal conditions these changes would be avoided.

Because there was insufficient room in the Animal House for the large cages used in Chapters 2 and 6, Ss were housed in a room situated beside the "tea room" and beneath a mathematician's office. The first location was the scene of a rhythmic disturbance signalled by a tuneful banging with a teaspoon on the fire bell outside the door of the improvised animal house. This central situation, and the lack of a door lock, encouraged not only the disappearing-apparatus trick (stop clocks and other small, but useful items) but also a certain lack of control over intruders and friendly visitors. Quite apart from these homely troubles, considerable time was spent by the author and a kind technician attempting to block the heating

vents with Sellotape in order to discourage the rising of hot air from rats to irate mathematician, upon stern admonishment and instruction from the Authority. These factors combined led the author to banish the prospect of further housing studies.

(2) Methods

This encompassed the growing realisation throughout the studies of Part 1 of this thesis of the unsatisfactory nature of testing individual Ss in the hope of discovering the effects of different home environments; a practice employed in many animal studies (e.g. Woods, 1959; Stern et al, 1960; Thiessen, Zolman & Rodgers, 1962; Myers & Fox, 1963; Thiessen, 1964; Essman, 1966; Archer, 1969; Syme, 1971; Bell et al, 1971). The problem is discussed by Syme & Syme (1973) with reference to the prolific work of Latané et al who remove Ss from the majority of their cagemates in order to discover the effects of social cage conditions on the subsequent sociability behaviour towards unfamiliar animals.

Such considerations precipitated the conclusion that "housing" studies may be confounding the response to a novel environment (test) with the effects of social disruption caused by the removal of Ss from the home-cage group. It was thought more realistic to maintain, or systematically disrupt, group stability to assess the efficacy of the test employed here - the open field.

(3) Frustration

If spatial parameters are considered important for housing studies (i.e. space per animal allocated in the cage environment) they should be examined carefully. The results of Chapter 2 indicate that spatial dimensions of the cage may affect the open-field behaviour of young, socially-isolated male rats, but not that of pair-housed Ss. Further investigation of this effect is required using older Ss, different strains and species, female Ss, and different sized cages, for example, with the same roof height. An interesting variation might be to use both round and square cages of different areas and to test Ss in both round and square fields - ensuring that every cage condition is tested in every field condition. But for the shortage of space etc. this would have been attempted here along with an investigation of the effects of complexity, or quality of space, in both cage and test environments.

Chapter 6 describes one attempt to manipulate spatial parameters. Besides the problems raised for theories of exploration, the results provide little information about the origins of "spatial choice" behaviour. The next step in these studies was the construction of an "expander box" which, although ordered and designed at the beginning of 1972 and nearly completed at the beginning of 1973 (promised for October, 1972) has still not been wrestled from the maker's grasp at the time of writing this thesis. However, if interest arises, the dimensions and mechanics of this

apparatus may be obtained from Mr. D.O. Watson at the University of Canterbury Psychology Department, in whose files the secrets lie.

The "expander box" apparatus was to be based on the dimensions of the medium box component used in the apparatus of Chapter 6 - which measured 30 x 30 x 20 cm. However one wall was to be attached in such a way to a runner-pulley system that the movement of the wall in either direction (in - out) was controlled by the S rat. Two manipulations were envisaged: (1) the wall came inwards in about 4-cm steps and S worked the "out" lever situated on the opposite wall to keep the approaching wall at the desired distance, and (2) S worked two levers -"in" and "out" - to find the desired space. Two or more Ss placed in the box for some time could have produced interesting results. Since the top was to be constructed of perspex a video-tape record of Ss' movement could have been obtained and a variety of exciting prospects explored. However according to the droll principle of "it won't work so why bother" which pervades many stimulating academic pursuits, the apparatus remains unfinished.

The "expander box" idea was derived from the work of Creed & Ferster (1972) who reported, from the performance of two pigeons, that access to space could act as an effective reinforcer. Since, in Chapter 6, the medium box component was found to be the least popular (in terms of occupancy-time) in the spatial-choice apparatus, this size was chosen as the basis for

the "expander box." It was supposed that this choice of box size might act as an incentive for S to push the wall out or, conversely, to bring it in. A minimum distance of about 15 cm was to be allowed from levers to approaching-receding wall, while the maximum distance would have been about 60 cm. Thus the common taunt "squash box" was unwarranted. Excluding tail length, the average mature domesticated rat would certainly have remained intact in this apparatus.

A recent study (Joffe, Rawson & Mulick, 1973) has found young rats allowed to control the incidence of food, water and light in the cage environment (from birth) to be less "emotional" upon testing at about 60 days of age than Ss not allowed this "contingent environment." However, when the Ss were raised in this self-administered environment from weaning only, no differences in open-field behaviour were found between "contingent" and "non-contingent" Ss. This suggests some developmental influence upon the effect; also that it would have been interesting to raise rat pups in the "expander box" and compare the later behaviour of these animals with those placed in the apparatus at weaning. This would provide a fruitful addition to the results quoted above.

(4) Measures

The experiment described in Chapter 3 would have been improved with the use of more Ss, and both sexes. However, in this context, it is notable that

knowledge of the behaviour of domesticated female animals (e.g. cows) is generally more relevant than that of males, which have traditionally been the subject of animal social research (e.g. aggression and "dominance" studies). The small sample sizes of the studies described in Chapter 2 (plus strain and age differences) were also a matter of circumstance. However it is probably better to use available resources (Ss, cages etc.) and obtain useful, though slightly untidy results (e.g. age differences at weaning and caging) than no results at all. For instance, comparisons of studies in the literature are quite acceptable when far greater procedural discrepancies exist. At least the present studies can, perhaps, serve as a stimulus for further research effort.

This point also applies to the use of the activity platform in Chapter 3 to provide an alternative record of "spontaneous" activity for the purposes of comparison with open-field data. Apart from seeking reassurances from the manufacturer as to the influence of weight differences on the data recorded, the validity of the measure was assumed. This weight-activity variable was especially important for the experiment described in Chapter 4, which also used the activity platform. Although the content of this study may be considered a pedantic and trivial argument (probably with some justification) the repeated-measures data and the two social cage conditions should provide a useful addition to the housing and repeated-measures open-field literature.

The study described in Chapter 7 is essentially independent of those preceeding it, except that a different spatial dimension, roof height, is manipulated. It is also a housing study since the Ss, in contrast to most confinement procedures, were kept in a social environment. But the developmental implications of this experiment are of greater interest, as too are sex differences observed in the response to the selective confinement.

General Limitations

Comments made in this chapter should be construed as an apology for inconsistencies and poor experimental design rather than as specific complaints about facilities. Undoubtedly few students ever obtain the facilities they would like to have. The author realises, however, that these limitations are particularly important for the specific area chosen for investigation.

Each study in Part 1 required more Ss, conditions, strains, and greater attention to sex differences in the response to housing and test settings. Whereas Chapter 2 could well have used female Ss, Chapter 3 should be repeated with males. Although some studies (e.g. Weltman et al, 1968; Archer, 1969) do use only female Ss, the possibility of disturbed oestrus function, and thus activity measures, cannot be discounted. However, as mentioned previously, in the application of housing studies to practical situations

(e.g. agriculture) females are probably the more important sex'.

Chapter 4 is essentially a "thought or digression; Chapter 6 an excursion into apparatus design and Chapter 7 a result of an idea fostered by observation of rats competing for food at high and low positions (Syme, 1972). This study is also concerned with social disruption. In this case however, an attempt is made to overcome the problems inherent in the interpretation of many earlier restriction studies which confound social isolation and confinement of Ss in small cages.

Thus the outcome of Part 1 was not only dissatisfaction but a realisation that the testing of animals isolated from the stable cage group was an unsound practice in terms of social stress, however popular and acceptable (e.g. operant methods, avoidance techniques, learning/maze experiments, open-field "emotionality" etc.). One situation where this could be of practical importance is pharmacological testing, where Ss are usually maintained in group conditions (particularly mice) but tested alone using gross activity measures.

Accordingly the four studies described in Part 2 of this thesis try to establish whether the earlier complaints about social limitations in test procedures can be substantiated with empirical data. This question is further discussed in Chapter 9 (the introduction to Part 2) and Chapter 14 (a general review of the methods and results of studies described in Part 2).

CHAPTER NINE

INTRODUCTION

TO

PART TWO

"Experimental behavioural studies with psychotropic drugs are carried out usually in individual animals which are taken out of their normal social environment. On the contrary, in human therapeutic use psychotropic drugs are administered to persons who are always involved in certain social interactions and the aim of the psychiatric therapy is often the improvement and normalization of social contactability of the patient. Therefore, it seems very necessary to study the effect of a new psychotropic drug on social behaviour of animals for improving the predictive value of animal studies for clinical use."

Tikal & Benešová (1972)

Part 1 of this thesis was concerned with the manipulation of a number of housing parameters using individual responsiveness as the dependent variable. Similarly the majority of pharmacological studies utilizing behavioural techniques have been concerned with the response of individual animals to psychotropic drugs using a variety of automatic devices to provide measures of gross activity which are further subjected to a battery of sophisticated parametric statistical tests. "It is ironic that, of all the procedures that comprise a screening program, these are the most critical, yet the least standardized, most highly individualized, and most vulnerable to environmental factors" (Kinnard & Watzman, 1966, p. 995).

Kršiak & Borgesová (1972) also criticise this approach, which arbitrarily selects a few responses only from the total repertoire and tends to ignore the social complexity of behaviour. Reasons given for the neglect of more realistic observational techniques

include : their subjective nature and thus unreliability, the tendency to fall asleep while watching the animals, and the time needed to use such methods.

