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An examination of the Temperamental and Ability
characteristics of large animals under
open-field and stress conditions.

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ABSTRACT

In this study an attempt was made to adapt two tests, developed for use with rats and mice, for work with the larger animals in order to assess their worth for measuring the temperamental and ability characteristics of domestic farm species.

To assess the temperamental characteristics an open-field, scaled to 72 feet by 72 feet, was used to score 30 pigs, 30 sheep and 44 cows on three criteria; ambulation, elimination and vocalisation. These scores were correlated with dairymen's ratings of the cows and plasma cortisol levels in the sheep. It became clear that the open-field test requires further modification before it can provide meaningful results for domestic stock.

The closed-field test was used with 63 pigs, 103 sheep, and 73 cows to measure the "intelligence" of normal farm animals. Time and error scores and general behaviour were recorded and analysed, and showed characteristic species differences.

In the evaluation of scores from both tests the importance of group effects found in herd animals was considered. A relationship between the closed-field test performance, and the social status of the animals in each test group was considered. Practical problems such as; animal-experimenter interactions; adequate motivation of ruminants; the impossibility of man-handling large animals like cows, and the kind of modifications which must be made to apparatus for this type of work, are fully discussed. Isolating herd or flock animals appears to cause stress.

The results of the closed-field test were compared with similar results from other studies where mice, rats, cats, dogs, ferrets, hens and other species have been tested in smaller versions of the closed-field. The general conclusion is that the potential for training, or utilising in other ways the ability inherent in the farm animal in New Zealand has hardly been touched. Though a number of experimenters have commented on these abilities during trials in research institutions such information has not been fully exploited in normal farm practice.

BACKGROUND TO THE STUDY

Considering the immediate importance in the national economy of the sheep, the cow and the pig, very little observational or experimental work has been undertaken on their behaviour patterns. The dog is the only domesticated animal on farms in New Zealand for which a full behaviour ethogram has been completed. The ethogram for the sheep has been started. The best indication of the dearth of material is a perusal of Psychological Abstracts since 1927 when they began. Total psychological studies carried out with each species are listed in Table 1. Those pertinent to behaviour patterns of practical importance to farming yield an even smaller number.

The Commonwealth Bureau of Agriculture has abstracted 47 papers on cow behaviour up to 1965 but 62% of these are directly related to grazing behaviour. The basic reference text "The Behaviour of Domestic Animals", (Hafez, 1969) lists 220 references for cows, 128 for sheep and 102 for pigs after the deletion of personal communications. Reports on the behaviour of pigs has shown an increase of 92% on references listed in the 1962 first edition while increases of 62% and 71% occur for sheep and cows respectively during these 7 years. This includes a number of studies written previous to 1962 and which are referred to by new co-authors in the 1969 Edition. Very few of the studies cited in Table 1 concern temperamental or ability characteristics or refer to such fields as learning, conditioning, emotion and motivation.

Table 1. A summary of the number of scientific papers published in recognised abstract sources or standard textbooks on the behaviour of sheep, cattle and pigs, (excluding personal communications).

Source	Species	Topic of published paper			Total
		Ingestive	Sexual	Other	
Psychol. Abstracts (1927-70)	sheep	9	6	52	67
	cattle	9	4	17	30
	pigs	3	-	26	29
A.B.A. Bibliog. to 1965	cattle	29	1	17	47
Hafez 1st Ed. 1962	sheep	31	26	22	79
	cattle	60	32	37	129
	pigs	16	15	22	53
- - - - -					
Hafez 2nd Ed. 1969	sheep	40	45	43	128
	cattle	107	54	59	220
	pigs	30	41	31	102
- - - - -					
Hafez 2nd Ed. 1969		Papers on temperament or ability		Total papers list- ed and written since 1962	
	sheep	12		40	
	cattle	15		56	
	pigs	16		34	

Why the rat and not the sheep has become the acceptable animal for psychological research on campuses where grass grows prolifically, (especially when one considers that the animal is usually available for sale as a carcass after the research is over) lies deep in the history of experimental psychology and need not concern us here. The lack of literature indicates that more attention should be paid to the common farm animals in psychological and behavioural research. This study was undertaken at the Ruakura Animal Research Station, as part of the author's responsibilities for behaviour studies of the large farm animals, to help fill some of the serious gaps in our knowledge as indicated above.

