

## The Open-Field Test: A Critical Review

Roger N. Walsh

*Department of Psychiatry and Behavioral  
Sciences, Stanford University*

Robert A. Cummins

*Department of Physiology, University of  
Queensland, Brisbane, Australia*

Over the past 40 years the open field has evolved as a commonly used tool for the measurement of animal behavior. This review takes a critical look at the use of this instrument, especially with regard to the development of a standard form for its use. The various procedures and their shortcomings are discussed, with particular reference to the seemingly inconsequential details which have been shown to modulate open-field performance per se. Dependent parameters are considered both with regard to their reliability and their validity for the measurement of such underlying constructs as emotionality.

Since its introduction some 40 years ago, the open-field test has attained the status of one of the most widely used instruments in animal psychology. Its popularity probably stems in large part from the simplicity of the apparatus, the easy and rapid measurement of clearly defined behaviors, and a generally accepted interpretation of these behaviors. In addition, certain of the measured behaviors are sensitive to a wide range of genetic, experiential, physiological, and pharmacological manipulations and are sufficiently reliable under standardized conditions to give repeatable measures on an enormous range of independent variables. Simplicity, ease of quantification, and wide applicability are therefore probably the prime determinants of its popularity.

However, in spite of its status as one of the most widely used tests of animal behavior, the open-field test has survived for 40 years with only one major review (Archer, 1973), and this was limited to a consideration of its usefulness for estimating emotionality in rodents. Apparatus, techniques, subjects, parameters, analyses, and interpretations have

diversified enormously, yet in the literature, sweeping generalizations and conflicting interpretations continue to be made on the basis of univariate studies. This paper aims at detailing the many variables involved in testing and their influences on dependent parameters, as well as methods of analysis and interpretation of results. We thereby hope to gain an overview of this area of study, to point out shortcomings of some present work, and to derive implications for future research.

The originator of the open field was Calvin Hall (Hall 1934; Hall & Ballechey 1932), who used defecation in the open field as an index of timidity. However, time has seen a proliferation of other dependent variables. Some 30 have been used at one stage or another, and the number of underlying constructs they supposedly measure has multiplied accordingly. In many cases, however, proof of construct validity has been sadly lacking.

What then is the open field and what, in general terms, does it really measure? In essence, the test consists of the measurement of behaviors elicited by placing the subject in a novel open space from which escape is prevented by a surrounding wall.

The elicitation of these behaviors is dependent upon the interaction of the animal with a variety of test factors such as (a) stimulation as a result of removal from a familiar home environment; (b) stimulation involved in transferring the animal to the open field; (c) exposure to the test environment, consisting of both the open field itself

We would like to express our gratitude to Otto Budtz-Olsen, Burr Eichelmann, Tom Horvath, and Alice Lee for their encouragement, advice, and criticism. Our experimental work and preparation of the manuscript were supported by grants from the Australian Research Grants Committee and the Foundation Fund for Research in Psychiatry.

Requests for reprints should be sent to Robert A. Cummins, Department of Psychology, University of Western Australia, Nedlands, Perth 6009, Australia.

and its surroundings; and (d) all prior experience of the test situation. In effect, this last factor means that one is measuring, among other things, habituation and learning in response to the test environment. Where several test sessions are employed, further factors to be considered include previous stimulation involved in removing the animal from the testing situation, transfer and re-exposure to the home environment at the completion of prior sessions, and modification of home-cage behavior and interaction with other home environment animals.

The magnitude of any particular behavior elicited will therefore be a function of the multiway interaction of these factors. As yet their relative importance is almost completely unknown, but there is evidence to suggest that each factor exerts a differential effect on animals of varying genetic and experiential backgrounds, and this is examined later.

Effectively any behavioral experiment measures responses to the above factors. However, in many studies, such as maze learning, one hopes that the subject will habituate to, and hence be minimally influenced by, aspects of the test situation other than the specific stimulus component being used as the independent variable. In the open-field test, on the other hand, the whole test situation (rather than any one specific stimulus component) is the independent variable, and by its very nature this independent variable must be multifactorial. These factors are now considered under the headings of Techniques and Apparatus Characteristics, Testing Environment, and Procedural Details.

#### TECHNIQUES AND APPARATUS CHARACTERISTICS

The difficulty of finding comparable techniques in the use of the open field has been mentioned previously. Almost every physical characteristic of the apparatus, its surroundings, and every procedural step have been widely varied, so that although standardization may have been established within individual laboratories, there is a disturbing lack of conformity in procedure and results within the literature as a whole.

Looking at the range of techniques employed, one finds that for the apparatus, its size, shape, color, subdivision, wall height, floor texture, odor, nature and location of the starting area, and presence or absence and nature of additional inherent stimuli have all been varied; while for the surroundings the nature, intensity and position of light, sound and odor sources, and the visibility and position of the observer have suffered similarly. In fact it is hard to think of any facet which has not been modified. This difficulty of standardization is compounded by the extreme rarity of reports which cite details of more than a small proportion of relevant procedural variables.

#### *Physical Characteristics of the Apparatus*

The most common shape of the open field has been circular, but square and rectangular designs are also prevalent. The wide range of shapes leads eventually to the question, When is an open field not an open field? The extreme of the rectangular design is usually termed a *straightaway* or a *runway*, yet the behaviors measured may be akin to those employed in the open field (e.g., Poley & Royce, 1970; Zimbardo & Montgomery, 1957). Perhaps in view of the paucity of evidence on the comparability of behavior observed in these devices and in the open field, they are best regarded separately. As yet there would seem to be no data available on the effect of open-field shape on behavior, but in view of the evidence on strain differences in thigmotaxis (or "wall hugging," Valle, 1970) and the tendency of some animals to remain in corners, standardization would seem a sensible precaution.

Different species have naturally been allocated appropriately sized open fields, such as a whole room for human infants (Rheingold, 1969) and a .5-m square field for mice (Manosevitz, 1970). More importantly, however, open-field size has commonly been varied for intraspecies studies, and the effects of such dimensional changes have been shown to exert a significant effect on some aspects of behavior. As a general rule, ambulation would seem to be more susceptible to change in apparatus and environment than would

defecation. Thus, while defecation is largely unaffected by arena size in rats (Broadhurst, 1957, 1958a, 1958b), gerbils (Oldham & Morlock, 1970), but not male C3H mice (Nagy & Forest, 1970), ambulation increases with increasing field size in rats (Broadhurst, 1957; Montgomery, 1951), mice (Blizard, 1971; Krsiak & Janku, 1971; Nagy & Forest, 1970), and gerbils (Oldham & Morlock, 1970). Large field size has been reported to produce a disproportionately large increase in ambulation under conditions of low illumination (Blizard, 1971).

An example of the difficulties of comparison where different apparatuses are used is afforded by Clark, Gorman, and Vernadakis (1970), who tested ambulation of the offspring of mothers injected with amphetamine or chlorpromazine. Treatment effects were found on Days 13-21 but not on Days 46 and 60, and the results were interpreted as being due to differential maturation rates (an Age  $\times$  Treatment interaction hypothesis). However, since two different field sizes were used for the infant and adolescent animals, an interaction between treatment and field size was also possible.

Color has ranged through white (Oldham & Morlock, 1970) to black (Delbarre, Dumas, & Guionniere, 1970), and the material composing the field, particularly the floor, has included wood, metal, concrete, rubber, and even glass (Satinder, 1968). There is almost no evidence as yet on the effect of these variables on behavior, but in view of the evidence for the effects of similarity of test environment to rearing environment on exploratory behavior (Nielson, 1970; Wells, Lowe, Sheldon, & Williams, 1969), some of these variables may be of particular relevance when testing animals with differential rearing histories.

Most commonly, the open field has been bare but occasionally experimenters have added objects, usually with the aim of obtaining a measure of interaction with these additional stimuli. The number of these objects has ranged from 2 (Ehrlich & Burns, 1958) to 15 (Furchtgott, Wechkin, & Dees, 1961) and they have usually been small solid objects, such as nuts and bolts, door stops, and

mirrors. However, the more exotic have included caged rats, flashing lights and loudspeakers (Ehrlich & Burns, 1958; Fox & Spencer, 1969), food pellets (Jarrard & Brunnel, 1968), designs painted on the floor and walls (Wimer & Sterns, 1964); and Rheingold's (1969) study of human infants included toys and the subject's mother or another person (basically a social facilitation study). The relevant dependant parameters are most commonly the number of approaches and time spent investigating the objects, and sometimes preference scores for particular objects.

#### THE TESTING ENVIRONMENT

Characteristics not only of the open field itself but also of its surroundings infringe upon the subjects and modify behavior.

The level of illumination has been the variable most closely examined; but in spite of repeatedly demonstrated effects, fewer than one third of the articles mention the test lighting used. With the exception of Candland and Nagy (1969), who reported the reverse, it has consistently been found that high levels of illumination are associated with diminished locomotor behavior. Valle (1970) found that ambulation, rearing, and thigmotaxis were all less under higher illumination.

A number of interactions of illumination level with other independent variables have been reported. Thus, Livesey and Egger (1970) found that ambulation was less under an illuminance of 9.3 lx than 0.005 lx in rats at 47 or 115 days of age but not at 18 or 24 days. Testing C57 BL/6J mice, Nagy and Glaser (1970) found no main effect for illumination (9.3 lx versus 0.09 lx) but found significant interactions between level of illumination, age of subjects, and day of testing. Under high illumination, there were no reliable activity differences due to age, while under low levels, 100-day-old subjects were more active than 50-day-olds. The subjects were less active under high than under low illumination on Days 1 and 2 of testing but not thereafter, suggesting that for the C57 BL/6J strain, illumination effects are largely transitory. Interactions with strain have been reported by McClearn (1960) and by Dixon

and Defries (1968b), who also found albinos to be more photosensitive than pigmented rats. Interaction with prior visual rearing environment (dark, alternating light-dark, or light in black, white, or patterned cages) was noted by Sachett (1967).