Chapters 11, 12 and 13 of this thesis present a photographic technique which not only answers these criticisms but also provides a way of testing larger groups of animals and standardising social conditions in the cage, post-injection and test environments. This is an extension of the observational method used by Tikal & Benešovâ (1972), which is described in Chapter 11, and involves the measurement of inter-subject distance in a group of animals moving within an open field. Variables investigated include: sex, familiarity with the test environment and other animals in the group, group size, and the shape of the field. Drugs used are lithium chloride, methamphetamine and chlorpromazine - all of which have previously been studied in a social context.

Firstly, however, the study described in Chapter 10 uses the much maligned (p. 9 - 1) automatic activity device (the activity platform, see p. 3 - 2) to determine the possible influence of social variables for studies investigating the action of lithium chloride on artificially-induced aggressive and hyperactive behaviour. Pairs of male rats are tested alone or in pairs in the apparatus. The finding that lithium chloride may act as a depressant in otherwise untreated subjects and lessens the responsiveness to the experimental setting, leads to a further investigation of this substance using

both sexes and a larger group of subjects in a study described in Chapter 11.

CHAPTER TEN

EFFECTS OF LITHIUM CHLORIDE ON THE ACTIVITY OF RATS TESTED ALONE OR IN PAIRS[+]

[+]The results of this study are reported in Psychopharmacologia (Berl.), 1973, 29, 85-89.

C H A P T E R T E N

Introduction

Lithium salts are used for the treatment of manic behaviour and as a prophylactic against manic-depressive disorder (for review, see Schou, 1968). The therapeutic effect on psychotic excitement was discovered by Cade (1949) who, among other things, reported that guinea-pigs injected with lithium carbonate "although fully conscious, became extremely lethargic and unresponsive to stimuli for one to two hours before once again becoming normally active and timid."

Two aspects of animal behaviour, aggressive responses and drug-induced hyperactivity, have provided the basis for recent research into the effects of lithium on laboratory rodents in controlled experimental situations. In this context, however, little evidence is available concerning the behavioural consequences of the substance for animals which have not been subjected to extraneous manipulations prior to drug administration.

Weischer (1969) found that experimentally-induced aggression in mice and hamsters was decreased by the addition of lithium chloride to the drinking water. Sheard (1970a) reported that chronic administration of lithium chloride over five days inhibited foot-shock aggression in rats, and in another study (Sheard, 1970b), that chronic lithium administration inhibited both the sexual and aggressive

behaviour of animals pre-treated with p-chlorophenyl-alanine.

Several studies have demonstrated effects of the lithium ion on drug-induced hyperactivity. D'Encarnacao & Anderson (1970) reported a potentiation of amphetamine-induced hyperactivity, while Cox, Harrison-Read, Steinberg & Tomkiewicz (1971) showed that lithium reduced dexamphetamine-amylobarbitone/chlordiazepoxide-induced hyperactivity. Carroll & Sharp (1971) obtained similar lithium-induced activity reduction using morphine sulphate.

Johnson & Wormington (1972), investigating the effects of lithium on otherwise untreated animals, reported a depression of rearing activity which was greatest 20 min after injection, when either 5, 20 or 60-min intervals elapsed before testing. In the course of their studies both D'Encarnacao & Anderson (1970) and Cox et al (1971) have, while establishing their control conditions, also compared the effects of lithium on the spontaneous motor activity of otherwise untreated rats. The latter study reports that "the results with acute lithium .. seem to indicate that .. lithium does not have any marked depressant effect on the spontaneous activity of rats unless the animals have been made hyperactive." This conclusion seems to be supported by D'Encarnacao & Anderson who found little difference in activity between lithium and saline-treated animals 1 h after drug administration. In contrast Sheard (1970b), whilst observing a decrease in

both sexual and aggressive behaviour 3 h after drug administration in lithium-treated animals, also recorded a considerable increase in "resting" behaviour. Sheard provides one possible interpretation of this decrease in social reactivity, reporting that "the lithium-treated animals are less reactive to the test situation - animals rest more and appear more sedated." Although this tranquilizing effect may only occur in animals treated with p-chlorophenylalanine, Sheard's results could also represent the effect of lithium on the responsiveness to the environment within a social testing situation. If this is the case it may be desirable for lithium research to seek a generalised effect on social behaviour rather than a specific influence of this drug upon complex social interactions such as aggression.

This study investigates whether the effects of lithium on spontaneous activity are potentiated by an interaction with social test conditions. Two variables included in the design are firstly, the social setting in which the results of lithium administration are observed, and secondly the length of the time period following injection.

Subjects

The Ss were 128 male rats (N.Z.B.W.S.) weighing 200 - 250 g at the time of the experiment. These were housed in groups of 6 - 8 animals in cages measuring 0.75 x 0.33 x 0.45 m high and maintained on

a reversed light-dark schedule from 7pm to 7am. Food and water were freely available.

Apparatus

Testing was carried out between 10am and 2pm on the activity platform described in Chapter 3, using standard room illumination and 40 db white masking noise. For the purposes of using this apparatus in the present study, a personal communication from the manufacturers was obtained with assurance that a weight range of 200-250 g should not be reflected linearly in the magnitude of the recorded activity score at the sensitivity setting used (the middle of the range). A further control for weight differences of Ss tested in the apparatus alone or in pairs was provided in the data analysis. Here the activity scores for 16 single Ss were randomly summed in pairs so that scores for paired animals represented those for two rats tested alone or together in the apparatus.

Procedure

The Ss received either 3 meq/kg of lithium chloride (LiCl, isotonic solution) or the same amount of isotonic saline, injected intraperitoneally. Sixty-four rats were injected with lithium chloride. Thirty-two of these Ss were placed individually in 18 x 18 x 18 cm holding cages. The remaining Ss were paired randomly and placed in identical cages. After 20 min 16 of the individually-caged Ss were placed

alone on the activity platform for 5 min, after which time the apparatus was switched off and the score read from the attached counter. Between each test the floor of the box was wiped with a damp cloth. The same number of paired Ss (eight pairs) were then tested with their cagemates; each pair was placed on the activity platform together for the 5-min test period. The remaining 16 individual and 8 paired Ss were tested 3 h after drug administration. For the saline control Ss the same procedure was followed.

Results

The recorded activities of animals tested individually over the two drug and injection-time conditions were paired randomly and combined so that the scores entered into the resultant three-way analysis of variance represented those for pairs of rats tested alone or together. Mean activity scores for the eight experimental groups are summarised in Table 10.1 and the relations between these in Figure 10.1.

Significant drug ($F = 134$; $df = 1/56$; $p < 0.001$) and social-testing ($F = 5$; $df = 1/56$; $p < 0.05$) main effects were obtained. However these will be discussed in terms of the significant interactions: drug x injection time ($F = 14$; $df = 1/56$; $p < 0.01$), drug x social test condition ($F = 6$; $df = 1/56$; $p < 0.05$), and injection-time x social test condition ($F = 7$; $df = 1/56$; $p < 0.05$). Individual t-tests revealed only five significant

differences between groups; three of these are shown in Figure 10.1, i.e. Ss receiving 3 meq/kg lithium chloride were significantly less active than those receiving saline for both 20-min post-injection conditions (t^{*}_{alone}= 12.76, $p < 0.001$; t_{pairs}= 4.88, $p < 0.001$). However this was only recorded for the Ss tested in pairs 3 h after injection (t_{alone}= 2.08, $p > 0.05$; t_{pairs}= 3.82, $p < 0.01$).

Whereas no significant difference was observed between the activities of lithium-treated rats tested alone 20 min or 3 h after injection (t = 1.86, $p > 0.05$) individually-tested saline Ss were significantly less active after 3 h than after 20 min (t = 7.5, $p < 0.001$). However there was little difference in the activity scores recorded for the pair-tested saline (t = 0.02, $p > 0.05$) and lithium Ss (t = 1.24, $p > 0.05$). For the 3-h post-injection condition there was no difference in the activity of lithium-treated Ss tested alone or in pairs (t = 0.07, $p > 0.05$) while the saline controls tested alone were significantly less active than Ss tested in pairs (t = 3.59, $p < 0.01$).

Discussion

In contrast to the results of two previous studies (D'Encarnacao & Anderson, 1970; Cox et al, 1971) lithium was found to inhibit the activity of individually-tested Ss after 3 h. Also, in finding

* : for all t-tests df = 14

the marked effect on activity by lithium after 20 min one may question the interpretation of results obtained by Johnson & Wormington (1972), who found that rearing behaviour was decreased 20 min after injection of either 2, 4, or 8 meq/kg lithium chloride and suggested that this inhibition could represent the lessening of exploratory behaviour by their Ss. A simpler explanation may be that activity, in general, was depressed rather than any selective component of the animals' behaviour.

Lithium-treated Ss were found to be more active 3 h after injection than after 20 min. Observed physical discomfort in the period immediately following drug administration may explain this finding since this discomfort was not noticeable after the 3-h period; it also appeared to be more prolonged in the pair-tested Ss. which showed aggressive behaviour when placed together subsequent to treatment with lithium. Such behaviour has previously been observed in rats chronically administered 0.1% lithium carbonate in their food (Schreiber, Roháčová & Přibyl, 1971).