DEFINITION OF TERMS

Temperamental characteristics.

In current usage temperament refers to the individual character of the physical organisation which permanently affects the manner of acting, feeling or thinking. Bridger and Burns (1968), speaking of humans, characterise temperament as "those intrinsic biological qualities which are reflected in the behavioural activity of the subject". They suggested that temperamental factors relate to processes in the central nervous system which excite or inhibit activity; that individual sensory thresholds as defined by the strength of external stimulation needed to produce a given amount of physiological excitation were involved; and yet they were careful to point out that there was not a one-to-one relationship between such nervous processes and the specific behaviour which they mediate. In so far as the quality and intensity of early experience (stimulation) may help alter sensory thresholds and general responsiveness, temperament could be influenced by pre- and post-natal events in addition to genetic predispositions.

Smith (1951) in discussing aspects of human temperament suggested that individual differences in endocrine balance, if not offset by experience, could account for consistent features of behaviour. These included such things as differences in thresholds, susceptibility to emotional stimuli, the intensity of the responses given, the nature of prevailing moods and perhaps even the fluctuations in moods. The physical and mental vigour of the person and the aspiration for some type of tasks

may be due to innate features of this type.

Sheldon (1940,1942) examined at some length the relationship between physique and temperament in humans using a method of exact body photography to determine the somatotype of each subject. He concluded that there are three main body components of physique:(a) the soft and round when endomorphy predominates; (b) the slim and light, predominant in ectomorphy and (c) the square and strong - with a mesomorphic physique. The anthropometric measurements on which the somatotype were based were standardised for average nutrition within a particular age range. His investigations of temperament which he defines generally as "the level of personality just above the physiological function and below acquired attitudes and beliefs the level where basic patterns of motivation manifest themselves", were carried out by using 60 defined traits of temperament. Sheldon used extensive interviews and he made assessments of the subject's posture, movement patterns, eating and sleeping habits, reactions to stress, alcohol sensitiveness, attitudes to people,etc. Again all these results fell into three basic components:(i) relaxation, love of comfort, conviviality and sociability, - named viscerotonia; (ii) tenseness, over-vigilance, sensitive attitude to people, a tendency to be inhibited in action and a degree of social ineptitude - called cerebrotonia and (iii) assertiveness, preference for action, rather dominating, non-sensitive attitude to people referred to as somatonia. Although very few people fall into these extreme types, Sheldon allowed for ratings of individual people on 7 point scales for each of the

values suggested.

The challenging part of this theory was the claim of Sheldon's that bodily constitution is an effective determinant of consistent individual differences in temperament, even being related to a preferred philosophy of life. We know of no studies which have applied such theories and techniques to animals and their temperaments though a recent study of Semiginovsky et. al. (1969) does purport to test the emotionality of rats on several different levels of nutrition. One might speculate that with the careful selection of domestic animals in recent years for better carcass conformation, major selection has accidentally been occurring with regard to animal temperament at the same time. However it is clear (Isaac, 1962) that most evidence confirms Hahn's early hypothesis that the original purpose for the domestication of cattle was to have a supply of sacrificial beasts, whose horns resembled the lunar crescent, ready for the worship of the lunar mother goddess.

When we turn to animal studies we find the term "temperament" less sparingly used. Hall (1941) in his survey of animal studies in this field declared "temperament to be the raw stuff of individuality", "independent of the conditioning effects of the physical environment, and social culture." His definition stated that temperament "consists of the emotional nature, the basic needs structure and the activity level of an organism".

As examples of temperamental traits Hall listed timidity, sexuality, aggressiveness, spontaneity, variability, speed of

reactions, etc. He went on to group these traits into two predominant types :

- A. fearfulness, timidity, emotionality, wildness which resulted in behaviour such as hiding, vocalisations, urination and defecation, trembling and other muscular tension, freezing, face-washing, withdrawal and restricted field activity: and
- B. aggressiveness, savageness which resulted in the behaviour of biting, exposing teeth, jumping at, squeaking and hissing, ear movements, fighting, crowding, pushing and vocalisations.

In his earlier work (Hall, 1934) he had already found that 'emotional' defecations and urinations were valid measures of individual differences in emotionality when a rat was placed in a strange "open-field" for a few minutes each day. He distinguished between normal and emotional defecations and urinations, the latter being those which ceased upon repeated exposure to the situation which originally provoked it. Hall preferred the term 'emotionality' rather than emotional. By emotionality he referred to "a group of organic, experiential and expressive reactions a general upset or excited condition of the animal."