Another commonly studied dependent parameter of illumination has been defecation, and with some exceptions (Blizard, 1971); no significant main effect has been reported (Nagy & Forest, 1970; Nagy & Glaser, 1970; Nagy & Holm, 1970). This result seems unexpected in terms of much current thinking which considers high illumination as "stressful" and defecation as the prime index of emotionality.

A disadvantage of the available studies of illumination is that they include only two, or at the most three levels, so that the precise relationship with the magnitude of the observed behavior is quite unknown.

Less study has been made of ambient noise and few papers refer to it. Presumably, therefore, in most cases it comprises merely the background noise of the test room, but white noise, most commonly of about 80 dB (e.g., Eysenck & Broadhurst, 1964; Ivinskis, 1968), has sometimes been superimposed. Its addition has usually reduced locomotion (e.g., Bindra & Spinner, 1958), but Livesey and Egger (1970) reported that white noise of 90 dB increased both ambulation and defecation. Certainly any abrupt loud noise can markedly inhibit locomotion and even induce *prolonged immobility in a variety of species* (Hofer, 1970; Cummins, Walsh, & Budtz-Olsen, Note 1).

Environmental odors have largely been ignored, although several experimenters have washed their apparatus with a variety of agents in order to obviate possible biasing effects of odor trials left by previous subjects. Whittier and McReynolds (1965) found this to be a significant effect for the test behavior of mice. However, Satinder (1969) found that the time spent by a rat on the side of the open field which had been occupied by its predecessor was significant only for males preceded by females. Interestingly, urination or defecation by the predecessor was without effect.

McCall (1969) has demonstrated the importance of odor for what he termed the "caretaker effect." It was found that rats tended to spend more time on the side of the field nearest to the caretaker, who had reared them, than on the side opposite where there was another experimenter, who had no previous experience with them. This effect was shown to be dependent on olfactory rather than visual cues. The visibility and behavior of the experimenter during testing have rarely been mentioned. Presumably, therefore, in most test situations he is visible to the subject except where observation is from behind a screen (e.g., Nielson, 1970) or a one-way mirror (e.g., Fox & Spencer, 1969). This hiding would seem a wise precaution, since although no precise studies of the effects of experimenter visibility are available, it is quite obvious that any visible abrupt movement may cause inhibition of ongoing activity and in some cases prolonged immobility (Cummins et al., Note 1).

#### PROCEDURAL DETAILS

As is obvious from the foregoing discussion, careful measurement can detect changes in behavior due to very small changes in the apparatus. It is therefore regrettable that there has been almost no study of the effects of variation in testing procedure. Testing normally consists of removing the animal from its home environment, carrying it to the test area, and placing it in the open field. The carrying can be done either by hand or via a start box. Testing itself may vary on a number of temporal factors, such as the duration of exposure to the open field and the inter-trial interval. It would be surprising if changes in these procedures did not measurably affect open-field behavior.

Details of the animal's removal from the home cage and transfer to the open field are seldom reported, so that presumably they are usually transported by hand. However, some workers aiming to reduce handling stress have employed transport compartments, such as a box (Nielson, 1971; Tighe, 1965), tube (Dixon & Defries, 1968a), or transparent cup (Hofer, 1970). In some cases, the subjects have been habituated to a transport compart-

TABLE 1  
CLASSIFICATION OF OPEN-FIELD-DEPENDENT  
PARAMETERS

- I. Behavior
  - A. Whole or major body movement
    - 1. Type of movement
      - a. Distance covered per unit time
      - b. Time spent in ambulation
      - c. Rearing frequency
      - d. Escape attempts
      - e. Latency (usually time taken to leave start area)
      - f. Time spent without movement
    - 2. Locations
      - a. Field area visited (inner or peripheral areas, corners, etc.)
      - b. Affiliation (distance from partner subject)
      - c. Stimulus interaction (e.g., distance from stimulus object)
  - B. Part body movement
    - a. Manipulation of objects
    - b. Sniffing
    - c. Scratching
    - d. Digging
    - e. Teeth chattering
    - f. Grooming
    - g. Vocalization
    - h. Visual exploration
- II. Autonomic nervous system
  - a. Defecation
  - b. Digestive transit time
  - c. Urination
  - d. Heart rate and rhythm
  - e. Respiratory rate
- III. Adrenal activity
  - a. Adrenal ascorbic acid
  - b. Serum corticosteroids
- IV. Electrophysiology
  - a. Hippocampal theta activity
  - b. Electromyogram activity

ment and carrying procedure prior to testing (e.g., Nielson, 1970). Such familiarization may increase the levels of ambulation at the start of an open-field trial (Abel, 1971).

Once transported, the animals may be placed either in the center of the open field (e.g., Clark et al., 1970) or against the retaining wall (King, 1970). In this context it is interesting to note Satinder's (1969) finding that rats tend to remain on that side of the field on which they are originally placed.

Individual trial durations are usually short (Krsiak & Janku, 1971), but trials of 1 hour

have been employed by Block and Essman (1965). Many workers measure only total behavior for each trial (intratrial time unit equals trial length), thus relinquishing any possibility of studying intratrial temporal patterns of behavior. Some go a stage further, measuring only total behavior over all trials. These practices sacrifice a considerable amount of available information, and their disadvantages are detailed in the discussion on temporal analysis of behavior. Many experimenters employ only one trial, a procedure of doubtful value in view of the difficulties of interpretation indicated by Whimbey and Denenberg (1967), who found a change in factor loading of ambulation from Day 1 to Day 2. Multiple trials avoid this criticism and afford greater reliability and the opportunity of temporal analysis. Those who give several trials seldom use more than 4, but up to 60 have been used (Bronstein, 1972). Where multiple trials are given, the question of the optimal intertrial interval arises; but most commonly, 24 hours has been chosen, partly from convenience but also since this obviates complications of diurnal rhythm.

Almost no study seems to have been performed on the effects of varying these temporal factors. However, Battig (1969) found that patterns of activity were unaffected by exposure to the apparatus 2 hours previous to the experiment, but that intertrial intervals of 3 and 12 minutes produced a mild inhibition of ambulation on subsequent testing.

#### DEPENDENT PARAMETERS

The number of dependent variables used to assay open-field behavior has grown substantially since the early work of Hall (1934), until now over 30 are listed. This list (see Table 1) is mostly comprised of behavioral measures, although recently some physiological parameters, such as heart and respiration rates, electromyogram recordings, and plasma steroid levels, have also been included.

As can be seen from Table 1 most parameters have been varieties of motor behavior, and of these, measures of ambulation have been most favored. This is presumably because of the ease of quantification and the evident face validity for interpretive con-

structs of exploration and arousal. Amount of ambulation has usually been scored spatially by the number of subdivisions entered, but has also been estimated temporally by the proportion of time spent in ambulation. It has also been quantified according to characteristics of its apparent aim, locality, and latency. Thus, ambulation directed toward escape has been measured by Ehrlich and Burns (1958), who scored an escape attempt if the subject got its head and forefeet over the wall of the field.

Ambulation has also been scored according to its locality, the most frequently used regional divisions being either inner or peripheral areas of the apparatus (Ehrlich & Burns, 1958; Ivinskis, 1968). Occupancy of the peripheral areas, either in corners (Morrison & Thatcher, 1969) or near walls (Valle, 1970), has been used as an index of timidity.

Locality of ambulation has also been used as a measure of interaction with either inanimate objects or other subjects. Fox and Spencer (1969) measured object interaction by the frequency and duration of activity occurring within the same square as the object. In addition to these measures, McCall, Lester, and Dolan, (1969) noted any qualitative differences in the animals' responses to the objects. These included the approach behavior to the object and the exploration of the object itself. Where conspecifics have been used instead of inanimate objects, measures of "affiliation" (Latané, Cappell, & Joy, 1970) have been obtained by scoring the average distance between the animals and the time spent in direct contact with one another.

Activity can also be scored by its absence. Here the two major parameters are identified by the terms *latency* and *freezing*. Latency is measured by the time taken from the start of a trial to the occurrence of a certain type of behavior. Theoretically, the latency of an arbitrary amount of any dependent parameter might be used, but open-field studies have mercifully confined themselves to a relatively small number, usually involving ambulation. Most commonly, latency to leave the start area has been used (Ivinskis, 1968; Poley & Royce, 1970). However, latency to reach the center from a peripheral starting

position (King, 1970) and latency to reach the periphery from the center (Tobach, 1966) have also been measured.

The other open-field parameter measuring the absence of activity is *freezing*, defined as the absence of movement. This is a widely used parameter usually taken as indicative of a high-stress state. Certainly it is a behavioral response which occurs across the phylogenetic scale in the face of perceived danger; elements such as abrupt change, environmental dislocation, physical restraint, and presence of predators are particularly potent eliciting factors. In the open field, freezing in response to stimuli such as the above shows a marked species specificity and has been recorded as sometimes lasting for over 1 hour. It has also been found to be associated with marked tachypnoea, bradycardia, and vagotonic cardiac arrhythmias (Hofer, 1970).

Another cause of prolonged immobility is of course sleep, and the not infrequent occurrence of apparent sleep has been noted by Fox and Spencer (1969) and Cummins et al. (Note 1). Fox and Spencer observed that dogs liable to apparent sleep were extremely inactive and that they would often defecate, urinate, and shiver when placed in the start box. Once apparently asleep they were easily roused by a sudden noise but would then appear to promptly fall asleep again, and the authors suggested that this might possibly represent displacement sleep as a result of intense arousal. Similar apparent sleep has been noted in rats by Cummins et al. (Note 1), sometimes associated with apparent shivering, which might actually be a result of the marked tachypnoea observed in subjects during immobility (Hofer, 1970). Against the suggestion of this apparent sleep being the direct result of hyperarousal is the fact that its frequency increases with increasing time elapsed within and between trials. This time course is more in accordance with that of habituation, and in point of fact, it has frequently been observed that habituation of an arousal reaction may be accompanied by the rapid onset of drowsiness and sleep (see Lynn, 1966, for a review). Paradoxically, a generalized orientation reaction may be easily elicited during this drowsy phase. Subjectively, it seems possible to differentiate the

immobility following sudden threat from that of apparent sleep by such features as the abruptness of onset, wide-open eyes, and muscular rigidity in the former case, as opposed to the gradual development, closed eyes, and relaxed posture accompanying apparent sleep. Perhaps the two behaviors represent examples of the startle reaction and habituation of the arousal reaction, respectively.