The decreased activity of the individually-tested saline animals from the 20-min to 3-h condition may be explained by the reaction of these Ss to social isolation upon removal from their normal grouped cage environment. As shown in Chapter 4, isolated rats are less active than grouped animals in a novel test situation and in the apparatus used here. Although neither of the lithium studies, with which the present

results conflict, state the previous housing conditions of their experimental Ss it is quite probable that they were socially isolated before drug administration since this is a common, if undesirable, practice (Anon., 1966; Weltman, Sackler, Schwartz & Owens, 1968). Prolonged social isolation before testing could be expected to further lower the activity of individually-tested control Ss and may provide an explanation for the lack of activity differences found in the studies previously quoted. For example, Hughes & Syme (1972), using a 3.75 mg/kg dosage of the minor tranquilizer chlordiazepoxide hydrochloride on two groups of previously group or individually-housed rats found the latter group to be less active, when all Ss were observed individually in a novel test situation, for both saline and drug conditions. Both groups of animals were isolated during the 30-min post-injection period.

An interesting aspect of the present results, which is further investigated in the following chapter, is that the activity of the lithium-treated Ss was not affected by the social isolation in the post-injection period. This suggests that lithium may affect the Ss' social responsiveness.

An alternative interpretation may be proposed for the 3-h results shown in Figure 10.1. Evidence for the social facilitation of activity (Hughes, 1969) might suggest that the activity scores for the pair-tested animals should have been greater than those for the individually-tested Ss. Three hours after drug

administration the appropriate activity differences did occur for the saline controls. However the individual and pair-tested Ss treated with lithium showed no facilitation effect. Noting that no facilitation effect occurred for either group in the 20-min condition it seems reasonable to suppose that this effect is merely an artifact of the housing variable discussed earlier. Although acceptance of the facilitation effect operating in the 3-h condition would implicate a direct lithium-social interaction, closer examination of the functions of (1) housing conditions, (2) length of the post-injection period, and (3) social factors in the test situation, is required before any broad generalisations about the effects of lithium salts on behaviour can be made. It is likely that no difference in the activity of saline and lithium-treated Ss in previous studies were observed because of the effects of social isolation on the control groups. If normal social interaction is restored lithium may be regarded as an activity depressant in otherwise untreated rats.

Methodological Considerations

Analysis : This study used a parametric analysis for similar reasons to those stated in Chapters 3 and 7 - convenience in summarising the type of data obtained. The main objection to treating activity measures of this sort as ratio data is that the activity recorded for two animals in the apparatus together may be

influenced by the weight variable. However the information obtained from the manufacturers plus the device of combining scores for Ss tested alone was considered sufficient to counter this difficulty.

Social measures : The social measure used for this study was concerned only with the social parameters operating in the three environments - cage, post-injection, and test. This is an advance on earlier studies described in Part 1 of this thesis which only vary the Ss' social cage conditions. Even so, in the present case, the social mechanisms which produce differential reactivity are not explored; it was considered sufficient to demonstrate their relevance.

An interesting aspect of the results is that, whereas the social isolation in the post-injection period affected the activity of saline Ss tested alone, this social state did not affect the behaviour of lithium-treated Ss. This suggests that Sheard's decreased reactivity may extend from the test situation to the post-injection setting. The activity of rats treated with lithium may thus be unaffected rather than potentiated by the social variables, the "effects" of lithium being caused by the social deprivation of saline controls.

One way of investigating this possibility may be to use a larger group of Ss and to determine how these distribute themselves under the influence of lithium. If the salts do decrease social reactivity these

distances may be expected to increase in comparison with control Ss and body contact measures to decrease.

Tikal & Benešovâ (1972) present a method which enables such information to be obtained. Briefly, their technique involves placing two groups of 5 Ss (treated and untreated) in two rectangular enclosures following injection and recording the distribution of animals under four categories every 150 sec over a 90-min test period: immobile and in contact (ImC), immobile but isolated (ImI), active in contact (AC), and active but isolated (AI). Measurement obtained still provides only a crude estimate of inter-group distance. Also, the placing of Ss in the experimental setting straight after drug administration eliminates the post-injection social condition.

Syme & Syme (1973) use a method which avoids these problems in that a time-sample photographic record provides accurate measures of both body contact and inter-group distance. The following chapter uses this method to further investigate the effects of lithium chloride on sociability.

TABLE 10.1

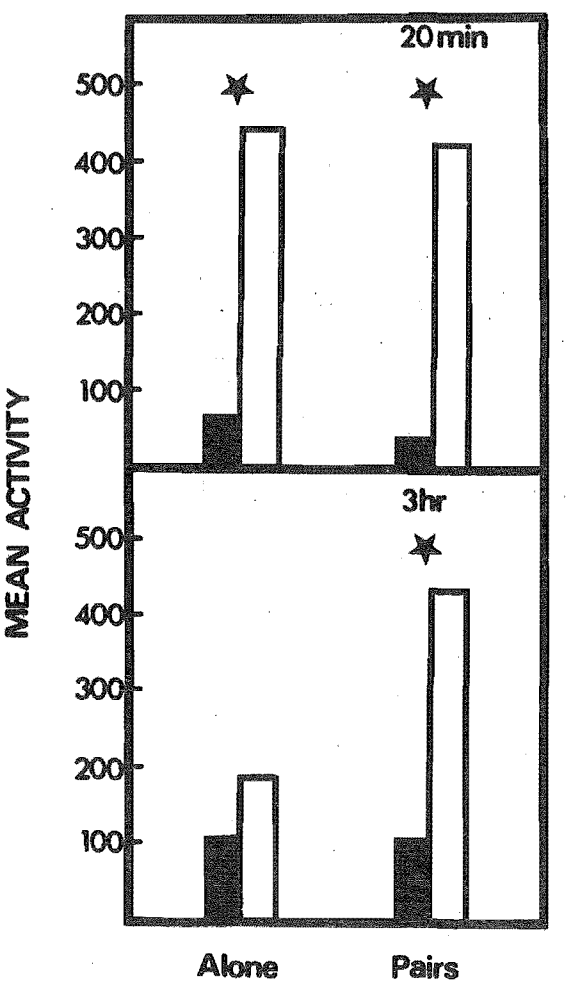
Mean activity scores (± S.E.) for each experimental condition.

Social Test Condition	Injection Time	Treatment	
		Lithium	Saline
ALONE	20 min	73.62±21.24	450.12±20.47
	3 h	124.75±17.31	192.37±27.57
PAIRS	20 min	46.37±23.29	439.75±77.19
	3 h	120.62±54.90	438.25±62.57

FIGURE 10.1

Effects of lithium (■) and saline (□) on the activity of rats tested alone or in pairs after a 20-min and 3-h period.

(★ $p < 0.001$, t-test)



CHAPTER ELEVEN

INFLUENCE OF SEX

NOVELTY OF THE TEST ENVIRONMENT

AND

LITHIUM CHLORIDE

ON

SOCIABILITY IN RATS

C H A P T E R E L E V E N

Introduction

"Sociability" has been used in a variety of experimental situations to describe the strength of animals' responses towards conspecifics within a social setting (e.g. Tolman, 1961; Shelley & Hoyenga, 1967; Salazar, 1968). While the earlier investigations often involved the caging of stimulus animals, later developments (Latanê, 1969; Tikal & Benešovâ, 1972; Syme & Syme, 1973) measure distances and amount of contact between freely moving rats in an open-field situation. The most recent of these methods is particularly suitable for pharmacological research in that it provides an objective photographic record of the distribution of the Ss. The procedure also allows animals to be tested in the groups in which they were housed, regardless of the group size. The significance of the second attribute has been emphasized by Wilson & Mapes (1964a) who state that a stable social condition within the testing situation is essential for meaningful results. This question is explored more fully in Chapter 13.

Using the photographic technique the present study observes sociability in groups of lithium-treated rats of either sex in both novel and familiar test environments. In this context a "novel" test setting is one in which the Ss have not spent the post-injection period (e.g. Chapter 12). A "familiar" test setting

is one in which the Ss have spent the post-injection period (e.g. Tikal & Benešová, 1972). This definition merely distinguishes between the two methods.

Subjects

The Ss were 28 male and 28 female 100-150 day old hooded rats (N.Z.B.W.S.) housed in groups of 7 animals for 28 days before the experiment under the conditions described in the previous chapter.

Apparatus

This was an open field measuring 1.2 x 1.2 x 0.4 m, the floor of which was divided into 16 squares each of area 0.3 x 0.3 m. The field was painted brown and the lines dividing the floor were white. Illumination was provided by six 22-W fluorescent lamps placed around the perimeter, but 1 m above, the field.

Procedure

The Ss received either 3 meq/kg of lithium chloride (LiCl, isotonic solution) or the same amount of isotonic saline injected intraperitoneally. Seven male rats were administered LiCl and placed in the field for 3 h. Similarly 7 male rats received LiCl and were placed together in their home cage for 3 h before testing. Saline controls were allocated in the same way to the two conditions, and the whole procedure was repeated for the female Ss. After the

3-h injection time had elapsed photographs were taken manually by an observer situated approximately 3 m above the field using a 35 mm camera and electronic flash. Twenty photographs were obtained by taking one every 30 sec over a 10-min period. Facilities were not available to shield the observer from the field. The flash did not appear to disturb the Ss' activity.

Results

The position of each S (identified by the distinctive natural fur markings) was noted for each of the 20 photographs. Two measures of "sociability" were then obtained for each animal in each photograph. The first measure was that of the average distance of each animal from each of its groupmates. This distance was not, however, calculated from the direct distance between the Ss but rather around the perimeter of the apparatus thus allowing for the wall-hugging behaviour shown by laboratory rats in an open-field situation. Distances for rats observed in centre squares were calculated linearly between the two Ss since no evidence exists regarding position preferences of animals returning to the perimeter.