Subsequent studies by other workers explored animal temperament in two ways. (a) Firstly emotionally arousing situations, generally the open-field, were used with additional stimuli of high intensity, i.e., such as a high intensity light. Others looked at the relationship between noxious stimulation during early development and the defecations of the animal at a later time. In this case the young animal was stimulated at some stage

of development and then at a pre-determined age these animals and their controls were tested in the open-field. (b) The second method was to 'validate' the emotionally-arousing situations which elicit the response. Parker (1939) used six different situations of a noxious nature designed to arouse fear and escape behaviour and found that the defecation scores in all of these situations correlated significantly and positively.

Both implicit and explicit in Hall's discussion is the postulate that the behaviour pattern of the defecatory reaction is quite fundamental to the animal; i.e., it is an innate factor related to the functioning of the nervous system (autonomic) which is more constitutionally than situationally determined. In later experimental work he went on to breed two strains of rats (i) 'emotional' rats which defecate consistently in a test situation and (ii) non-emotional rats which do not.

Hall's work came under some criticism when it was established that the relationships with other purported measures of "emotionality" were found by some to be low. Bindra and Thompson (1953) after comparing results from a timidity test of fear and the open-field, concluded that emotional elimination is not a valid index of fearfulness. It could be a measure of autonomic reactivity or even susceptibility to a very general type of emotional disturbance which is perhaps what Hall means when he talks in terms of "emotionality".

Broadhurst (1957) took up this challenge and made another thorough study of rats using the procedures of Hall, with a view

to standardising the fear-provoking components of the test. In his investigations he studied a number of variables including the size of the arena, the intensity of the illumination, the intensity of sound during the test; the effects of sex, food deprivation, and shock before the trial began. He related these variables to both the defecation and ambulation scores; i.e., the number of squares which the animal entered during the trial period. Using two sizes of open field, 72 inch and $32\frac{3}{4}$ inch in diameter, Broadhurst found that the small arena elicited more defecation than the large. This made the test a very useful one. However there was less ambulation in the small arena. The greater the intensity of the physical stimulus for both light and sound, the more defecation.

There are differences between sexes in the defecation and ambulatory scores. In summary, Broadhurst stated that defecation is the emotionality index of choice, measured preferably by the amount rather than the frequency. When he turned to study antecedent factors such as handling, the prior experience of sexual contacts, Broadhurst (1958) found that only two factors, previous experience of the test and age after maturity when tested, significantly altered the defecation score.

Tobach and Schneirla (1962) gave a different point of view in a review which deals with "emotionality" in both rats and mice. They cite evidence from their own studies to show that the defecation reaction in mice can be viewed as a situationally specific response rather than an individually generalised pattern resting upon a native or constitutional basis. It was affected

by the nature of an individual's developmental experience. They suggest that Hall would not have insisted on the maintenance of a constant environment for subjects to be tested if this were not so.

This controversy initiated much work on the use of the open-field and the number of published works covering aspects of the validation of the open-field, or the reliability of defecation as a measure of 'emotionality' run into several score. In 1964, Eysenck reviewed this field and in particular gave a full account of the work done in his laboratory. Using the Maudsley strains selected for performance on the open-field and termed 'reactive' and 'non-reactive' they confirmed the correlation between defecation and ambulation in their version of the open-field. The Maudsley rats used had been selected for 21 generations and each group had been reared under a uniformity of lighting and prescribed diets as well as having set ages after birth for weighing, ear-marking, etc. A fixed number of rats were kept in each cage. Eysenck defined "emotionality" as 'an inherited predisposition of the autonomic nervous system to react particularly strongly, quickly and lastingly to certain kinds of stimuli (mainly in the rat).' Emotionality is thus a quality in the animal not the situation to which it is being subjected. To define 'emotionality' operationally, Eysenck uses elimination and ambulatory scores in the open-field. He concluded that a wide variety of experimental

situations have shown these behavioural reactions to be not merely test reactions. The 'reactive' rats showed different behaviour from the 'non-reactive' rats in all situations studied. The reactive rats were susceptible to fear, anxiety, frustration and conflict. Here is the differentially inherited basis of emotional behaviour. Though certain inconsistencies are acknowledged, he insists that the evidence is over-ridingly in favour of the basic concept. The evidence produced by Eysenck is largely related to results from the white rat.