One test of this hypothesis might be the use of electroencephalograph (EEG) recording, since the orientation reaction is accompanied by hippocampal theta rhythms, whereas hippocampal desynchronization accompanies the startle reaction—an interesting example of electrophysiological data differentiating two behaviorally similar responses. In summary then, immobility in the open field has been regarded as indicative of high stress but may actually confound two distinct behaviors.

Another widely used measure of activity has been rearing and has proved a reliable (Ivinskis, 1968) and valuable measure. Combined with ambulation it has proved to reflect a stable individual trait, "nonspecific excitability level," which has been significantly correlated with hippocampal slow wave activity as well as with a variety of other behaviors. This measure also displays systematic variations with individual differences in somatic functions such as growth rate, body temperature, caloric intake per surface area, qualitative food preference, and endocrine functions (Lát & Gollová-Hemon, 1969; Martinek & Lát, 1969). However, attempts other than the above to systematically link rearing with other variables have been rare, and it is most frequently taken at face value as an index of activity.

As might be predicted, sitting has been found to be more frequent during conditions associated with low levels of activity and to be negatively correlated with ambulation, rearing, and sniffing (Prescott, 1970). A summary of the influences exerted by different experimental procedures on whole body movement and defecation can be seen in Table 2.

With the exception of defecation, parameters other than whole body movement have been less closely studied and in many cases have been cited in very few reports. These

include scratching, digging, teeth chattering, respiration, electromyograph (EMG), digestive transit time, cardiac rhythm, and EEG measures. Of these part body movement measures, sniffing has been relatively common and has generally been taken as an index of exploration. It has also proved a useful co-index for nonspecific excitability, although a less adequate one than either ambulation or rearing. The terms *scratching* and *digging* probably refer to essentially the same behavior evinced under conditions of hard and loose flooring material, respectively. Prescott (1970) found that greater amounts of digging in the sawdust floor of the open field were associated with other evidence of high-activity states. Teeth grinding was used by Hughes (1969) as a possible indicator of anxiety on the rationale that it may represent a "tooth sharpening defensive behavior." Respiration and EMG were used by Hofer (1970) in her studies of prolonged immobility and have been mentioned previously. *Grooming* and *washing* are terms describing the same behavior and have been found to be of relatively low reliability (Ivinskis, 1968) and to be negatively related to indexes of high-activity states (Prescott, 1970). *Vocalization* has been taken as another indication of distress, and the vocalization emitted on placing an animal in the open field has sometimes been termed *distress calling* (e.g., Candland & Nagy, 1969). Candland and Nagy have suggested distress calling as the major index of emotionality in species for whom the normal indexes of defecation and ambulation are not reliable, such as the cat and domestic fowl, although Martinek and Lát (1969) found that it was not a reliable measure in dogs.

Possible parameters of autonomic nervous system function are legion, but in practice they have been limited to the more easily measurable ones of excretory and cardiac function. Defecation, the parameter for which the open field was designed, remains as one, if not the most widely used, measure and remains as the prime index of emotionality, a role whose validity has been confirmed by factor-analytic studies (Whimbey & Denenberg, 1967). A related, but uncommon, measure is digestive transit time, defined as the

time interval between consumption and first appearance of a fecal staining agent such as chromic acid. Not surprisingly, digestive transit time and amount of defecation would appear to be negatively correlated. These two parameters have been used by Tobach (1966) to demonstrate that open-field testing elicits a significantly greater effect than the manipulative procedures involved prior to actual testing. The third excretory measure, urination, has been scored by frequency, presence or absence, or amount and has occasionally been combined with defecation to yield a composite elimination score (Tobach, 1966), but in any form has failed to yield reliable results in a variety of species (Ivinskis, 1968; Manosevitz, 1970; Martinek & Lát, 1969).

Cardiac measures have been used little except by Hofer (1970), whose study has previously been mentioned, and by Candland and Nagy (1969) in an attempt to validate the use of the two most commonly used indexes of emotionality, ambulation and defecation. The CFE strain of rats were exposed to the open field for 21 minutes for 30 days and compared with home caged animals. Cardiac rate and defecation were greater in the open field, but whereas defecation declined over trials, there was no similar adaptation of cardiac rate, although the rate did fall within trials. Furthermore, there was no significant correlation between heart rate and defecation, so that although both changed in stable fashions and were both considered as indexes of emotionality, they changed in largely independent ways.

Recent years have begun to see the application of physiological techniques to the open field, a movement which would seem to have immense potential for expanding the scope of studies of reactions to novel environments, for behavioral-physiological correlation, and for validity testing of parameters and behavioral constructs. The examples of respiration and cardiac rate have previously been discussed, which leaves biochemical and electro-physiological parameters.

The number of biochemical parameters of potential interest is boundless, but studies have as yet been largely restricted to assays of adrenal function. This interest stems from the long-held view of the interrelatedness of

adrenal gland function and emotional behavior. However, studies have shown little relationship between open-field behavior and adrenal weight or steroid output, and as yet adrenalectomy has yielded inconsistent or negative effects in the rat, mouse, and hamster (Fuller, Chambers, & Fuller, 1956; Moyer, 1958; Paul & Havlena, 1962). Pare and Cullen (1965) were unable to detect consistent relationships between adrenal ascorbic acid levels and open-field behavior, and similar negative findings were reported by Ader (1969) for plasma and adrenal corticosterone in hooded and albino rats. Furthermore, although there was a significant effect across trials for ambulation, defecation, and latency, there was no such change in plasma corticosterone levels sampled 15 minutes after each test. Ader concluded that the data provided no evidence for a relationship between open-field behavior and adrenal function.

In contradistinction to this is the report by Levine, Haltmeyer, Karas, and Denenberg (1967) of greater plasma corticosteroid levels in nonhandled than in handled subjects 15 minutes after testing. There was no change, however, in these corticosteroid levels across the 4 days of testing, and the immediate post-test steroid levels did not differentiate the two treatment groups. This difference in ability of the steroid levels to differentiate the handled and nonhandled subjects at 0 and 15 minutes after testing can probably be explained in terms of the differences which Levine has consistently noted in the time course of adrenal response in these two groups. However, plasma corticosteroid levels also failed to differentiate between enriched and isolated C57BL/6J mice or to correlate with defecation or adrenal weight changes in a study by Denenberg, Wehmer, Werhoff, and Zarrow (1969). It would therefore seem that plasma steroid estimates represent a potentially useful tool but that their relationship to other open-field measures is as yet unsettled. Future studies will probably require a temporal analysis of the adrenal response after testing, rather than the simpler but less informative method of sampling only immediate or maximum (approximately 15 minutes after testing) levels.

TABLE 2  
EFFECTS OF OPEN-FIELD DESIGN, TESTING ENVIRONMENT, AND GENETIC BACKGROUND

Independent variable	Study	Subject	Parameter	Effect
Increased open-field size	Broadhurst (1957, 1958a, 1958b)	Rat	Defecation	0
	Oldham & Morlock (1970)	Gerbil	Defecation	0
	Montgomery (1951)	Rat	Ambulation	↑
	Broadhurst (1957)			↑
	Nagy & Forest (1970)	Mouse	Ambulation	↑
	Blizard (1971)			↑
	Krsiak & Janku (1971)			↑
Increased illumination	Oldham & Morlock (1970)	Gerbil	Ambulation	↑
	Naby & Forest (1970)	Mouse	Defecation	0
	Nagy & Glaser (1970)			0
	Nagy & Holm (1970)			0
	Blizard (1971)			↑
	Valle (1970)	Rat	Ambulation	↓
	Livesey & Egger (1970)			↓ only after 24 days of age
	McClearn (1960)	Mouse	Ambulation	↓ albinos more than pigmented
	Dixon & Defries (1968b)			↓ albinos more than pigmented
	Candland & Nagy (1969)			↓
Nagy & Glaser (1970)			↓ only on Days 1 and 2 in 100- but not 50-day-olds	
Environment noise White noise	Bindra & Spinner (1958)	Rat	Ambulation	↓
	Livesey & Egger (1970)			↓
Abrupt noise	Hofer (1970)	Rat	Immobility (freezing)	↑
	Cummins, Walsh, & Budtz-Olsen (Note 1)			↑
Odor	Whittier & McReynolds (1965)	Mouse	Location of ambulation	↑ ambulation in areas in which prior subjects had ambulated
	Satinder (1969)	Rat		As above but significant only for males preceded by females
	McCall (1969)			"Caretaker effect"—time spent on side of open field nearest to a familiar caretaker

TABLE 2—(Continued)

Independent variable	Study	Subject	Parameter	Effect
Intratrial temporal analysis	Broadhurst & Eysenck (1964)	Rat	Ambulation	↓—quadratic trend
	Cummins, Walsh, & Budtz-Olsen (Note 2)			↓—quadratic trend
	Woods, Ruckelshaus, & Bowling (1960)			↓—linear trend
	Oldham & Morlock (1970)	Gerbil		↓—linear trend
	Candland & Nagy (1969)	Cat		0 change—ambulation described as nonexploratory pacing
	Collins (1966)	Mouse	Defecation	↓ across six trials, inverted U over 10 days
	Nagy & Glaser (1970)			
	Bronstein (1972)	Rat		↓
	Broadhurst (1969)			↓
	Cummins, Walsh, & Budtz-Olsen (Note 1)			↓
	Furchtgott, Wechkin, & Dees (1961)			↑
	Ader (1969)			↓ from Day 1 to Day 2 but then ↑
	Ehrlich & Burns (1958)	Ferret		↓
	Manosevitz (1970)	Mouse	Ambulation	↓ across trials
	LaBarba & White (1971)			↓ across trials
	Dixon & Defries (1968a)			↓ across trials
	Nagy & Holm (1970)			↓ across trials
	Nagy & Glaser (1970)			↓ across trials
	Ader (1969)	Rat		↓ linear trend
	Broadhurst & Eysenck (1964)			↓ quadratic trend
	Cummins, Walsh, & Budtz-Olsen (Note 1)			↓ quadratic trend
	Furchtgott, Wechkin, & Dees (1961)			0
Martinek & Lát (1969)	Dog		↓ both studies show reliable	
Lát & Gollová-Hemon (1969)			↓ individually specific rates of decrease across trials	
Candland & Nagy (1969)	Cat		0	
Candland & Nagy (1969)	Domestic fowl		↑	

OPEN-FIELD TEST

Possibly electroencephalographic measures represent some of the most useful and fascinating parameters of the future. As yet they are a novelty, but the success of the Czechoslovakian workers Lát and Gollová-Hemon (1969) in relating hippocampal theta activity to behavioral open-field measures augurs well for this and other electroencephalography.