The second measure used in this study, evident in the photographs obtained, concerned body contact with group-mates. However, because of the tendency for the group to be found in total, or near-total aggregation, difficulties were experienced in assessing the number

of animals with which any S was in contact. Although it could be clearly established that all animals were in contact, it was impossible to ascertain the exact number of contacts for each animal. In such cases each rat was defined as being effectively in contact with every other animal in the aggregation providing there were no observable gaps between animals.

A non-parametric analysis was adopted in this study because the underlying distribution of the variables is not, as yet, fully understood. This will be further discussed in Chapter 14. Table 11.1 shows the median values for both distance and contact measures in the novel and familiar test conditions. Distances were calculated from the midpoints of occupied squares. For all comparisons there was a higher degree of body contact between animals in the familiar environment. Social distances also showed a higher degree of sociability in that average inter-subject distances were significantly less in the familiar condition, except in the case of the female saline comparison where there was no significant difference between the two observations.

Table 11.1 also shows the comparisons between median values on both sociability measures in the drug/saline conditions. Here the lithium-treated females showed a higher degree of sociability than their saline counterparts on all measures. However the results were more complex for the males. In the novel condition there was no significant difference between the saline

and lithium-treated Ss on the distance measure, while the contact measure showed increased values for the lithium Ss. In the familiar test setting, however, the lithium-treated animals were significantly less sociable than controls on both measures. But in this case it is interesting to note the significant decrease in inter-subject distance and increase in body contact from the novel to familiar saline observations. There was also no significant difference in either distance (Mann-Whitney $U = 20$, $p > 0.05$) or contact ($U = 12$, $p > 0.05$) sociability measures between lithium-treated males and females in the familiar test setting.

Discussion

The general increase in sociability, as familiarity with the test setting increased, is consistent with the results of Latanê & Glass (1968) who found, over a number of 5-min testing periods spread over several days, that distances between pairs of rats gradually decreased.

Contrary to the hypothesis advanced in the introduction to this study, lithium increased the sociability of the female Ss on both measures and in both novel and familiar test environments. For the males, however, the position is less clear. In the novel situation the finding that lithium increased body contact but did not alter social distance hints that the major effect of the salt was merely to increase corner preferences rather than alter aggregation;

however the two possibilities cannot be empirically distinguished. But in the familiar field both lithium measures showed a significant tendency towards decreased aggregation in comparison with saline controls. Again a purely social interpretation seems unwise because of the high degree of sociability in the saline group.

This extreme aggregation could mean that the male Ss habituated to the apparatus more quickly than the females. Such an hypothesis is consistent with the results of Hughes (1968) who reported that male rats habituated to a novel environment faster than females. Since lithium has been shown to decrease exploratory responses (Johnson & Wormington, 1971) and it increased corner preference by males in the present study, the predominant effect of the salt may be that it decreased the amount of habituation to the apparatus by the males during the post-injection period. However the decrease in sociability in both distance and contact lithium measures in relation to the saline conditions indicates that social factors are also involved. Either interpretation (habituation or social) shows that, in lithium experiments in which the Ss are tested repeatedly in the same situation (Sheard, 1970a,b), male rats will be generally less responsive to their conspecifics than their saline controls. This basic lack of social responsiveness may, therefore, represent a more parsimonious description of the animals' social behaviour than interpreting results in terms of the inhibition of aggression.

Unfortunately Tikal & Benešová (1972) do not elaborate on possible sexual differences in the response of their "monosexual groups." Their method corresponds with the present familiar condition, while the usual procedure of presenting an unfamiliar environment to treated Ss after the post-injection period, thus increasing the "time economy and sensitivity" of the measure (Kršiak & Janků, 1971), is adopted here for the novel condition.

Under both familiar and novel test conditions, the lithium-treated females were more sociable than saline controls, although the majority of interactions appeared "immobile" (Tikal & Benešová, 1972). This is of interest with regard to the possible anti-aggressive effects of lithium. If there is a direct relationship between degree of sociability and likelihood of aggression in, for example, a foot-shock situation, one could reasonably expect an increase in aggressive levels of lithium-treated females. Further work is necessary to determine the relationship of sociability measures to the more complex induced social interactions, particularly for the assessment of psychotropic drug effects.

Methodological Considerations

Besides lithium salts, two other drugs have been the subject of research incorporating social variables. The effects of both the central stimulant amphetamine and depressant chlorpromazine have been found to be accentuated by testing in a group situation

(for review, see Kinnard & Watzman, 1966). However, apart from crude social measures (e.g. Rothlin & Cerletti, 1952; Melander, 1960; Tikal & Benešová, 1972), the nature of the group processes affected by such drugs has not been investigated.

At this stage some methodological differences between the observational procedure of Tikal & Benešová (1972) and the present photographic technique will be discussed, since these differences are investigated in Chapters 12 and 13.

(1) The distribution of the Ss is estimated whereas the present technique provides a precise record of physical distance between group members, in terms of measures between the midpoints of occupied squares or segments. This point is discussed further in Chapter 14. Greater precision in the analysis of results is achieved.

(2) The enclosure used by Tikal & Benešová (1972), measuring 60 x 40 x 40 cm is not a symmetrical space making it difficult to obtain distances from a distribution of Ss i.e. the probability of an animal occupying the wall areas will be unequal since these areas are unequal.

(3) The Ss are placed in the experimental environment immediately after injection. This is contrary to most drug-testing procedures, and may reduce sensitivity to the test environment in that it eliminates the

"period of hypermotility which occurs when animals are first placed into a new environment" (Kinnard & Watzman, 1966).

(4) The familiarity of the S groups is not stated by Tikal & Benešová (1972). This is relevant to the experimental results since the stability of the group may affect these (Wilson & Mapes, 1966a,b).

The following two chapters are concerned with an investigation of the consequences of these methodological differences. However, one important point remains to be discussed. In the present study a square open field was used and the possibility of differing position preferences for the corner squares was raised. The use of a round open field precludes such position preferences (e.g. Latané, 1969). However it presents further problems when only two rats are observed in the field in that the S has a choice (in a square enclosure) between <u>two</u> environmental landmarks - the other rat and the corners of the field (Syme & Syme, 1973) making comparison between the two situations difficult. The housing of laboratory rats in rectangular cages (of widely differing size) compounds the problem, if Ss from cages of varying size show differing spatial behaviour in the field.

Since cage size was not incorporated as a variable in the present study, and both position preference and sociability were found to be affected by

the drug treatment, a round open field was used for the experiments described in Chapters 12 and 13.

TABLE 11.1

Median values for the average social distance between animals per photograph (cm) and median values for the number of animals in contact per photograph.

Measure		Female			Male		
		Familiar	Novel	p^+	Familiar	Novel	p^+
CONTACT	Li	5.0	1.9	0.004	4.2	0.7	0.004
	Sal	1.2	0.3	0.004	5.6	0.3	0.004
	p^+	0.004	0.02		0.004	0.01	
DISTANCES	Li	18.59	71.09	0.008	21.72	100.38	0.004
	Sal	100.45	105.68	NS	2.44	103.89	0.004
	p^+	0.004	0.004		0.004	NS	

$^+$Mann-Whitney U test. Two-tailed probabilities.

CHAPTER TWELVE

EFFECTS OF CHLORPROMAZINE AND METHAMPHETAMINE ON SOCIABILITY IN RATS[+]

[+]The results of this study are reported in Psychopharmacologia (Berl.), 1973 (in press).

C H A P T E R T W E L V E

Introduction

Joy & Latané (1971) injected pairs of rats with adrenalin (1.3 mg/kg), saline, or chlorpromazine (3 mg/kg) and allowed them to interact freely in a circular open field. Over a 5-min test period observers recorded the location of each rat at 10-sec intervals. Adrenalin-treated rats were found to be significantly more sociable than those administered chlorpromazine. Consequently these authors hypothesized that "affiliation in rats appears to be a positive monotonic function of the arousal level operating at the time of the interaction between pairs." However the Ss in this study were individually housed and thus unfamiliar in the test situation, so it is impossible to separate two sources of behavioural influence in the experimental condition: social and environmental. Thus the social requirements advocated by Wilson & Mapes (1964a), and mentioned in the previous chapter, were not met; because both rats were strangers, group-specific effects may have been obscured (Syme & Syme, 1973).

If the (autonomic) arousal-affiliation effect is generalisable it should extend to the action of any central stimulant drug administered in a dosage sufficient to produce an "arousing" or activating response. The present study was designed to test this generality using a dosage of methamphetamine (2 mg/kg i.p.) to produce an increase in psychomotor activity but not

stereotyped behaviour (Del Rio & Fuentes, 1969) which might mask social processes. Chlorpromazine was administered in a similar dosage to that used by Joy & Latanĕ (3 mg/kg i.p.). Injection times followed those given in the two previous studies, 30 min and 45 min respectively, and the area of the test apparatus was also equivalent to that employed by Joy & Latanĕ (1971).

Subjects

The Ss were 18 group-housed male rats of the Wistar strain weighing 100-150 g and aged 80-100 days at the time of the experiment. They were housed in three groups of 6 Ss under the conditions described in Chapter 10.

Apparatus

This was a circular open field of 1.2 m diameter, with an enclosing wall 0.4 m high. The floor and walls of this were painted brown and the lines, painted white, divided the floor into 49 numbered sections of equal area and approximately equivalent shape. Illumination and photographic technique were the same as described in the previous study.