Fuller and Thompson (1967) when discussing 'personality and temperament' in animals from the point of view of genetical studies cover three main areas of behaviour in their summary; (i) activity level, (ii) 'emotionality' including wildness, aggression, and timidity and (iii) social behaviour. The first two of these are relevant to this discussion. They concluded that from the evidence of Hall's two strains of high-emotional and low-emotional rats (1938), the inheritance of some aspect of "emotionality" has been convincingly demonstrated. In separate studies Thompson (1953) made a systematic analysis of the activity of a number of inbred mice from the Jackson Laboratory in the open-field apparatus. Highly significant between-strain variances were found indicating the operation of a genetic factor. Strains of mice from a common ancestor gave evidence of constancy of exploratory behaviour even when some of the strains were already 100 generations removed. In a later study where open-

field results were compared with results from a Y-maze, the same rank order with one exception was shown between these two tests. There was little doubt that activity level as measured in a number of animals and animal species was strongly dependent on genetic factors.

An example of a recent study is that of Morrison and Thatcher (1969), relating rearing densities to emotionality. With five minute observations of rats in an open-field, they recorded the following data from single and pairs of rats. (a) Centre entry; i.e., being in a square where the wall is not a boundary; (b) corner occupancy, - being in one of the four corner squares; (c) movement - squares crossed; (d) rearing up against the wall; (e) grooming; (f) keeping together in pairs; (g) Ss touching each other; (h) freezing - remaining motionless for more than 5 seconds; (i) defecations. Rats from groups reared at higher densities were found to be less "emotional".

A further summary of some of the recent studies using the open-field test and giving details of the size of field, the scores used, the length of trials, the number of days used for testing, is found in table 7.

Bruell (1963) suggested that defecation by mice in a strange environment may represent a territorial marking response. Swanson (1969) after studying Golden Hamsters in the open-field indicated that no defecation by these animals occurred during the testing period. Only ambulation scores were recorded.

A recent development in open-field testing has been the attempt to relate behavioural scores to various physiological measurements such as heart rate, (Candland et al, 1967), adrenal steroids or sex hormones (Ader, Friedman and Grotta, 1967; Swanson, 1969, Swanson and McKeag, 1969; Gray, Lean and Keynes, 1969.)

Lat and Gollova-Hemon (1969) reported on a variant approach to emotionality termed by them lability, a factor independent of the non-specific excitability level (NEL) of the rat. A full evaluation of activity was made including vertical activity such as rearing and lifting the head; horizontal activity, moving from place to place and other spontaneous reactions like sniffing, biting and defecations. The type of activity was then rated on a continuum (of activity) ranging from high arousal, to the relaxed or sleeping state. Such an index correlated closely with hippocampal slow wave activity. On a population basis the rats studied were classified into groups and the independent factors responsible were considered to be (a) the frequency of spontaneous reactions (b) the rate of habituation and (c) an emotionality factor related to defecations.

In general the open-field has been used more and more in studies of temperamental characteristics in the rat. Other tests, including emergence-from-cage; the stove-pipe test; the reaction-to-handling test; shuttlebox activity with or without compressed air have been used. Of all these the open-field test is most

easily modified for large animals. The open-field has not been widely used with species other than rats, mice and hamsters. Different methods have been chosen by the investigators of emotional reactivity in the dog and the cat. No study was encountered in which open-field testing has been attempted with dogs.

Pavlov classified his dogs as excitable or inhibited and the procedures devised by the Russians for establishing this typology have been described by Peters (1966). He selectively reviewed the Russian literature concerning the use of the conditioned reflex to type the temperament of dogs or other animals. Four basic types of dogs were defined.

Type I. Strong, unequilibrated excitatory such a dog salivated strongly to the positive signal during conditioning but did not entirely suppress salivation to the negative stimuli.

Type II. Strong equilibrated mobile such dogs managed the discrimination easily even under certain drugs, and they readily reversed the meanings of the signals if required to do so.

Type III. Strong equilibrated immobile as for the dog above but the signals are not easily reversed.

Type IV. Weak; i.e., dogs showing poor performance on strengths of excitation, inhibition and mobility. There is the possibility that this group should be further subdivided.