#### RELIABILITY OF OPEN-FIELD VARIABLES

As yet there have been very few studies of the reliability of the many variables in use. This represents a very disturbing state of affairs, since unless a parameter can be shown to possess a satisfactory degree of reliability and hence to be a stable characteristic of individual subjects or situations, its usefulness is almost nil. Fortunately, the most widely used variables, ambulation and defecation, have been found to possess acceptable reliability in several species. However, ambulation yields a complex pattern of test-retest correlations because it is a factorially complex parameter, loading on both exploration and emotionality, yet changing the direction of its loading on emotionality from positive on Day 1 to negative thereafter (Whimbey & Denenberg, 1967). While correlations of Day 1 ambulation with scores of subsequent days are satisfactory (about .5), they are lower than the intercorrelations between other days.

Ivinskis (1968) studied a variety of variables measured in several ways. Albino and hooded rats were tested over four daily trials, and albinos were retested in the same way 63 and 217 days thereafter. In examining the test-retest reliability of variables for the albino group, scores were averaged over 4 days, and it was found that ambulation and the frequency of both defecation and washing yielded product-moment correlations greater than .4 ( $p < .01$ ) over the 217 days. The frequency of rearing, latency to leave the center circle when initially placed there, and duration of washing all yielded coefficients of .34 ( $p < .05$ ) or above. This left all three measures of urination (frequency, presence or absence, and amount in milligrams), duration of rearing, and inner circle ambulation with very low and quite nonsignificant correlations. A further test was provided by an

odd-even correlation. Scores were summed across Days 1 and 3 and across Days 2 and 4 and correlated for both strains separately. Coefficients for ambulation with both defecation and rearing scores were .68 or above for both strains, while frequency and duration of washing were reliable for albino but not for hooded subjects. All other variables failed to display acceptable reliability.

Somewhat similar findings have been reported by Martinek and Lát (1969) in their study of the long-term stability of individual differences in exploratory and other behavior and the rate of habituation in dogs. The subjects were given 10 trials of 10 minutes' duration each spread over 2 days and were then retested in a similar manner approximately 300 days later. Ambulation proved satisfactorily stable, with the combination of ambulation, rearing, and sniffing giving the highest reliability even though sniffing alone proved insufficiently reliable. Vocalization, defecation, urination, and body position (standing, sitting, lying) all proved inadequate. Furthermore, the rate of habituation of the combination of ambulation, rearing, and sniffing, given either by the regression coefficient or by the relative difference between first and last trials on a day, was also found to be stable. This study of the stability of habituation has been further expanded by Lát and Gollová-Hemon (1969), who reported that habituation curves show clear intrinsic oscillations whose size represents a stable individual characteristic. The sum of these oscillations has been termed a *lability score* and a correlation coefficient of .77 ( $N = 20$ ) was found when retesting was performed after 2 months in a different situation.

Thus, there would seem to be evidence for the reliability not only of the total magnitude but in some cases also for the rate and intrinsic oscillations of habituation of certain behaviors. Ambulation, rearing, and defecation would seem to afford adequate reliability, while urination, sniffing, body position, and inner circle ambulation would seem to be definitely inadequate; and a number of others, such as washing and latency to leave the central circle where initially placed, must be viewed as only marginally reliable. How-

ever, these few variables represent less than a third of those reviewed in this paper, so that it is obvious that most of the remainder must as yet also be viewed with suspicion. It is interesting to note the apparent strain differences in the reliability of the washing measures (Ivinskis, 1968), which suggest that due care must be exercised in extrapolating the reported reliabilities to subjects of other genetic and experimental backgrounds. Also interesting is Ivinskis' finding that different measures of the same behavior gave comparable coefficients. It is disturbing to note the unacceptably low reliabilities of many of the parameters which have been tested and to reflect on the probable unacceptability of the reports employing them. These low reliabilities may partially account for the plethora of inconsistent findings which fill the literature.

#### TEMPORAL ANALYSIS OF OPEN-FIELD BEHAVIOR

It was mentioned in the discussion on techniques that testing may consist of more than one trial and that these trials may be subdivided into intervals, thus allowing temporal analysis and effectively adding another dimension to the behavioral study. Many workers measure only total behavior per trial or even total behavior over all testing. This failure to perform temporal analyses within and between trials effectively collapses results across two dimensions and hence the worker tends to view behavior as static rather than as constantly changing, as an event rather than as a process, and partially ignores the effect of prior exposure to the apparatus. In so doing, the analyses must result in a diminished sensitivity, since the subjects may differ in their behavior only at certain phases of testing. The failure to perform temporal analyses also results in the discarding of an immense amount of information including the possibility of studying the nature, rate, and lability of habituation—characteristics whose individual stability and importance have been clearly demonstrated (Lát & Gollová-Hemon, 1969; Martinek & Lát, 1969). Occasionally where an experiment calls for the manipulation of multiple independent variables, the discarding of temporal analyses may confer

some advantage in obviating the difficulties of interpreting higher order interactions, but against this must be weighed the disadvantages listed above.

Intratrial temporal analyses have been less frequent than those across trials and have largely been limited to ambulation. The general pattern for a variety of species seems to be a decreasing frequency of ambulation across intervals within trials. This decreased rate may either remain approximately steady (linear trend) or diminish exponentially from an initially relatively high value (quadratic trend). The latter trend has been reported in both male and female rats of the Maudsley Reactive and Nonreactive strains by Broadhurst and Eysenck (1964) and in young White Leghorns (*Gallus domesticus*). The former linear trend has been noted by Oldham and Morlock (1970) in Mongolian gerbils and in Sprague-Dawley rats (Woods, Ruckelshaus, & Bowling, 1960).

Studying vocalization in the cat, Candland and Nagy (1969) found differences in intratrial trends to be a function of age. Kittens showed a marked intrasessional decline over 10 minutes but did not reach the considerably lower levels of the adult cats, whose vocalization diminished only slightly. In view of the absence of defecation and the apparently nonexploratory nature of ambulation (subjects paced backwards and forwards near the unit door without any apparent exploratory intent), the authors suggested that vocalization might yield a better index of emotionality in this species than the traditional measures.

Studies across trials have been more extensive than those within trials. The varieties of statistical analysis are of course limited by the number of trials. The simplest and most common analysis has been determination of the significance level of intertrial differences. A more informative method is trend analysis, and where several trials are used, it is possible to examine not only the general trend but also the nature, magnitude, and periodicity of trend fluctuations.

Once again ambulation has most often been studied and a variety of patterns has been noted. Consistency has been greatest in the

mouse where the majority of workers have reported decreasing ambulation across trials. This has been reported as a significant effect for subjects reared under enriched and standard colony conditions (Manosevitz, 1970), in small or large litters (LaBarba & White, 1971), and for BALB/c.J and C57BL/6.J inbred mice and their reciprocal F1 hybrids at several ages (Dixon & DeFries, 1968a). Ambulation decreased across 4 days in handled and unhandled C3H mice tested under high or low illumination at 50, 70, or 100 days of age (Nagy & Holm, 1970). This report furnishes an example of the added sensitivity and information afforded by inter-trial analysis, since although the main effect for handling was not significant, a number of its interactions with trials were. Thus, 50-day-handled subjects were more active than controls on the first day, but their ambulation decreased more rapidly such that it was less than the controls on Days 3 and 4, and this pattern was different at the three ages. Similar examples are available in the study of Nagy and Glaser (1970), who demonstrated a significant (apparently asymptotic) decline across 10 days in C57BL/6.J mice.

Less consistent results have been obtained with the rat, although a decrease across days has been most often reported. This has sometimes been linear (Ader, 1969) or apparently quadratic (Broadhurst & Eysenck, 1964) where a decrease was reported from Day 1 to 2 which was partially recouped on Days 3 and 4. Broadhurst and Eysenck hypothesized that inhibition may account for the initial intertrial reduction as well as the intra-trial decline already discussed, while reduction of fear may account for the increase in ambulation across Days 3 and 4. The rate of decrease was heightened by prior rearing in a complex environment, a finding attributed to a more rapid habituation of the arousal response to novel stimuli (Walsh & Cummins, in press; Cummins et al., Note 1). Barrett and Ray (1970) and Valle (1971) found that young rats become more active across trials, but other workers have found no significant intertrial change (e.g., Furchtgott et al., 1961). Thus, every possi-

ble change—increase, decrease, or none—has been reported.

Other species have been less closely studied. In the dog, Martinek and Lát's (1969) finding of individually reliable decreases in ambulation across trials has already been discussed, but Fox and Spencer (1969) found that exposure to the field some weeks previously resulted in modest increases. Neither kittens nor adult cats displayed any significant change across 10 days, while the domestic fowl showed a dramatic increase in spite of consistent decreases within trials (Candland & Nagy, 1969).