Procedure

Testing was carried out between 3 pm and 4 pm. Six rats received 2 mg/kg methamphetamine injected intraperitoneally and were placed together in their

home cage for 30 min (Del Rio & Fuentes, 1969) prior to testing. Similarly 6 rats received an equivalent volume of isotonic saline and were placed in their home cage for the same period before testing. The remaining 6 rats were injected with 3 mg/kg chlorpromazine and were placed in their home cage for 45 min (Joy & Latané, 1971) prior to testing.

The day before testing each rat was marked with black alcohol dye to enable individual recognition. The same procedure was used for the three groups. The six animals were placed in the open field and allowed to roam freely for 1 min, after which time photographs were taken every 30 sec for a 10-min period. In this way 20 photographs of the whole field were obtained. These photographs enabled the exact positioning of each rat every 30 sec over the test period. The black dye marks on the Ss proved to be distinctive enough for the individual recognition of each rat in the 20 photographs.

Results

The sociability measures used conformed with those in the previous chapter. The perimeter-distance measure gave a maximum distance between animals of 12 segments (1.68 m) while the maximum linear-distance measure was six segments (1.04 m).

Results for the three groups on the two distance measures and the proximity measure are shown in Table 12.1. Distances were calculated from the

midpoint of each occupied segment. As in the previous study a nonparametric analysis was used to analyse the data.

Discussion

Contrary to the findings of Joy & Latanĕ (1971) the results show that animals treated with chlorpromazine were significantly more sociable than those administered methamphetamine on both the linear-distance and proximity measures. The increased sociability of the methamphetamine-treated Ss on the perimeter-distance measure may be explained by the greater tendency of these rats to occupy the inner area of the field. This would tend to reduce the distances between Ss and thus the differential between the two distance measures. Observed position preferences were obtained from the 120 positions shown by each group of six rats in the 20 photographs. These revealed that, whereas only 2% of the observations of chlorpromazine and saline-treated rats were in the inner segments of the field, 18% of the methamphetamine observations were within these segments.

The arousal-affiliation hypothesis proposed by Joy & Latanĕ (1971) is thus not supported by the present study. Several methodological differences may account for the discrepancy: individual or group housing of Ss, the presence of unfamiliar or familiar animals in the test situation, and the number of animals interacting in the experimental environment.

Kinnard & Watzman (1966) suggest that the effect of a drug may be a function of the stimulus change from housing to test condition. The present method does enable a degree of social control over such changes. The effects of drugs on the spatial distributions of animals can be observed under all housing states with testing conducted under identical social parameters.

Methodological Considerations

As stated in the previous chapter methodological differences preclude direct comparisons with results obtained by Tikal & Benešová (1972) in that their criterion for the spatial distribution of Ss was essentially a subjective one. Also the animals were placed in the observation area immediately after injection, thus eliminating any novelty of the test setting which could otherwise "tune up" exploratory behaviour (Kršiak & Janků, 1971).

Even so, it is interesting to note that, using their test (Tikal & Benešová, 1972), administration of 1.25, 2.5 or 5 mg/kg amphetamine increased the number of active postures. The lowest dose significantly increased the number of AC postures (see p. 10 - 11) while higher doses led to an evident predominance of AI postures. Thus it would seem desirable to repeat the present study using the "novel" and "familiar" conditions of the previous chapter (p. 11 - 7) to determine the effects of the different post-injection

environment using the more precise photographic method. This could well provide a dramatic example of the need to standardise conditions in the post-injection period.

Variables manipulated in this study, and in the two previous chapters, have not included the familiarity of the S groups. Perhaps the results obtained by Tikal & Benešová (1972) can be attributed to this factor, rather than to the "familiarity" of the test environment. Using methamphetamine, the study described in Chapter 13 investigates this possibility.

TABLE 12.1

Median values for the average social distance between animals per photograph (cm) and median values for the number of animals in contact per photograph (proximity).

Measure	Chlorpromazine	Saline	Methamphetamine
Perimeter distance	21.09^{++}	66.03^{+}	63.66^{+}
Linear distance	20.98^{++}	46.97^{+}	53.72^{+}
Proximity	30.0^{++}	10.0^{+}	3.5^{+}

$^{++}$Differs significantly from both other groups in the row, $p < 0.002$;

$^{+}$ $p < 0.02$ (Mann-Whitney U test, two-tailed).

CHAPTER THIRTEEN

GROUP INSTABILITY AND THE SOCIAL RESPONSE TO METHAMPHETAMINE

C H A P T E R T H I R T E E N

Introduction

Effects of group instability on the action of psychotropic drugs in a social environment have received little attention, despite the emphasis placed by Wilson & Mapes (1964a) on the methodological consequences of such instability for animal drug studies. In the only empirical investigation to date Wilson & Mapes (1964b) demonstrated marked effects on the activity of rats tested in systematically disrupted groups of constant size. However the effects of group instability on the social behaviour of animals within a pharmacological setting have not yet been examined.

Psychopharmacological studies which have investigated the effects of drugs on simple social measures such as sociability have tended to confound such effects by providing stimulus animals which were previously unknown to their Ss (e.g. Heimstra, 1962a,b) and by testing animals in social conditions differing from those in the cage environment (Cappell & Latané, 1969; Joy & Latané, 1971). Techniques devised by Tikal & Benešová (1972) and Syme & Syme (1973) enable rats to be tested in the groups in which they are caged so that one can ascertain the effects of group instability on social interactions in treated rats.

In the previous chapter 2 mg/kg methamphetamine was used to produce an increase in psychomotor activity but not stereotyped behaviour (Del Rio & Fuentes, 1969)

in a group of familiar rats. This treatment decreased the amount of physical contact and modified social distances within the group 30 - 40 min after injection.

The present study investigates whether this effect is modified in any way when the Ss are tested in a group size consistent with that in which they were caged, but of an unstable constitution.

Subjects

The Ss were 28 male hooded rats (N.Z.B.W.S.) weighing 150-200 g at the time of the experiment and selected from an experimental stock of 63 animals. All rats were housed in constant groups of 7 for a month before the experiment began. The same housing conditions were maintained as in the previous chapters.

Two of the groups were retained intact during testing and served as controls for the unstable group conditions. The two unstable groups were obtained by randomly selecting two animals from each of the remaining seven groups immediately before testing to form two groups of 7 Ss in which all animals were unfamiliar to each other.

Apparatus

The apparatus was identical in all respects to that described in the previous chapter and photographs were obtained in the same manner.

Procedure

Testing was carried out between 2 pm and 3 pm. The rats in the first stable group were injected with the same dosage of methamphetamine as used in the previous chapter (2 mg/kg i.p.) and were placed individually in 18 x 18 x 18 cm holding cages for 30 min prior to testing. Similarly the second stable group was injected with an equivalent volume of isotonic saline and placed in holding cages for 30 min before testing. Members of the unstable groups were taken from their home cages, injected with methamphetamine or saline and, as with the stable groups, were placed in holding cages for 30 min before testing.

The testing procedure was identical to that described in Chapter 12.

Results

The three measures described in the previous two chapters were used for the analysis of this study; the median values for each condition and the probabilities associated with between-group comparisons are shown in Table 13.1. All probabilities were derived from the Mann-Whitney U test.

Although group instability did not have a significant effect on the amount of physical contact under the saline conditions, the methamphetamine-treated unstable group showed significantly less contact than the stable drug-treated group. Both methamphetamine

groups had significantly less body contact than their controls.

The distance measures demonstrated identical effects. Although the median inter-individual distances were lowered by methamphetamine in both cases for the stable group, no significant effect on either measure was shown for the unstable group. On both distance measures the saline-treated unstable group had a significantly lower inter-animal distance than its stable counterpart. This observation was reversed, however, in the methamphetamine groups on the perimeter distance measure.

The use of nonparametric methods for the presentation of an "interaction" effect will be discussed in Chapter 14.

Discussion

These results support the contention that group instability can affect reactions to drugs in a social setting (Wilson & Mapes, 1964a) and extend this to social responses. For the proximity measure, which is the most socially powerful of the three sociability measures, group instability accentuated the response to methamphetamine. On the second social measure, that of inter-individual distance, group instability obscured the effects of methamphetamine which were observed in the stable group. Thus it appears that group stability must be considered when the effects of drugs on social responses are interpreted.

Both the contact and perimeter measures in this study produced results consistent with those obtained previously in that methamphetamine not only decreased contact but also reduced social distances. In contrast to the earlier study, however, methamphetamine decreased direct inter-individual distances rather than increased them, as was previously the case. This lack of reliability reinforces the conclusion (Syme & Syme, 1973) that social distances are best calculated in terms of the animals' natural spatial behaviour. Although, as the previous chapter shows, there is an increase in centre entries by methamphetamine-treated rats as compared with controls, both this study and Melander (1960) have shown that a large degree of wall-hugging behaviour exists in rodents treated with this drug in a group situation. It may be necessary to re-evaluate this preference for the perimeter measure if drugs are used which alter the natural spatial behaviour of the rat.

Although methamphetamine administered at the level used in the present study decreased body contact, it also decreased inter-animal distance. Consequently the two measures, despite earlier reports of a high correlation (Latané et al, 1971) should be regarded separately. While physical contact can be regarded as the primary index of sociability, it is necessary to discover the different properties of this contact and social distance which allow the two measures to vary independently after drug administration.

TABLE 13.1

Median values for each condition and the probabilities associated with between-group comparisons (Mann-Whitney U test, two-tailed). Obtained from the average social distance and average number of animals in contact per photograph.