While not denying the validity of the Pavlovian techniques described, Fuller (1948) stated that they cannot easily be used

with large numbers of dogs because of the time involved, and secondly that because of the nature of the tests, some dogs are impaired for future research.

Scott and Fuller, (1965) define emotional reactivity of dogs as "the intensity of all responses, external and internal, to a stimulus change." Thus a battery of tests has been devised by some workers with dogs in contrast to the single test approach, the open-field test as used by investigators with rats and mice. Mahut (1958) examined the patterns of emotional behaviour in different breeds of dogs. These dogs were subjected to a series of tests, many of them difficult to standardise, including the following : (1) a mechanical snake which slithered about two feet; (2) a balloon inflated to 12 inches in diameter; (3) an umbrella opened near to the subject; (4) and a mask to cover the face of the owner. The resultant behaviour was scored on a six point scale, which ranged from N = no response; C = curiosity; T = teasing after the initial approach to the object; AA = approach-avoidance with some stalking; W = wariness with trembling and some growling; and Av = clear-cut avoidance and escape. Significant breed differences were found in five of the six responses.

Other workers have added further tests. Scott (1954) described methods of measuring reactions to human handlers and also barrier problems; Fuller (1967) used an emergence from the transport cage and an arena test. Behavioural reactions were

coded on a numerical scale for the computer. The arena was $3\frac{1}{2}$ meters square and was surrounded by an opaque barrier one meter high. The floor was divided into nine equal squares. An arena was also used by Fox and Stelzner (1966) but no size was given. Distress vocalisations have been recorded by some workers. Murphree et al. (1967) used the tests of Scott and Fuller (1965) but also added a test modified from Krushinskii (1960). It was an approach-avoidance test where the observer approached the entrance to the dog's home paddock. These tests were used by Murphree on two groups of pointers selected for stable and unstable characteristics in their temperament.

Frequent use of the arena as well as detour tests for dogs reinforced the conclusion that the building of an open-field which could be used as an arena for large animals was a sensible course of action.

Work with cats has been even more restricted. Seitz (1959) when studying the effect of infantile experience on adult behaviour used the following type of tests; (a) random movements on an arena floor; (b) emergence from the home cage test; (c) various tests in unfamiliar enclosures and (d) feeding frustration tests. Collard (1967) used modifications of several of the above.

Liddell (1954) described a device for recording the movements of sheep in a closed field with or without other sheep or lambs. Various tracings of the movement of lambs have been provided by this method to show the influence of early deprivation on

behaviour. Two studies, Beilharz and Cox (1967) and McCann (1966) have described the use of the open-field for pig studies. This is further evidence of the general usefulness of the open-field apparatus.

Lamond (1961) gives a two fold definition of temperament in cattle: the reaction of the cow in isolation to dogs, noises, machines or man and the reactions of the cow within the herd or social group to similar or additional stimuli. Lamond talked in terms of the excitable temperament and the placid dairy type. The excitable animals tend to be culled while the placid cows make the farmer-cow relationship much easier. Dickson (1967) defined temperament as follows: the sum total of characteristics which contribute to the disposition or individual behaviour of an animal. Temperament was generally considered innate or inherent and was the result of the animal's physical and nervous organisation. Dickson and a number of other workers have developed ratings to help farmers assess the temperament of their cows and these are shown in table 2. (Tulloch, (1961); Scott, (1958)). Dickson asked dairymen to rate their cows on a four point scale with a description given of each class.

The typological approach to the assessment of cattle temperament was used by Fraser (1957) to define certain "personality types" of dairy bulls. Fraser distinguished six basic types and provided some description of each. See Table 3.

Table 2 : Suggested categories for temperament ratings
of cows (after Tulloh, 1961; Dickson, 1967.)

Tulloh's ratings

1. Docile. Cow stands quietly, may raise or lower head; may lean forward or backwards. Well positioned for observations; in general is unperturbed.
2. Slightly restless. Generally docile but moves frequently; i.e., every few seconds. Flicks tail and blows quietly through nostrils. Stubborn docile animals are included here.
3. Restless. Moves about continuously pulling or pushing on the side of the crush. Stance difficult to define, frequently flicks tail, snorts, difficult to see ear tag; may be stubborn.
4. Nervous. Restless animal which quivers when hand is on its back. Defecates in bail - may also be stubborn.
5. Wild. Restless; struggles violently; bellows and froths at the mouth, - may be stubborn.
6. Aggressive. Wild animal; attacks observer by kicking. Attempts at biting or lunging; - may also be stubborn.