Latency to leave the starting unit was found to increase across 3 days in rats of various ages (Furchtgott et al., 1961). A more complex picture was noted by Ader (1969) when latency fell markedly from Day 1 to 2 but then increased slightly over the next 2 days. Latency declined across 5 test days in ferrets (Ehrlich & Burns, 1958) and there was a similar trend for both rearing and scratching, while vocalization declined over 6 days in adult cats but not in kittens (Candland & Nagy, 1969). On the other hand, sniffing by rats increased across 3 days, though this was dependent on the age of the subject (Furchtgott et al., 1961).

Cross-trial studies of defecation have been almost entirely limited to the mouse and the rat, and once again only three or four trials has been the norm. However, within these limitations there would seem to be consistent evidence of species differences in trend, for while the rat shows a lessening in defecation across days (a pattern that has been accepted as the norm and the basis for hypotheses building both within and between species), the mouse displays the opposite trend. This decrease in the rat has been widely reported, thought not without exceptions (Ader, 1969), and has been confirmed over as many as 60 trials (Bronstein, 1972). Furthermore, this decrease has been shown by Broadhurst (1969) to have a clear genetic component with a high average level of dominance, with the suggestion that natural selection will tend to favor low-scoring strains resistant to change across trials.

For the mouse on the other hand (practically the only other species for which evidence is available, indicating the reliability of the defecation measure), there has been a high degree of consistency between reports on intertrial trends. Thus, defecation has been found to increase across as many as six trials (e.g., Collins, 1966). These studies afford an interesting example of the oversimplification which may result from taking a relatively small number of levels of any factor under investigation, for when the number of trials was increased to 10 (Nagy & Glaser, 1970), it was found that the trend could now be identified as an inverted U with the number of boluses increasing through to Day 6 followed by a decrease over the remaining 4 days. The marked consistency existing between studies of intertrial changes in defecation has recently become explicable in light of a quantitative genetic analysis of open-field behavior in mice by Defries, Hegman, Ross, and Howard (1969). It was found that change in defecation displayed as high a degree of heritability as did the daily and total scores. In spite of a similarly high consistency between reports on change in mouse ambulation, genetic influence on change in this measure was found to be considerably less than for either daily or total scores or for any of the defecation scores.

Interpretations of temporal changes in open-field behavior have varied with the parameter under study and the meaning attached to it by the experimenter. Thus, for example, the cross-trial decrease in ambulation and defecation in the rat has been taken as indicating a diminution in emotionality, anxiety, fear, escape attempts, and territorial marking, or at the more general level, of the development of inhibition or habituation. However, in conjunction with any interpretation must be an awareness that the placement of a subject in an originally novel environment must elicit an orientation reaction which subsequently habituates. One might conceive of this reaction as a high-order factor in a psychophysiological construct hierarchy, modulating multi-determined lower order constructs such as fear, anxiety, territoriality, and the like, which would in turn modulate the even more

overdetermined specific behaviors observed in the open field. The precise nature and magnitude of the changes in these behaviors will of course be determined by the genetic-experiential background of the individual, but any attempt to explain temporal behavioral changes must certainly incorporate the concepts of orientation reaction and habituation.

#### INTERRELATIONSHIPS AMONG DEPENDENT PARAMETERS

It has long been known that many dependent variables in the open field correlate significantly with one another. This is all the more to be noted since some positively correlated behaviors are mutually exclusive (ambulation and rearing) and hence their degree of relatedness is presumably underestimated by simple correlation.

A basic deduction from these correlation studies has been that many parameters tend to measure the same psychophysiological state and as such have provided several useful implications. First, such correlations allow for validity testing, since the patterns of behavior serving as assays for altered psychological states should be predictable under diverse conditions. Second, they may afford an increased sensitivity and reliability of measurement. At the same time, they may also allow an economy of measurement because where parameters are highly correlated, one may well dispense with some of them. Thus, Lát and Gollová-Hemon (1969) were able to dispense with measures of sniffing and cleaning in the knowledge that a weighted sum of ambulation and rearing would still yield an adequate correlation with hippocampal theta activity.

Not surprisingly the correlation between ambulation and defecation scores has most often been studied. Since Hall's (1936) report there has been a high degree of consistency in the literature affirming a negative relationship between these measures in the rat. In the mouse a similar trend has most often been noted, and this in spite of the previously mentioned increase in defecation across days. More detailed studies in this species, however, have begun to reveal some of the complexity of the relationship, and

in a diallel study, Bruell (1967) found a positive significant correlation ( $r = .124$ ) in males, with a negative and equally significant correlation ( $r = -.159$ ) in females.

The relationship has been less frequently studied in other species and has almost always yielded nonsignificant correlations, especially for species in which defecation has been found to be an unreliable measure (e.g., Candland & Nagy, 1969).

In the vast majority of cases, correlation has been performed between scores totaled over all trials. However, considerably more light has been afforded by recent studies which have examined the relationships between scores obtained on individual trials. Nagy and Glaser (1970) divided C57BL/6.J mice into high and low ambulators and studied the cross-trial patterns of defecation under a variety of ages and illuminations. High and low ambulators did not differ in defecation on Day 1, but thereafter the low subjects defecated significantly more; and their defecation continued to rise until declining from Day 6, whereas high ambulators defecated maximally on Day 2. Meanwhile, ambulation decreased steadily in both groups, suggesting that the correlation is not a simple one and affording another example of the loss of information contingent on failure to perform temporal analyses.

As might be anticipated, the various measures of motor activity tend to be positively correlated, even in cases in which the behaviors tend to be mutually exclusive, as with ambulation and rearing. These two parameters have been found to be highly (up to .81) correlated in a variety of rat strains (e.g., Ivinskis, 1968; Ray & Hockhauser, 1969), although Delbarre et al. (1970) have noted a dose-dependent, pharmacologically induced dissociation between ambulation and rearing.

Since the definition of latency usually involves the absence of ambulation, it is not surprising that these two measures have been found to be negatively correlated. This has been widely reported for both the rat and mouse, and both parameters have been found to load on common factors but in opposite directions—namely, exploratory behavior in

the rat (Denenberg & Whimbey, 1968) and on a factor which was unnamed and uninterpreted by the authors in the mouse, but by analogy with studies on the rat would seem to represent a factor of emotionality (Poley & Royce, 1970).

Correlational studies of ambulation with other variables have been less frequent. Ader's (1969) use of corticosteroids has already been mentioned. A negative correlation with urination, just significant at the .05 level, was reported by Satinder (1968), a doubtful finding in view of the demonstrated low reliability of urination measures. Similarly, ambulation displayed a significant positive correlation with inner circle activity in spite of the latter's demonstrated unreliability (Ivinskis, 1968). Finally, ambulation and vocalization showed a positive nonsignificant trend in dogs (Fox & Spencer, 1969) and the reverse in human infants (Rheingold, 1969).

As the most widely studied parameter, defecation has frequently been used as a correlate. The negative correlation with ambulation has already been detailed. In view of the negative correlation of ambulation and latency, it might be anticipated that defecation and latency would be positively related, but in the main only nonsignificant trends have been found (e.g., Ader, 1969; Porter & Wehmer, 1969). The lack of correlation with changes in heart rate (Candland & Nagy, 1969) has already been mentioned, while Satinder (1968) reported a negative correlation with grooming over four trials.

A logical extension of intercorrelating open-field variables is the study of their relationship to measures obtained on other behavioral tests. Such correlations may afford the advantages previously mentioned of increased sensitivity, reliability, and economy as well as providing valuable information on the apparatus specificity of any apparent relationships. Perhaps the best example of this specificity is afforded by ambulation. Thus, although some workers report good correlations between ambulation scores obtained in different apparatuses (e.g., ambulation in the open field, enclosed maze, and an exploratory box [Stretch, 1960, cited by Broadhurst & Eysenck, 1964]), most have not been so en-

thusiastic. Particularly common have been studies of ambulation as measured by activity wheel and open field. These studies have yielded consistent reports of significant but not particularly high correlations (Manosevitz, 1970; Weasner, Finger, & Read, 1960; correlation coefficient of .41). Considerably lower correlations have been found where motor activity is measured by cage tilting or stabilimetry. Here it is obvious that the highly coordinated motor wheel activity may be only slightly similar to the multitude of part and whole body movements registered on the stabilimeter. It should be noted that even simultaneous measurement of motor activity may yield relatively low correlations. Thus, simultaneous measurement of total open-field activity over 30 minutes gave coefficients of .65, .65, and .49 for cage tilting-beam interruption, cage tilting-floor contact, and beam interruption-floor contact, respectively (Sparks & Lockard, 1966). Open-field activity is sometimes used synonymously with ambulation, but in view of the term's varying usage by different workers and the relatively low correlations above, it is best avoided in this context.

Ambulation has also been found to be correlated with measures whose ambulatory nature is less obvious. Woods, Ruckelshaus, and Bowling (1960) found significant correlations of the Hebb-Williams' maze error scores with ambulation in rats reared under free or restricted environments. They therefore suggested that the often reported finding of lower error scores on maze and discrimination tasks in animals reared under conditions of increased environmental complexity might be due to a reduction in conflicting exploratory tendencies rather than to an increase in learning ability per se. This suggests an as yet apparently untried usage of the open field, that is, the use of one or more of its parameters as covariate adjustors in cases in which related behaviors are believed to be confounding variables. Thus, in the above study the use of ambulation as a covariate of error scores might yield a clearer picture of the origin of the error score difference.

Saunders (1968), using measures of ambulation, defecation, urination, grooming, and

rearing, found little relation to conditioned escape avoidance behavior in the rat except for positive correlations of avoidances and intertrial crossings with ambulation and a negative relationship between intertrial crossings and defecation.

Lát and Gollová-Hemon (1969) have described the relationship of their previously described open-field-derived measures (nonspecific excitability level, inhibition, and lability) to both behavioral and physiological measures. Thus, an analysis of individual differences in learning a double-T maze revealed that these three factors accounted for a major portion of variance on measures of learning, running time between starting box and first runway, and decision time on choice points. Furthermore, nonspecific excitability level was found to vary systematically with individual differences in such diverse physiological measures as growth rate, body temperature, caloric intake, qualitative food preference, and endocrine functions; a wide range to be sure and an interesting example of what will hopefully be one of many demonstrations of physiological substrates of open-field behavior.