MEASURE		Saline	Methamphetamine	p
Proximity	Stable	0.95	0.40	0.002
	Unstable	0.90	0.25	0.002
	p	NS	0.02	
Linear Distance (cm)	Stable	60.98	55.47	0.004
	Unstable	55.28	56.62	NS
	p	0.002	NS	
Perimeter Distance (cm)	Stable	70.78	60.94	0.002
	Unstable	63.20	63.27	NS
	p	0.002	0.04	

C H A P T E R F O U R T E E N

G E N E R A L R E V I E W

C H A P T E R F O U R T E E N

The photographic method introduced in the previous three chapters permits standardisation of social cage, post-injection, and test conditions. It also overcomes the limitations of observational techniques: watching more than two Ss in the field, estimating distances between animals, and defining proximity measures subjectively. Some implications, extensions and improvements of the method will be further discussed.

Standardisation of Social Techniques

This is a central issue for the promotion of the photographic technique. For example, the results of Chapter 12 illustrate the consequences of comparing measures which, superficially, appear similar in both intention and technique (cf. Joy & Latanĕ, 1971; Tikal & Benešová, 1972; pp. 12 - 1 and 10 - 11).

Perhaps the most satisfactory solution would be to use the best characteristics of all tests to enable a social-screening of psychotropic drugs, supplemented by the single-animal methods used at present. There are a number of ways in which the photographic method presented here could be extended and made more efficient.

Improvements

Manual positioning of the camera, for instance, produces a slightly distorted picture which does not allow the exact analysis of such factors as head alignment and absolute distances between Ss. In the present case the distance between midpoints of occupied squares (or segments) was adopted since the photographs were taken at a slight angle to the field.

McBride, James & Shoffner (1963) used a hidden observer above a shed housing deep-litter domestic hens to obtain photographs of groups of Ss and thus measures of spacing and head orientation. Herron & Frobish (1969) used an automatically-operated camera (with a fish-eye lens) centrally mounted in the roof of a childrens' playroom, the floor of which was divided into a grid of 3-ft squares. Coordinates were noted for the position of each child in each photograph, and these data and coordinates for the areas occupied by equipment served as input to a computer. Thus this method provides information which is not available with asymmetrical photographs: changes in position by each S and the mean distance for each S in each condition, the mean distance between each S and each other S during each condition as a function of time, and the frequency each S is accompanied by selected permutations of the other Ss in each square as a function of time. Apart from these measures, those obtained in Chapters 11, 12 and 13 are also derived, as is also

information about the positioning of Ss around equipment i.e. information about the spatial quality of the play area and its influence on Ss' behaviour.

It should be noted at this point that the original use of the photographic technique for analysing sociability in rats (Syme & Syme, 1973) was done without knowledge of Herron's work, and is concerned only with the interaction of Ss within the confined space. However, when facilities become available the logical advance is the use of a centrally-mounted camera to obtain more precise measures, and an automatic analyser (suggested by Herron, 1972) to eliminate the present tedious and time-consuming analysis of photographs. Although, in the present case, the experimental time is short, the analysis and interpretation of data is hampered by the laborious process of manual scanning. More sophisticated photographic apparatus would also be a great advantage in clarifying definition of the markings on the Ss' backs. For the present experiments the author's camera was used, since the departmental equipment (which would have given superior results) was unavailable at this time.

If equipment of sufficient quality were available, a video-tape system would provide even more precise information about the pattern of movement of S groups within the field. This is particularly important for gaining information about the sequences of behaviour through the experimental period - social, drug-induced,

or both. Between-group studies have, as yet, received little empirical attention. Performance in social familiar/novel preference situations could provide another dimension to social drug screening. A further variation might be to place two groups in the field together; treated and untreated. This would certainly enhance the results of Chapter 11. Similar observational procedures have been used with pairs of rats (Silverman, 1966; Kršiak & Borgesová, 1972).

Another refinement is the use of different photocell arrangements in the field to provide a measure of overall activity of the group of Ss (e.g. Watzman et al, 1966). Long exposures have also been used in a photographic method (Rothlin & Cerletti, 1952; Melander, 1960) to show the areas of the field occupied most by the group (see p. 13 - 5).

All of the improvements discussed here would still enable Ss to be tested in their stable housing conditions, the present criterion for meaningful results. However there are still a number of variables to be investigated more fully.

(1) Shape of the Field

Syme & Syme (1973) suggest that environmental landmarks (i.e. corners of square fields) are important in determining the rat's choice of position in the open field (p. 11 - 9). Difficulties were experienced in differentiating between social and spatial changes in the square field (e.g. see p. 11 - 5); it may be best

to use both round and square fields so that results for different drugs can be compared. Although it seems reasonable to assume that results will be similar, the question requires systematic investigation. Effects of space could also be studied by placing physical barriers in the field (perhaps giving a new lease of life to the Hebb-Williams' maze). This is similar to Herron's inclusion of playroom-equipment positions in his analysis of the behavioural movements of children in this environment (Herron, 1972).

(2) Group Size

Group size is not investigated in Part 2 of this thesis. However the differences in the results of the chlorpromazine effect in Chapter 12 and that observed by Joy & Latané (1971) may be attributable to the different group sizes used (p. 12 - 1). Group-size effects could be studied by holding the area per animal constant. Similarly, density effects (animals/area) could be observed by manipulating both group size and field area.

(3) Perimeter-distance measure

Further development of this measure is required. Using video-tape methods one could establish more clearly the spatial probabilities associated with a "centre" animal (i.e. S not occupying the perimeter). Problems do arise in defining this "perimeter." In these explorative studies the typical round and square open-

field perimeter distances were arbitrarily decided upon as the outside squares or segments. This requires further attention and, perhaps, standardisation. However it is a healthy sign that, despite such discrepancies, the perimeter measure was found to be reliable.

The particular nature of the perimeter-distance measure necessitates the use of simple non-parametric analyses for the purpose of rat-sociability studies. This is because perimeter distances between animals are "longer" than linear distances, thus restricting statistical methods (until the distribution of this variable is better understood) to those using ordinal measures only e.g. the Mann-Whitney U test. At this stage it is considered desirable to consolidate a variety of experimental results and, ultimately, build up a model of spatial behaviour of groups of Ss in the field to determine the appropriate data distribution.

CHAPTER FIFTEEN

CONCLUSION

C O N C L U S I O N

Although this thesis began as an investigation of the effects of housing on the behaviour of laboratory rats it became apparent that the primary task was to explain contradictory findings, rather than to augment the fickle bulk of existing knowledge. Apart from the simple study described in Chapter 4, which showed that an inappropriate species comparison had tended to create a meaningless controversy in the housing literature, it seemed as though this investigation of contradictory evidence ultimately rested on methodological issues.

Most housing studies have cursorily adopted individual measures, being concerned with manipulations of the environmental variables (social and spatial) rather than with the characteristics of the measurement of these variables. This is understandable, since such methods (e.g. open field, activity platform) do have a surface validity in that they have been used previously. However, although it is often time-consuming to develop a new technique, this should not be avoided for the sake of quick and respectable results. Housing studies should be constructed from the basis of methods devised <u>for</u> such studies. There is no need to limit the investigation of behaviour to such popular techniques as the open field.

For a substantial review of this measure one should consult Archer (1973) to see that too few people,

who have been investigating the effects of behavioural manipulations on the performance of laboratory rodents in this "standard" test environment, have bothered to concern themselves with the response dimensions of this apparatus.

Unless housing studies manage to shift the emphasis from external environmental manipulations to the development of a coherent series of testing techniques such efforts will continue (as with the open field) to be published for 40 years until it is "discovered" that many of them are inappropriate. Also, as with the development of social pharmacological tests within the open-field, new uses of familiar apparati may hold as much potential for solving theoretical problems as the housing manipulation.

REFERENCES

ANGERVALL, L. Alloxan diabetes and pregnancy in the rat. Effects on offspring. Acta endocr. (Kbh.) Suppl. 44, 1959, 16-20.

ANGERVALL, L., and CARLSTRÖM, E. Theoretical criteria for the use of relative organ weights and similar ratios in biology. J. Theoret. Biol. 1963, 4, 254-259.

ANON. One or many animals in a cage? Nutrition Rev. 1966, 24, 116-119.

ARCHER, J. Contrasting effects of group housing and isolation on subsequent open field exploration in laboratory rats. Psychon. Sci. 1969, 14, 234-235.

ARCHER, J. Effects of population density on behaviour in rodents. In J.H. Crook (Ed.) Social behaviour in birds and mammals: essays on the social ethology of animals and man. London: Academic Press, 1970, pp. 169-210.

ARCHER, J. Tests for emotionality in rats and mice: a review. Anim. Behav. 1973, 21, 205-235.

BAILEY, E.D. Social interaction as a population regulating mechanism in mice. Canad. J. Zool. 1966, 44, 1007-1012.

BARNETT, S.S. Social stress. In J.D. Carthy and C.L. Duddington (Eds.) Viewpoints in biology. London: Butterworths, 1964, pp. 170-218.

BARON, A., ANTONITIS, J.J. and SCHELL, S.F. Effects of early restriction and facilitation of climbing on later climbing behavior of mice. J. comp. physiol. Psychol. 1962, 55, 808-812.

BAUMEISTER, A., HAWKINS, W.F. and CROMWELL, R.L. Need states and activity level. Psychol. Bull. 1964, 61, 438-453.

BELL, R.W., MILLER, C.E., ORDY, J.M. and ROLSTEN, C. Effects of population density and living space upon neuroanatomy, neurochemistry, and behavior in the C57B1/10 mouse. J. comp. physiol. Psychol. 1971, 75, 258-263.

BERLYNE, D.E. Novelty and curiosity as determinants of exploratory behavior. Brit. J. Psychol. 1950, 41, 68-80.