Dickson's ratings

1. Very quiet, never gives any trouble; extremely docile during milking and preparation; the ideal milker.
2. Stands quietly in stall; not bothered by preparation for milking but may move frequently shifting weight from side to side; may flick tail occasionally; gives very little trouble.
3. Generally quiet, but moves around a lot; may lift feet occasionally during preparation or milking but does not kick. Flicks tail frequently or appears restless at times.
4. Appears very restless during preparation or milking; kicks at handler occasionally. Steps from side to side a great deal. Quivers when a hand is placed upon her.

Table 3 : Suggested categories for temperament ratings of bulls (Fraser, 1957).

- A. Stable personality showing little self-will and much interest and curiosity. These bulls, usually sexually immature, show compliance when being handled. (49% of sample).
- B. Stable personality, mature sexually. Show some sex drive and are masterful with some self-restraint. They are audacious without being malevolent. (22% of sample).
- C. Of uncertain stability; sometimes aggressive and generally of high dominance; i.e., show aggressiveness to other bulls; high in libido. (8% of sample).
- D. Very aggressive even to man, who is threatened or attacked. However frequency of such acts is not high. (5% of sample).
- E. High in libido and aggressiveness to man, (potential killer bulls). Exhibit constant aggression. (5% of sample).
- F. Apprehensive bulls, many of them exceptionally fearful. Always taking flight from disturbing stimuli. (11% of sample).

Whereas Tulloh (1961) and Dickson (1967) provide a descriptive coverage of certain behaviour which could be observed of cows in a bail, to enable the allotment of a numerical rating to each animal, the typological description of Fraser would not enable this to be done with accuracy. Comments such as "showing little self-will", "being masterful" or "being audacious" have little objective meaning.

In summary, it is clear that there is some agreement as to what temperament is in the various definitions cited. There are at least four connotations to the term as follows;

a. Temperament shows meaningful variation among individual members of the same species - "the raw stuff of individuality".

b. Temperament is consistent and predictable for a specific animal and thus characterises the actions of that animal.

c. Temperament is related to the animal's constitution; i.e., its inherent physical, hormonal or nervous organisation, and is minimally influenced by past history or present environmental circumstances. It can be used as a factor in genetic selection.

d. Temperament is linked with the intensity of response of a particular animal to a stimulus change.

Temperament could be defined as "the sum total of behavioural characteristics, resulting from the individual's physical, hormonal or nervous organisation, which contribute to the unique and consistent disposition of one animal in contrast to others of the same species".

In the attempts to provide operational definitions for the animal species under study recourse to the use of some sort of open-field or general arena is frequent. This survey led us to believe that the open-field test could be the most practical first attempt to provide an objective index of "temperament" in the farm animals. From the available terminology in animal work; i.e., timidity, excitability, emotionality, reactivity, placidity, etc., and the Pavlovian typology, we tend to use the term 'emotionality' for convenience and because of its general acceptance to date. As an indicator of emotionality the elimination score normally used for rats and mice could apply to cattle and perhaps even to sheep and pigs. It is known that cows will defecate in unusual environments or when presented with strange stimuli. This is true for the water buffalo also (Whittlestone, 1967). In this respect the cow would seem to resemble the rat. The open-field also provides an assessment of the activity score for each animal, a score which for rats correlates to some degree with elimination and for most investigators is also recorded during open-field testing. See table 6. Following the suggestion from some of the work with dogs it is simple enough with sheep and cows to record a vocalisation score as a measure of social disturbance caused by temporary isolation from the herd, flock or group.

ABILITY CHARACTERISTICS.

Of all human abilities, intelligence has been the most carefully studied. Yet according to Guilford (1967) the concept has not been given "a firm, comprehensive and systematic theoretical foundation". Nevertheless it has been considered that 'intelligence' could be measured and as a result the spectacular development of tests has far outrun the understanding of what the tests have measured.

Binet's first scales were designed before 1905 and consisted of a comprehensive group of tests, 30 in all, to distinguish between advanced and retarded children. His 1908 scales distinguished between levels of normal children. During the first World War the group tests, Army Alpha and Army Beta were given to almost 2 million men and set the stage for many attempts to assess this particular human performance variable.