In view of its multiple intercorrelated variables, most of them of doubtful meaning and their correlations with variables obtained in other tests, the open field would seem to lend itself ideally to factor-analytic studies. Indeed, such an approach would seem to afford an optimal method of interpretation and determination of the factorial structure of open-field behavior, yet such studies remain a rarity. Since it furnishes an excellent example of the potential of this method, the study by Whimbey and Denenberg (1967) is described in some detail.

Wistar rats were assigned to one of 16 treatment combinations that resulted from completely crossing four independent experiential conditions, each at two levels, yielding a  $2 \times 2 \times 2 \times 2$  factorial design. The four variables were handling of the subject's mother during the latter's infancy, handling of the subject during infancy, housing of mother and young between birth and weaning, and, finally, housing for the first 21 days after weaning. Commencing at 220 days of age, scores were obtained on a number of widely

used measures of exploration, emotionality, avoidance learning, consummatory behavior, and the like, yielding a total of .52 scores including open-field ambulation and defecation on Days 1-4 and after an intervening period of testing on several other apparatuses, on Day 14. Outstanding features of the analysis were the relatively low correlations of the first day's ambulation score with those of other days and the positive correlation of Day 1 ambulation with all defecation scores in comparison to the negative correlations of ambulation on other days. The two orthogonal factors accounting for most of the variance of these variables were interpreted as *emotional reactivity* and *exploration*. Defecation loaded only on *emotional reactivity*, whereas ambulation proved factorially complex, loading positively on *exploration* but changing its loading on emotional reactivity from positive on Day 1 to negative for other days. In addition, defecation was found to load on a third factor which was named consummation-elimination (Denenberg, 1969b). The factorial complexity of the ambulation score provides, for the first time, an explanation for some of the large number of contradictory findings and interpretations of this parameter. Ambulation has for many years been the traditional measure of rat exploration, while others have used it (sometimes in conjunction with defecation but sometimes not) as an index of emotionality, fear, or escape behavior. It can now be seen that it may well be indicative of exploration as well as either high or low emotionality but that interpretation is next to impossible where only one trial is given and the information from defecation scores is not taken into account. In view of the similarity of the within- to the between-trials decline in ambulation in the rat, it is interesting to speculate as to whether there might be a similar reversal of loading on emotionality within trials, especially for Trial 1. The advantage conferred by the finding that the two major parameters of the open field load well on these two important dimensions of animal behavior is immense, but it must be noted that the generality of this finding for other species and strains, for different experiential backgrounds,

and for different test conditions remains unproved. One has only to remember the increasing defecation across trials found in the mouse, as compared with the decrease of the rat, to realize the relevance of these qualifications.

#### FACTORS DETERMINING OPEN-FIELD BEHAVIOR

What then are the factors determining the qualitative and quantitative nature of behavior evinced by a subject in the open field? Basically, as is true of any behavioral test, this behavior represents the interaction of the subject with the experimental situation. This concept of operationalism, that is, the interaction between that which is measuring and that which is being measured and the inseparability of the properties and effects of one from the other, might well be extended from physics to the behavioral sciences. Furthermore, each of these factors influencing behavior may be divided into interacting sub-components which of course may be further subdivided ad infinitum. Division will mainly be carried only to the first stage in this study, since it is at this level of behavioral determination which most open-field studies are concerned with and because of the increasing complexity and diminishing returns which further subdivision brings.

Subject variables are perhaps best classified under genetic, developmental, and experiential headings. Genetic components of species, strain, and sex are most often discussed. Developmental features usually refer to the physiological maturation processes, but one might subsume biological rhythms under this heading. Experiential variables have been classified by a variety of criteria, most commonly by the nature of the stimulus and the development phase at which it was given. For the purpose of the present discussion, the most useful classification is into experience gained prior to testing, manipulation of the subject involved in bringing it to the experimental situation, and experience of the experimental situation up to the instant at which behavior is being measured.

Some idea of the interactional complexity of behavioral determination may be gained

from looking at studies which have simultaneously examined the effects of several variables from just one of the above divisions. Denenberg and his co-workers (Denenberg, Karas, Rosenberg, & Schell, 1968; Denenberg & Rosenberg, 1968; Denenberg & Whimbey, 1968) manipulated the handling of the subjects, their preweaning and postweaning environments, using both male and female Wistar rats and found a significant four-way interaction among all variables on open-field ambulation.

Coming now to the test situation side of the equation, this may be divided into the test environment and measurement procedure. The test environment has previously been considered in some detail under the headings *Techniques and Apparatus Characteristics*, *The Testing Environment*, and *Procedural Details*. The nonequality of results obtained by different methods of measurement of supposedly the same behavior has also previously been mentioned, and interactions between treatment and measurement techniques are well known in the literature. Such an interaction was reported by Weasner et al. (1960), who demonstrated that photoelectrically registered home-cage ambulation and revolving-wheel counts yielded different results for equivalent treatments. In comparing such measures of behavior obtained by different techniques, there are several factors to be considered. First, there is the question of whether the behaviors being measured by each method are in fact the same. Presumably they can never be identical; the study of Sparks and Lockard (1966) using cage tilt, beam interruption, and floor contact measures of activity affords a gross example of this. Second, there is the question of differential sensitivities of techniques, as regards both threshold and sensitivity to increments of behavior. And third, turning full circle, there is the matter of interaction between the subject and the measurement apparatus. The concept of operationalism fits well here.

In summary then, any behavior represents the determinant of the interaction of genetic background, maturation, biological rhythms, experience prior to testing, stimulation involved in bringing the subject into the experi-

mental situation, stimulation afforded by the experimental apparatus, stimulation afforded by the test environment, experience of the test situation up to the instant of measurement, and method of measurement. The implications of this for open-field studies are discussed below but may also be generalized to other areas of behavioral research.

This interactional nature of the behavior places severe limitations on the extent to which generalizations can be made from the results of any individual experiment. It also increases the potential importance of changes in any one factor of the interaction equation, so that apparently trivial alterations of any one stage of the chain reaction may result in totally unexpected changes in behavior. The importance of this for comparisons between treatment groups rests on the differential effects of any changes. Meier (1968), in discussing the conditions which modify behavioral development, has stated:

The conditions that have been described (e.g., handling, litter size, maternal strain and prepartal experience, cage size and complexity, to name a few), were previously relegated to the graceless limbo of maintenance routines which were infrequently recorded and codified, and even then for only limited or local consumption. Now we realize that these variables are awesome in their potency to effect behavior change that is demonstrable for periods often extending far into adulthood. We cannot help but wonder how many of the now-classic controversies in the behavior sciences could not now be resolved were detailed information available on the maintenance routines employed by the protagonists in those controversies. (p. 77)

A note of despair has been cast by Henderson (1970), who stated "for the time being investigators must be aware of the possibilities that early environmental interactions with genotype may limit the validity of their findings to their own unique laboratory situations" (p. 509). This statement stems from the author's work on effects of genetic and early environmental interactions on a number of subsequent behaviors (Henderson, 1968, 1969), including open-field defecation, in which it was obvious that there was no single relationship between prior treatment and subsequent defecation across different mouse strains. Moreover, this is only one of the possible 72 one-way, let alone multiway, inter-

actions derivable from the nine major independent variables listed earlier! As early as 1958, King listed variables likely to be of importance in determining subsequent behavior and pointed to the lack of concern by investigators for control of variables other than the one in which they themselves were interested. Today, little has changed except for the enormous growth of the list of variables known to be important. It is small wonder then that contradictions and failures of replication abound in open-field and much other behavioral research.

What then can be done short of abandoning a nomothetic for an ideographic approach. First, experimenters must become aware of the nonadditive nature of behavioral determination. With this in mind, one can see that studies which examine only one factor in isolation are of considerably less value than those which permit consideration of a variable in light of the effects of others. To this end Henderson (1969) recommended the use of considerably more elaborate multifactorial multivariate designs than have previously been customary and felt that drawbacks of size and multiway interactions are a necessary price to be paid if this area is to advance beyond its present limitations. A further need which will enlarge such designs even more is the need for large numbers of factorial levels in view of the nonlinearity of response to so many variables. Furthermore, those relevant variables not included in the design must be scrupulously controlled, and the levels at which they were controlled must be reported.

#### INTERPRETATION OF OPEN-FIELD MEASURES

What then does the open field measure? Interpretation may be in terms of underlying constructs or on the basis of the behavior's presumed purposive or adaptive nature. Underlying constructs may be suggested by the face validity or anthropomorphic interpretation of a particular behavior, by resemblance to a natural behavior pattern or to other constructs, or by factor analysis. Intuitive or face validity interpretations have been the norm until very recently; the difficulties and dangers of which are compounded by the

widespread ignorance of the ethological significance of much behavior studied in laboratory situations (Henderson, 1968).

The construct of emotionality has been the major one for open-field work. Although rarely defined except in circular operational terms (Denenberg, 1969b), it can be thought of as an entity underlying the nonspecific affective components of behavior. We say nonspecific components because an adequate stimulus and appropriate goal-oriented behavior cannot be identified, although anthropomorphic analysis or experimental manipulation suggests the presence of an affective state (Ader, 1969). While initially based on anthropomorphic interpretation, the construct has been factorially validated (Whimbey & Denenberg, 1967). Although widely assumed to underlie a large number of behaviors, factorial loadings have as yet been demonstrated only for defecation and ambulation. Ivinskis (1970) attempted to test the validity of defecation, ambulation, latency, rearing, washing, inner circle activity, and urination as indexes of emotionality in rats. His criteria of validity were, first, intertrial decrease of scores across 4 days; second, effects of prior open-field testing to reduce scores; and third, effects of alterations in ambient auditory and visual stimulation. The adequacy of these criteria would seem to be debatable, and in fact Ivinskis concluded that of the three, only stimulus variation was satisfactory. Using this criterion, of the seven parameters tested, only two—defecation and latency—could be considered valid indexes of emotionality. The necessity for interpretive caution when using the open-field test is even more apparent in light of this study, especially when it is remembered that of these two measures only defecation has been found to be acceptably reliable (Ivinskis, 1968).