BOICE, R. Some behavioral tests of domestication in Norway rats. Behaviour, 1972, 42, 198-231.

BROADHURST, P.L. Determination of emotionality in the rat I. Situational factors. Brit. J. Psychol. 1957, 48, 1-12.

BRONFENBRENNER, U. Early deprivation in mammals: A cross-species analysis. In: Early experience and behavior (Edit. G. Newton and S. Levine). Springfield, Ill.: Charles C. Thomas, 1968.

BRONSTEIN, P.M. Repeated trials with the albino rat in the open field as a function of age and deprivation. J. comp. physiol. Psychol. 1972, 81, 84-93.

CADE, J.F.J. Lithium salts in the treatment of psychotic excitement. Med. J. Austral. 1949, 2, 349-352.

CALHOUN, J.B. A method for self control of population growth among mammals living in the wild. Science. 1949, 109, 333-335.

CANDLAND, D.K. and NAGY, Z.M. The open field: some comparative data. Ann. N.Y. Acad. Sci. 1969, 159, 831-851.

CAPPELL, H. and LATANÉ, B. Effects of alcohol and caffeine on the social and emotional behavior of the rat. Quart. J. Stud. Alc. 1969, 30, 345-356.

CARROLL, B.J. and SHARP, P.T. Rubidium and lithium: opposite effects on amine-mediated excitement. Science, 1971, 172, 1355-1357.

CHANCE, M.R.A. Aggregation as a factor influencing the toxicity of sympathomimetic amines in mice. J. Pharmacol. 1946, 87, 214-219.

CHANCE, M.R.A. Factors influencing the toxicity of sympathomimetic amines to solitary mice. J. Pharmacol. 1947, 89, 289-296.

CHRISTIAN, J.J. The adreno-pituitary system and population cycles in mammals. J. Mammal. 1950, 31, 247-259.

CHRISTIAN, J.J. Effects of population size on the weight of reproductive organs in white mice. Am. J.

Physiol. 1955, 181, 477-480.

CHRISTIAN, J.J. The roles of endocrine and behavioral factors in the growth of mammalian populations. In: Comparative Endocrinology (Edit. A. Gorbman and H.A. Burne). New York: Wiley, 1959.

COLLINS, R.L. What else does the defecation score measure? Proc. 74th Ann. Conv. A.P.A. 1966, 147-148.

COX, D.R. Planning of experiments. New York: Wiley, 1958.

COX, C., HARRISON-READ, P.E., STEINBERG, H. and TOMKIEWICZ, M. Lithium attenuates drug-induced hyperactivity in rats. Nature (Lond.) 1971, 232, 336-337.

CREED, T.L. and FERSTER, C.B. Space as a reinforcer in a continuous free-operant environment. Psychol. Rec. 1972, 22, 161-167.

DEL RIO, J. and FUENTES, J.A. Further studies on the antagonism of stereotyped behaviour induced by amphetamine. Europ. J. Pharmacol. 1969, 8, 73-78.

D'ENCARNACAO, P.S. and ANDERSON, K. Effects of lithium pretreatment on amphetamine and DMI tetrabenazine produced psychomotor behavior. Dis. nerv. Syst. 1970, 31, 494-496.

DEMBER, W.N. Response by the rat to environmental change. J. comp. physiol. Psychol. 1956, 49, 93-95.

DIXON, L.K. and DeFRIES, J.C. Development of open-field behavior in mice: effects of age and experience. Devel. Psychobiol. 1968, 1, 100-107.

ESSMAN, W.B. The development of activity differences in isolated and aggregated mice. Anim. Behav. 1966, 14, 406-409.

EWBANK, R. Behavioural implications of intensive animal husbandry. Outlook on Agriculture, 1969, 6, 41-46.

FOWLER, H. Curiosity and exploratory behavior. New York: MacMillan, 1965.

FURCHTGOTT, E., WECHKIN, S. and DEES, J.W. Open-field exploration as a function of age. J. comp.

physiol. Psychol. 1961, 54, 386-388.

GUNN, J.A. and GURD, J. The action of some amines related to adrenaline: cyclohexylalkylamines. J. Physiol. (Lond.), 1940, 7, 463-470.

HAHN, W.W. Some effects of group size on behavior and physiology of the rat. J. Psychosom. Res., 1965, 8, 455-465.

HALL, C.S. Emotional behavior in the rat. I. Defecation and urination as measures of individual differences in emotionality. J. Comp. Psychol. 1934, 18, 385-403.

HALL, C.S. Emotional behavior in the rat. III. The relationship between emotionality and ambulatory behavior. J. Comp. Psychol. 1936, 22, 345-352.

HARLOW, H.F. Social facilitation of feeding in the albino rat. J. Genet. Psychol. 1932, 41, 211-221.

HATCH, A.M., WIBERG, C.G., BALAZS, T. and GRICE, H.C. Long-term isolation stress in rats. Science, 1963, 142, 507.

HATCH, A.M., WIBERG, G.S., ZAWIDZKA, Z., CANN, M., AIRTH, J.M. and GRICE, H.C. Isolation syndrome in the rat. Toxicol. Appl. Pharmacol. 1965, 7, 737-745.

HEIMSTRA, N.W. Social influence on the response to drugs. I. amphetamine sulphate. J. Psychol. 1962, 53, 233-244 (a).

HEIMSTRA, N.W. Social influence on the response to drugs. II. chlorpromazine and iproniazid. Psychopharmacologia (Berl.) 1962, 3, 72-78 (b).

HERRON, R.E. Mapping human movement with the aid of a computer. In: Behavior and environment. The use of space by animals and men. (Edit. A. H. Esser) New York: Plenum Press, 1971, pp. 115-117.

HERRON, R.E. and FROBISH, M.J. Computer analysis and display of movement pattern. J. exp. Child. Psychol. 1969, 8, 40-44.

HOLLAND, H.C., GUPTA, B.D. and WELDON, E. A note on rearing and an environmental constraint. Activ. nerv. sup. 1966, 8, 140-144.

HOYENGA, K.T. and AESCHLEMAN, S. Social faciliation of eating in the rat. Psychon. Sci. 1969, 14, 239-241.

HUGHES, R.N. Behaviour of male and female rats with free choice of two environments differing in novelty. Anim. Behav. 1968, 16, 92-96.

HUGHES, R.N. Social facilitation of locomotion and exploration in rats. Br. J. Psychol. 1969, 60, 385-388.

HUGHES, R.N. and SWANBERG, K.M. Effects of food deprivation on exploration in deprivationally naive rats. Aust. J. Psychol. 1970, 22, 79-84.

HUGHES, R.N. and SYME, L.A. The role of social isolation and sex in determining effects of chlordiazepoxide and methylphenidate on exploratory behaviour. Psychopharmacologia (Berl.) 1972, 359-366.

IRWIN, S. Variability in drug response. In: Animal and clinical pharmacologic techniques in drug evaluation. (Edit. J.H. Nodine and P.E. Siegler) Chicago: Year Book Medical, 1964, pp. 15-26.

JEWETT, R.E. and NORTON, S. Measurement of behavior of rats under isolation and observations on preliminary drug effects. Psychopharmacologia (Berl.) 1964, 6, 151-158.

JOFFE, J.M., RAWSON, R.A. and MULICK, J.A. Control of their environment reduces emotionality in rats. Science, 1973, 10, 1383-1384.

JOHNSON, F.N. and WORMINGTON, S. Effect of lithium on rearing activity in rats. Nature (Lond.) New Biol. 1972, 235, 159-160.

JOY, V. and LATANÉ, B. Autonomic arousal and affiliation in rats. Psychon. Sci. 1971, 25, 299-300.

KINNARD, W.J. and WATZMAN, N. Techniques utilized in the evaluation of psychotropic drugs on animal activity. J. Pharm. Sci. 1966, 55, 995-1012.

KRŠIAK, M. and BORGESOVÁ, M. Drugs and spontaneous behaviour: why are detailed studies still so rare? Activ. nerv. sup. 1972, 14, 285-293.

KRŠIAK, M. and JANKŮ, I. Measurement of pharmacological depression of exploratory activity in mice: a contribution to the problem of time-economy and sensitivity. Psychopharmacologia (Berl.) 1971, 21, 118-130.

KUO, ZING-YANG. The dynamics of behavior development. New York: Random House, 1967.

LÁT, J. The spontaneous exploratory reactions as a tool for psychopharmacological studies. Proc. 2nd Int. Pharm. Meeting, Prague, 1963.

LATANÉ, B. Gregariousness and fear in laboratory rats. J. Exp. Soc. Psychol. 1969, 5, 61-69.

LATANÉ, B. and GLASS, D.C. Social and nonsocial attraction in rats. J. Pers. Soc. Psychol. 1968. 9 142-146.

LATANÉ, B., SCHNEIDER, E., WARING, P. and ZWEIGENHAFT, R. The specificity of social attraction in rats. Psychon. Sci. 1971, 23, 28-29.

LATANÉ, B. and WALTON, D. Effects of social deprivation and familiarity with the environment on social attraction in rats. Psychon. Sci. 1972, 27, 9-11.

LORE, R.K. Activity-drive hypothesis: effects of activity restriction. Psychol. Bull. 1968, 70, 566-574 (a).

LORE, R.K. Effect of confinement upon subsequent activity. J. comp. physiol. Psychol. 1968, 65, 372-374 (b).

McBRIDE, G., JAMES, J.W. and SHOFFNER, R.N. Social forces determining spacing and head orientation in domestic hens. Nature, 1963, 197, 1272-1273.