Other human abilities such as manual dexterity, mechanical ability, music or art required special aptitude tests. In chimpanzees and other apes and monkeys, manual skills are also important but the manipulative skills of the domestic animal are rather limited by the lack of finesse of their prehensile organs. With this in mind it has been considered inappropriate to define the 'ability characteristics' of domestic animals in any other way than the "intelligence" or "mental ability" of the animals concerned. The term ability has been reserved for those

capacities in animals which would be referred to as intelligence in humans. "Intelligence" has anthropomorphic overtones. Other animal workers have talked in terms of "bright" or "dull" animals or more specifically "maze-bright" or "maze-dull" (Tryon, 1929) or have referred to specific areas of "intelligent behaviour" such as insight (Maier, 1932); learning sets (Harlow, 1949) or problem-solving behaviour (Kohler, 1925).

Spearman, (1927) suggested that the word intelligence had been used in so many ways, with so many meanings that it had merely become a vocal sound. The truth of this statement led many workers in the field to attempt better definitions. Wechsler (1958) suggested that his definition, "the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment "was an operational one and he discusses each of the major terms at some depth. Boring (1923) defined intelligence "as the capacity to do well in an intelligence test" and Guilford (1967) argued that such a definition was operational because Boring was calling attention to the proper study of the tests themselves. He further suggested that the answer to this lies with factor analysis. Other definitions contain a wide variety of ideas including some of the following; the capacity to meet novel situations; to learn by making adaptive responses; the ability to perform tasks or tests involving the grasping of relationships; to deal with relation-

ships both abstract and complex, or a general tendency in an individual to perform a wide variety of tasks intelligently.

Butcher (1968) summarising the contribution of statistical studies to knowledge of the structure of human abilities makes these points.

(1). If a representative sample of people undertake a broad selection of mental tasks a common component appears which may be characterised as "general intelligence", or "g". Spearman termed such theories monarchic or one-factor theories where general intelligence is equally important in every cognitive task. He proposed a refinement of this, (1904) where general intelligence was considered to enter into different tasks in different degrees.

(2). Supplementary common factors must be proposed to account for all the facts and these may be interpreted as special abilities such as verbal or spatial abilities. It is possible to analyse a set of mental performances in such a way that no general intelligence factor is found. Thurstone (1938) found seven recurring factors to be important and these he termed 'primary mental abilities'. They were S = spatial ability; P = perceptual speed; N = numerical ability; V = verbal meaning; M = memory; W = verbal fluency and I or R = inductive reasoning. In these studies the analytical technique adopted precluded finding "g". The term oligarchic has been used to cover cases

where several large ability factors of roughly equal significance are found.

An hierarchical structure of human abilities which begins with the general intelligence factor "g" and is progressively broken down into group factors, both major and minor, and finally into specific factors was the approach of Burt (1940); This is an extension of the earlier work of Spearman and is a widely accepted theory among British psychologists.

Guilford (1967) and his associates provide an example of the multivariate approach to "Intelligence". Guilford started by classifying, in a logical way, the kinds of possible ability under three headings. The aim was then to make up several tests for each of the 120 resulting abilities. From these tests it was hoped to define each ability as a factor. Twenty years of work have charted some of these possible abilities but many gaps remain. It can be seen that in the differing approaches to human intelligence the old debate between "one intelligence" or "many abilities", continues.

Breland and Breland (1966) after their survey of work with 60 different animal species and 8,000 individual animals sought to answer this question; 'Under what circumstances should we call an animal "intelligent"?' In a certain sense it is correct to speak about each animal as being the most intelligent for the ecological niche in which it lives. In this study we have been interested to see if the farm animals which have been shifted to

a new ecological niche are still intelligent in this new sphere of living. More generally however, the question of 'intelligence' is referred to in the context of a comparative appraisal of the degree to which the behaviour of the species concerned showed characteristics similar to so-called human "intelligent" behaviour. As Breland and Breland stated, rapid conditioning was not an index of intelligence. One-trial learning could occur in chickens as well as men, apes and dolphins.

The ability to form discriminations was not a mark of intelligence either. The purest discriminations of all occurred in the species where behavioural reactions were built in as it were from birth; i.e., fixed action patterns to specific stimuli like the male 3-spined stickleback's reaction to the change of colour in the rival male, Tinbergen, (1951).