Another widely referred to affective construct, which would seem to be very close to emotionality, is that of fear. It does not seem certain to what extent the behavioral and physiological components of fear can be differentiated from those of emotionality, and the two terms often seem to be used synonymously. Since measures of emotionality have most often been obtained in situations which

anthropomorphically would seem likely to induce fear, one wonders if there is an advantage to be gained at this stage by trying to differentiate them except denotatively in terms of the specific experimental stimulus situation.

Specific affective behaviors and constructs have naturally been rare in view of the absence of adequate stimuli in most open-field testing. However, with two subjects in the field simultaneously, the construct of gregariousness has been used to explain differences in average distance between and time spent in contact by the subjects (Latané et al., 1970).

Exploration has been a much used construct whose prime measure has been ambulation. While this assumption has been validated by factor analysis, its limitations have been pointed out by McCall et al. (1969). Once again, many other parameters are thought to be indicative of exploration (sniffing, rearing, etc.), but factor-analytic validation is still awaited. At the psychophysiological level, arousal-habituation has proved extremely useful, especially in the work of Lát and Gollová-Hemon with their derived constructs of nonspecific excitability level, inhibition, and lability.

One of the most pressing needs in the formulation of open-field constructs is an increased reporting of validity studies.

The establishing of validity is always tenuous, for in the long run validity is determined by whether the majority of investigators, or at least the most outspoken, believes the external criterion to have been adequate. (Candland & Nagy, 1969, p. 841)

Such has largely been the case in the open field, but this consensual validity must now rest on the basis of further criterion and construct validity testing, for which, in addition to the correlational studies which form the basis of most convergent validity testing (Nunnally, 1967), factor analysis would seem particularly suited.

#### INDICATIONS FOR FURTHER RESEARCH

It is obvious in reviewing this area that many of the all-too-numerous discrepancies, failures of replications, and contradictions stem from preventable methodological and experimental design causes. Many of these

have been enumerated already, but their inclusion in a concluding section seems more than warranted in view of the danger of "the growing body of literature in this area suffocating under its own weight" and in the hope of helping to "convert the current paper explosion in this area into a knowledge explosion" (Henderson, 1969, p. 867).

First, with regard to procedural matters, there is a need for a more precise specification of subjects including their genetic background, prior treatment, apparatus, testing conditions, measurement techniques, and temporal factors. Where replication or comparison is the aim, all possible factors other than the one under manipulation must be scrupulously controlled.

As regards experimental design, there is a need for the recognition of the essentially nonadditive nature of behavioral determination. With this in mind experiments which manipulate only one independent variable would be better replaced by multiway factorial designs, which because of their economy and nonassumption of additivity yield vastly more information and whose limitations regarding generality of conclusions can be assessed in light of interaction terms. Similarly, there is a need for increased numbers of levels in factors under investigation. Testing subjects under light and dark tells nothing about the precise relationship between behavior and level of illumination unless demonstrably untenable assumptions of linearity are made. Similarly, comparing two species or strains tells nothing of the genetic basis of behavioral differences, whereas an approach such as the diallel cross, which affords a large number of precisely quantifiable genetic levels, allows very detailed psychogenetic analysis. Failure to perform temporal analyses of behavior discards large amounts of information and may result in diminished sensitivity.

For dependent parameters, there is a great need for reliability and validity testing for a wide range of conditions and subjects. Many papers base far-reaching assumptions and conclusions on parameters whose reliability and validity remain unproven. The wider use of physiological variables, particularly bio-

chemical and electrophysiological, and the determination of their relationship to behavioral parameters would seem to hold considerable promise.

As regards interpretation of behaviors, there is a need for construct validation for which factor analysis and ethological data would seem to be particularly relevant. The former tendency to regard variable and construct as almost equivalent and constant across subjects and treatments must be abandoned except where construct validation indicates that it is permissible. Individual dependent parameters should not be considered in isolation but in light of changes in other parameters. This has been demonstrated particularly for ambulation. Finally, the dangers of unqualified generalization across genetic, experimental, and testing backgrounds must be appreciated.

#### REFERENCE NOTE

1. Cummins, R. A., Walsh, R. N., & Budtz-Olsen, O. E. Environmentally induced changes in open-field behavior. Paper presented at the 44th annual meeting of the Australian and New Zealand Association for the Advancement of Science, Sydney, August 1972.

#### REFERENCES

- Abel, E. L. Habituation as a factor in early handling. *Journal of Comparative and Physiological Psychology*, 1971, 74, 219-222.
- Ader, R. Adrenocortical function and the measurement of emotionality. *Annals of the New York Academy of Science*, 1969, 159, 791-805.
- Archer, J. Tests for emotionality in rats and mice: A review. *Animal Behavior*, 1973, 21, 205-235.
- Barrett, R. J., & Ray, O. S. Behavior in the open-field, Lashley III maze, shuttle box, and Sidman avoidance as a function of strain, sex and age. *Developmental Psychology*, 1970, 3, 73-77.
- Battig, K. Drug effects on exploration of a combined maze and open-field system by rats. *Annals of the New York Academy of Science*, 1969, 159, 880-897.
- Bindra, D., & Spinner, N. Response to different degrees of novelty: The incidence of various activities. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 341-350.
- Blizard, D. A. Situational determinants of open-field behavior in *mus musculus*. *British Journal of Psychology*, 1971, 62, 245-252.
- Block, J. B., & Essman, W. B. Growth hormone administration during pregnancy: A behavioral difference in offspring rats. *Nature*, 1965, 205, 1136-1137.
- Broadhurst, P. L. Determinants of emotionality in the rat: I. Situational factors. *British Journal of Psychology*, 1957, 48, 1-12.
- Broadhurst, P. L. Determinants of emotionality in the rat: II. Antecedent factors. *British Journal of Psychology*, 1958, 49, 12-20. (a)
- Broadhurst, P. L. Determinants of emotionality in the rat: III. Strain differences. *Journal of Comparative and Physiological Psychology*, 1958, 51, 55-59. (b)
- Broadhurst, P. L. Psychogenetics of emotionality in the rat. *Annals of the New York Academy of Science*, 1969, 159, 806-824.
- Broadhurst, P. L., & Eysenck, H. J. Interpretations of exploratory behavior in the rat. In H. J. Eysenck (Ed.), *Experiments in motivation*. Elmsford, N.Y.: Pergamon Press, 1964.
- Bronstein, P. M. Open field behavior of the rat as a function of age: Cross sectional and longitudinal investigations. *Journal of Comparative and Physiological Psychology*, 1972, 80, 335-341.
- Bruell, J. H. Behavioral heterosis. In J. Hirsch (Ed.), *Behavior-Genetic Analysis*. New York: McGraw-Hill, 1967.
- Candland, D. K., & Nagy, Z. M. The Open-Field: Some comparative data. *Annals of the New York Academy of Science*, 1969, 159, 831-851.
- Clark, C., Gorman, D., & Vernadakis, A. Effects of prenatal administration of psychotropic drugs on behavior of developing rats. *Developmental Psychobiology*, 1970, 3, 225-235.
- Collins, R. L. What else does the defecation score measure? *Proceedings of the Annual Convention of the American Psychological Association*, 1966, 1, 147-148.
- Defries, J. C. Hegman, J. P., Ross, D., & Howard M. A quantitative genetic analysis of change in open field behavior of mice. *Psychonomic Science*, 1969, 17, 153-154.
- Delbarre, B., Dumas, G., & Guionniere, M. An automated open-field method. *Psychopharmacologia*, 1970, 18, 227-230.
- Denenberg, V. H. Open-field behavior in the rat: What does it mean? *Annals of the New York Academy of Science*, 1969, 159, 852-859. (b)
- Denenberg, V. H., Karas, G. G., Rosenberg, K., & Schell, S. Programming life histories: An experimental design and initial results. *Developmental Psychobiology*, 1968, 1, 3-9.
- Denenberg, V. H., & Rosenberg, K. M. Programming life histories: Effects of maternal and environmental variables upon open-field behavior. *Developmental Psychobiology*, 1968, 1, 93-96.
- Denenberg, V. H., Wehmer, F., Werhoff, J., & Zarrow, M. X. Effects of postweaning enrichment and isolation upon emotionality and brain weight in the mouse. *Physiology and Behavior*, 1969, 4, 403-406.
- Denenberg, V. H., & Whimbey, A. E. Experimental programming of life histories: Towards an experimental science of individual differences. *Developmental Psychobiology*, 1968, 1, 55-59.