MASUR, J. Sex differences in "emotionality" and behavior of rats in the open field. Behav. Biol. 1972, 7, 749-754.

MELANDER, B. Psychopharmacodynamic effects of Diethylpropion (Tylinal ®). Acta pharmacol. et toxicol. 1960, 17, 182-190.

MONTGOMERY, K.C. The relation between exploratory behavior and spontaneous alternation in the white rat. J. comp. physiol. Psychol. 1951, 44, 582-589.

MORRISON, B.J. Effect of size of rearing group on emotionality: possible confounding with cage size. Psychol. Rep. 1968, 22, 1071-1072.

MOYER, K.E. and KORN, J.H. Behavioral effects of isolation in the rat. Psychon. Sci. 1965, 3, 503-504.

MUNN, N.L. Handbook of Psychological Research on the Rat. Boston: Houghton Mifflin Company, 1950.

MYERS, R.D. and FOX, J. Differences in maze performance of group- vs. isolation-reared rats. Psychol. Rep. 1963, 12, 199-202.

PRESCOTT, R.G.W. Some behavioural effects of variables which influence the 'general level of activity' of rats. Anim. Behav. 1970, 18, 791-796.

ROTHLIN, E. and CERLETTI, A. Über einige pharmakologische Untersuchungen an Mäusen mit congenitaler Drehsucht. Helv. Physiol. Acta. 1952, 10, 319-327.

RUSSELL, W.M.S. and BURCH, R.L. The principles of Humane Experimental Technique. London: Methuen, 1959.

SALAZAR, J. Gregariousness in young rats. Psychon. Sci. 1968. 10, 391.

SCHIØRRING, E. and RANDRUP, A. Social isolation and changes in the formation of groups induced by amphetamine in an open-field test with rats. Neuro-Psychopharm. 1971, 4, 1-12.

SCHNÜRER, L-B. Maternal and foetal responses to chronic stress in pregnancy. Acta Endocrinologica, Suppl. 80, 1963.

SCHOU, M. Lithium in psychiatric therapy and prophylaxis. J. Psychiat. Res. 1968, 6, 67-95.

SCHREIBER, V., ROHÁČOVÁ, J. and PŘIBYL, T. Endocrine changes after chronic lithium carbonate administration in rats. Physiol. Bohemoslov. 1971, 20, 249-254.

SELYE, H. The general adaptation syndrome and diseases of adaptation. J. clin. Endocrin. 1946, 6, 117-230.

SHEARD, M. Effect of lithium on foot shock aggression in rats. Nature (Lond.) 1970, 228, 284-285 (a).

SHEARD, M. Behavioral effects of p-chlorophenylalanine in rats: inhibition by lithium. Comm. Behav. Biol. 1970, 2, 71-73 (b).

SHELLEY, H.P. Eating behavior: social facilitation or social inhibition. Psychon. Sci. 1965, 3, 521-522.

SHELLEY, H.P. and HOYENGA, K.T. Sociability behavior and the social environment. Psychon. Sci. 1967, 8, 501.

SIGG, E.B., DAY, C. and COLOMBO, C. Endocrine factors in isolation-induced aggressiveness in rodents. Endocrinology, 1966, 78, 679-684.

SILVERMAN, A.P. Ethological and statistical analysis of drug effects on the social behaviour of laboratory rats. Brit. J. Pharmacol. 1965, 24, 579-590.

STERN, J.A., WINOKUR, G., EISENSTEIN, A., TAYLOR, R. and SLY, M. The effects of group vs. individual housing on behavior and physiological responses to stress in the albino rat. J. Psychosom. Res. 1960, 4, 185-190.

SYME, G.J. Experimental Investigations of Social Behaviour in Animals: Competitive Orders as Measures of Social Dominance. Unpublished PhD Thesis, University of Canterbury, 1972.

SYME, G.J. and SYME, L.A. Evidence for cagemate preference in the laboratory rat. Psychol. Rep. 1973, 32, 391-394.

SYME, L.A. Effects of caging on the behaviour of rats in the open field. Unpublished Masters' Thesis, University of Canterbury, 1971.

THIESSEN, D.D. and RODGERS, D.A. Population density and endocrine function. Psychol. Bull. 1961, 58, 441-451.

THIESSEN, D.D., ZOLMAN, J.F. and RODGERS, D.A. Relation between adrenal weight, brain cholinesterase activity, and hole-in-wall behavior of mice under different living conditions. J. comp. physiol. Psychol. 1962, 55, 186-190.

THIESSEN, D.D. Varying sensitivity of C57B1/Crgl mice to grouping. Science, 1963, 141, 827-828.

THIESSEN, D.D. Population density, mouse genotype, and endocrine function in behavior. J. comp. physiol. Psychol. 1964, 57, 412-416 (a).

THIESSEN, D.D. Population density and behavior: a review of theoretical and physiological contributions. Tex. Rep. Biol. Med. 1964, 22. 266-314 (b).

TIKAL, K. and BENEŠOVÁ, O. Socioactography - a method

for quantification of contact behaviour and motor activity of rats in a group and its use in psychopharmacology. Activ. nerv. sup. 1972, 14, 273-279.

TOLMAN, C.W. Social preference in the albino rat pup. Psychol. Rep. 1961, 8, 522.

VALLE, F.P. Rats' performance on repeated tests in the open field as a function of age. Psychon. Sci. 1971, 23, 333-335.

WALSH, J.E. Handbook of Nonparametric Statistics III. Canada: Van Nostrand Co., 1968.

WATZMAN, N., BARRY, H., KINNARD, W.J. and BUCKLEY, J.P. Comparison of different photobeam arrangements for measuring spontaneous activity of mice. J. Pharm. Sci. 1966, 55, 907-909.

WEISCHER, M-L. Über die antiaggressive wirkung von lithium. Psychopharmacologia (Berl.) 1969, 15, 245-254.

WELTMAN, A.S., SACKLER, A.M. and SPARBER, S.B. Endocrine, metabolic and behavioral aspects of isolation stress on female albino mice. Aerospace Med. 1966, 37, 804-810.

WELTMAN, A.S., SACKLER, A.M., SCHWARTZ, R. and OWENS, H. Effects of isolation stress on female albino mice. Lab. Anim. Care, 1968, 18, 426-435.

WILSON, C.W.M. and MAPES, R.E.A. The effects of group composition on drug action. Animal Behaviour and Drug Action (Edit. H. Steinberg, A.V.S. de Reuck and J. Knight) London: Churchill, 1964, pp. 238-247 (a).

WILSON, C.W.M. and MAPES, R.E.A. The relationship between group composition and drug action in mice. Psychopharmacologia (Berl.) 1964, 5, 239-254 (b).

WINER, B.J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

WOODS, P.J. The effects of free and restricted environmental experience on problem-solving behavior in the rat. J. comp. physiol. Psychol. 1959, 52, 399-402.

ZIMBARDO, P. and MONTGOMERY, K.C. Effects of 'free environment' rearing upon exploratory behavior. Psychol. Rep. 1957, 3, 589-594.

Addendum

CHANCE, M.R.A. Environmental factors influencing gonadotrophin assay in the rat. Nature, 1956, 177, 228-229.

CHANCE, M.R.A. The contribution of environment to uniformity: variance control, refinement in pharmacology. Coll. Papers Lab. Animals Bur. 1957, 6, 59-74.

CROOK, J.H. Social organisation and the environment: aspects of contemporary social ethology. Anim. Behav. 1970, 18, 197-209.

DENENBERG, V.H. Open field behavior in the rat: what does it mean? Ann. N.Y. Acad. Sci. 1969, 159, 852-859.

DIMOND, S.J. The Social Behaviour of Animals. Batsford, London, 1970.

HALL, C.S. Temperament: a survey of animal studies. Psychol. Bull. 1941, 38, 909-943.

HATCH, A.M., WIBERG, G.S., BALAZS, T. and GRICE, H.C. Long-term isolation stress in rats. Science, 1963, 142, 507.

HATCH, A.M., WIBERG, G.S., ZAWIDZKA, Z., CANN, M., AIRTH, J.M. and GRICE, H.C. Isolation syndrome in the rat. Toxic. Appl. Pharmacol. 1965, 7, 737-745.

KILGOUR, R. An examination of the temperamental and ability characteristics of large farm animals under open field and stress conditions. Unpublished Doctoral Thesis, Univ. of Waikato, 1972.

KING, J.T., PUH LEE, Y.C. and VISSCHER, M.B. Single versus multiple cage occupancy and convulsion frequency in C_3H mice. Proc. Soc. Exp. Biol. Med. 1955, 88, 661.

LANE-PETTER, W. Some behaviour problems in common laboratory animals. Brit. J. Anim. Behav. 1953, 1, 124-127.

LEVINE, S. Maternal and environmental influences on the adrenocortical response to stress in weanling rats. Science, 1967, 156, 258-260.

PORTER, G., SCOTT, P.P. and WALKER, A.I.T. (ed.) Caging standards for rats and mice. Recommendations by the Laboratory Animal Science Association Working Party on caging and penning. Laboratory Animals, 1970, 4, 61-66.

RUSSELL, W.M.S. and BURCH, R.L. The Principles of Humane Experimental Technique. Methuen, London, 1959.

WELTMAN, A.S., SACKLER, A.M., SCHWARTZ, R. and OWENS, H. Effects of isolation stress on female albino mice. Laboratory Animal Care, 1968, 18, 426-435.

YEN, C.Y., STANGER, R.L. and MILLMAN, N. Ataractic suppression of isolation-induced aggression behaviour. Arch. int. Pharmacodyn. 1959, 123, 179.