- Dixon, L. K., & Defries, J. C. Development of open-field behavior in mice: Effects of age and experience. *Developmental Psychobiology*, 1968, 1, 100-107. (a)
- Dixon, L. K., & Defries, J. C. Effects of illumination on open field behavior in mice. *Journal of Comparative and Physiological Psychology*, 1968, 66, 803-805. (b)
- Ehrlich, A., & Burns, N. Exploratory behavior of the black footed ferret. *Canadian Journal of Psychology*, 1958, 12, 235-241.
- Eysenck, H. J., & Broadhurst, P. L. Introduction. In H. J. Eysenck (Ed.), *Experiments in motivation*. Elmsford, N.Y.: Pergamon Press, 1964.
- Fox, M. W., & Spencer, J. W. Exploratory behavior in the dog: Experimental or age dependent? *Developmental Psychobiology*, 1969, 2, 68-74.
- Fuller, J. L., Chambers, R. M., & Fuller, R. P. Effects of cortisone and of adrenalectomy on activity and emotional behavior of mice. *Psychosomatic Medicine*, 1956, 18, 234-242.
- Furchtgott, E., Wechkin, S., & Dees, J. W. Open-field exploration as a function of age. *Journal of Comparative and Physiological Psychology*, 1961, 54, 386-388.
- Hall, C. S. Emotional behavior in the rat: Defecation and urination as measures of individual differences in emotionality. *Journal of Comparative Psychology*, 1934, 18, 385-403.
- Hall, C. S. Emotional behavior in the rat: III. The relationship between emotionality and ambulatory activity. *Journal of Comparative Psychology*, 1936, 22, 345-352.
- Hall, C. S., & Ballechey, E. L. A study of the rat's behavior in a field: A contribution to method in comparative psychology. *University of California Publications in Psychology*, 1932, 6, 1-12.
- Henderson, N. D. The confounding effects of genetic variables in early experience research: Can we ignore them? *Developmental Psychobiology*, 1968, 1, 146-152.
- Henderson, N. D. Prior treatment effects on open-field emotionality: The need for representative design. *Annals of the New York Academy of Science*, 1969, 159, 860-868.
- Henderson, N. D. Genetic influences on the behavior of mice can be obscured by laboratory rearing. *Journal of Comparative and Physiological Psychology*, 1970, 72, 505-511.
- Hofer, M. A. Cardiac and respiratory function during sudden prolonged immobility in wild rodents. *Psychosomatic Medicine*, 1970, 32, 633-647.
- Hughes, R. N. Social facilitation of locomotion and exploration in rats. *British Journal of Psychology*, 1969, 60, 385-388.
- Ivinskis, A. The reliability of behavioral measures obtained in the open-field. *Australian Journal of Psychology*, 1970, 22, 175-183.
- Ivinskis, A. A study of validity of open-field measures. *Australian Journal of Psychology*, 1970, 22, 175-183.
- Jerrard, L. E., & Brunnel, B. N. Open-field behavior of hippocampal lesioned rats and hamsters. *Journal of Comparative and Physiological Psychology*, 1968, 66, 500-502.
- King, D. L. Comparison between two methods of demonstrating relatedness of emotionality variables in rats. *Journal of Comparative and Physiological Psychology*, 1970, 72, 238-243.
- King, J. A. Parameters relevant to determining the effects of early experience upon the adult behavior of animals. *Psychological Bulletin*, 1958, 55, 46-58.
- Krsiak, M., & Janku, I. Measurement of pharmacological depression of exploratory activity in mice: A contribution to the problem of time economy and sensitivity. *Psychopharmacologia*, 1971, 21, 118-130.
- Labarba, R. C., & White, J. L. Litter size variations and emotional reactivity in BALB/c mice. *Journal of Comparative and Physiological Psychology*, 1971, 75, 254-257.
- Lát, J., & Gollová-Hemon, E. Permanent effects of nutritional and endocrinological intervention in early ontogeny on the level of non-specific excitability and on lability (emotionality). *Annals of the New York Academy of Science*, 1969, 159, 710-720.
- Latané, B., Cappell, H., & Joy, V. Social deprivation, housing density, and gregariousness in rats. *Journal of Comparative and Physiological Psychology*, 1970, 70, 221-227.
- Levine, S., Haltmeyer, G., Karas, G., & Denenberg, V. Physiological and behavioral effects of infantile stimulation. *Physiology and Behavior*, 1967, 2, 55-59.
- Livesey, P. J., & Egger, G. J. Age as a factor in open-field responsiveness in the white rat. *Journal of Comparative and Physiological Psychology*, 1970, 73, 93-99.
- Lynn, R. *Attention, arousal, and the orientation reaction*. Elmsford, N.Y.: Pergamon Press, 1966.
- Manosevitz, M. Early environmental enrichment and mouse behavior. *Journal of Comparative and Physiological Psychology*, 1970, 71, 459-466.
- Martinek, Z., & Lát, J. Long term stability of individual differences in exploratory behavior and rate of habituation in dogs. *Physiologia Bohemoslovenica*, 1969, 18, 217-225.
- McCall, R. Caretaker effect in rats. *Developmental Psychology*, 1969, 1, 771.
- McCall, R., Lester, M., & Dolan, C. Differential rearing and the exploration stimuli in the open-field. *Developmental Psychology*, 1969, 1, 750-762.
- McClearn, G. E. Strain differences in activity in mice: Influence of illumination. *Journal of Comparative and Physiological Psychology*, 1960, 53, 142-143.
- Meier, G. W. The half told tale and the half replication. *Developmental Psychobiology*, 1968, 1, 77-78.
- Montgomery, K. C. The relation between exploratory behavior and spontaneous alternation in the white rat. *Journal of Comparative and Physiological Psychology*, 1951, 44, 582-589.

- Morrison, B. J., & Thatcher, K. Overpopulation effects on social reduction of emotionality in the albino rat. *Journal of Comparative and Physiological Psychology*, 1969, 69, 658-662.
- Moyer, K. E. Effect of adrenalectomy on emotional elimination. *Journal of Genetic Psychology*, 1958, 92, 11-16.
- Nagy, M. Z., & Forest, E. J. Open-field behavior of C3H mice. Effect of size and illumination of field. *Psychonomic Science*, 1970, 20, 19-21.
- Nagy, Z., & Glaser, D. N. Open-field behavior of C57BL/6.J mice: Effect of illumination, age, and number of test day. *Psychonomic Science*, 1970, 19, 143-145.
- Nagy, M. Z., & Holm, M. Open-field behavior of C3H mice: Effect of early handling, field illumination, and age at testing. *Psychonomic Science*, 1970, 19, 273-275.
- Nielson, T. C. Early experience and explorative behavior in the white rat. *Scandinavian Journal of Psychology*, 1970, 11, 1-6.
- Nielson, T. C. Visual and tactual exploration in rats reared in different degrees of visual and tactual stimulation. *Scandinavian Journal of Psychology*, 1971, 12, 53-60.
- Nunnally, J. *Psychometric theory*. New York: McGraw-Hill, 1967.
- Oldham, J., & Morlock, H. The effects of open-field size on activity in the mongolian gerbil. *Psychonomic Science*, 1970, 20, 290.
- Pare, W. P., & Cullen, J. W. Emotional behavior and adrenal function in the rat. *Psychological Reports*, 1965, 16, 283-286.
- Paul, C., & Havlena, J. Maze learning and open-field behavior of adrenalectomized rats. *Psychological Reports*, 1962, 16, 283-286.
- Poley, W., & Royce, J. R. Genotype, maternal stimulation, and factors of mouse emotionality. *Journal of Comparative and Physiological Psychology*, 1970, 71, 246-250.
- Porter, R. H., & Wehmer, F. Maternal and infantile influences upon exploratory behavior and emotional reactivity in the albino rat. *Developmental Psychobiology*, 1969, 2, 19-25.
- Prescott, R. Some behavioral effects of variables which influence general level of activity of rats. *Animal Behavior*, 1970, 18, 791-796.
- Ray, O., & Hockhauser, S. Growth hormone and environmental complexity effects on behavior in the rat. *Developmental Psychology*, 1969, 1, 311-317.
- Rheingold, H. L. The effect of a strange environment on the behavior of infants. In B. M. Foss (Ed.), *Determinants of infant behavior IV*. London: Methuen, 1969.
- Sachett, G. P. Response to stimulus novelty and complexity as a function of rats early rearing experiences. *Journal of Comparative and Physiological Psychology*, 1967, 63, 369-375.
- Satinder, K. P. A note on the correlation between open field and escape avoidance behavior in the rat. *Journal of Psychology*, 1968, 69, 3-6.
- Satinder, K. P. Effects of odour trails on open-field behavior in rats. *Psychological Reports*, 1969, 25, 115-116.
- Sparks, L. M., & Lockard, R. B. Relationships among three measures of home cave activity. *Psychological Reports*, 1966, 19, 740.
- Tighe, T. G. A handling device for small animals. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 261-262.
- Tobach, E. Manipulation effects, open-field experience, and digestive transit time in Wistar male and female rats. *Psychological Reports*, 1966, 19, 375-378.
- Valle, F. P. Effects of strain, sex, and illumination on open-field behavior of rats. *American Journal of Psychology*, 1970, 83, 103-111.
- Valle, F. P. Rats' performance on repeated tests in the open field as a function of age. *Psychonomic Science*, 1971, 23, 333-335.
- Walsh, R. N., & Cummins, R. A. Mechanisms mediating the production of environmentally induced brain changes. *Psychological Bulletin*, 1975, 82, 986-1000.
- Walsh, R. N., & Cummins, R. A. Neural responses to therapeutic environments. In R. N. Walsh & W. T. Greenough (Eds.), *Environments as therapy for brain disorders*. New York: Plenum Press, in press.
- Weasner, W. H., Finger, F. W., & Read, L. S. Activity changes under food deprivation as a function of recording device. *Journal of Comparative and Physiological Psychology*, 1960, 53, 470-474.
- Welis, P. A., Lowe, G., Sheldon, M. H., & Williams, D. I. Effects of infantile stimulation and environmental familiarity on exploratory behavior in the rat. *British Journal of Psychology*, 1969, 60, 389-393.
- Whimbey, A. E., & Denenberg, V. H. Two independent behavioral dimensions in open-field performance. *Journal of Comparative and Physiological Psychology*, 1967, 63, 500-504.
- Whittier, J. L., & McReynolds, P. Persisting odours as a biasing factor in open-field research with mice. *Canadian Journal of Psychology*, 1965, 19, 224-230.
- Wimer, R., & Sterns, H. Controlled visual input and exploratory activity in C57BL/6.J mice. *Perceptual and Motor Skills*, 1964, 18, 299-307.
- Woods, P. J., Ruckelshaus, S. I., & Bowling, D. M. Some effects of "free" and "restricted" environmental rearing conditions upon adult behavior in the rat. *Psychological Reports*, 1960, 6, 191-200.
- Zimbaro, P. F., & Montgomery, K. C. Effects of free environment rearing upon exploratory behavior. *Psychological Reports*, 1957, 3, 589-594.

(Received January 28, 1975)