Breland and Breland considered the first mark of an intelligent animal to be the ability to generalise. Thus a pig which was trained to put toys in a toy box would pick up a camera if it were put down by a cameraman or try to lift the tripod or even the photographers arm if care was not taken. The second mark was the interchangeability of behaviour from one drive system to another. Work with the dolphin indicated that both the male and the female patterns of sex behaviour can be brought under the control of food reinforcement and such cross-drive conditioning was considered to be a mark of a highly intelligent animal. Flowing from this easy

connectibility of behaviour patterns was the third suggested quality; i.e., the degree of playfulness. Many animals invent quite complex games which help in the exploration of their environment and their preknowledge of situations that might be useful in later contexts. It must be remembered however that playfulness is a function of a favourable ecological niche where predatory pressures are not great. These very conditions might be due to the animal being highly intelligent and making such a niche for itself.

In his discussion of "intelligence" in animals, Lenneberg, (1967) stated that zoological definitions were very difficult to devise. He considered that intelligence was tied to specific tasks. However when animals from different species were required to solve these tasks they would do it in their own specific manner as a species. Thus comparing intelligence of different species was comparable to making relative measurements in different universes and comparing the results in absolute terms. If a layman said a cat was more intelligent than a rat he meant it had a greater ability to solve human tasks.

Rumbaugh and McCormack, (1967) in their discussion for the layman on great ape 'intelligence' worked from the human analogy and suggested that intelligence covered many abilities such as the ability to learn, to synthesize, to extrapolate, and that to assess these a battery of tests was necessary. The ability to learn was critical so they used "learning-set" measurements

based on the experimental work and concepts developed by Harlow (1949). The battery of tests included discrimination, reversal training and oddity tests. This is a multi-variate approach.

Jolly (1966) in her discussion of Lemur behaviour suggested that although by monkey-level intelligence one means the ability to solve problems with objects under controlled laboratory conditions, under wild conditions there are three main uses of "insight"; toward objects, toward other active species, and toward fellow-members of one's own species. Though some monkeys took hundreds of trials to begin to solve two-choice object discriminations they could, in a matter of a few seconds, adapt to a particular dominance status when introduced for the first time to three strange cage mates.

Nissen, (1951) when discussing phylogenetic comparisons of intelligence equated 'intelligence level' with "behavioural complexity" or "spatio-temporal span of behaviour determination", or the "sum total of the organism's cognitions or adjustments". He suggested two types of behaviour in infra-human animals demanded symbolic processes for their interpretation: (a) delayed reaction type learning and (b) prompt solution situations involving insight, foresight or inferential reasoning.

Riopelle, (1960) in his review of 'complex processes' concluded that no single trait will suffice in defining animal intelligence. The order of species arranged on a test of "pure"

ability to shift set, for instance, would not necessarily coincide with similar orders for other components of intelligence. It is of interest to compare the comparative summary from various workers provided by Fink (1954) as shown in table 4.

Historically there are a number of approaches to the study of animal ability. We have followed the precedent set by Riopelle (1960) when he stated in his summary of work concerned with "higher mental processes or cognitive function" that ... "in the absence of a universally acceptable theory, we shall concern ourselves with a description of several examples of procedures and experimental approaches in the area." He then proceeded to deal with aspects such as discrimination learning; reasoning; learning sets; imitation and observational learning; delayed response tests and flexibility.

In one of the earliest attempts to assess ability, Thorndike (1911), had already used a number of these approaches including imitation and problem-solving techniques. Kohler was very critical of this early work of Thorndike in which cats and dogs had been imprisoned in wooden cages 20" x 15" x 12" high and 41" x 20" x 23" respectively. He considered that the structuring of the experimental situation led to the subsequent trial and error type learning shown by the animals concerned. He devised situations in which the animals were able to encompass the whole of the problem including the relationships which might be present. Under these conditions

Table 4 : Rank orders of animal species based on the
relative performance in various learning tasks
(after Fink, 1954 p. 87)

Hamilton (1911)	Yerkes (1916)	Liddell James & Anderson (1934)	Fink (1954)	Crile* (1941)	Overall
man			man	man	man
				horses	
	apes			apes	apes
monkey	monkey				monkey
	pig	pig	pig	pig	pig
				sheep	
dog		dog	dog	dog	dog
		sheep/goat	goat		sheep/goat
	crow				birds
cat				cat	
			chicken	birds	
	rat		rat		rat
horse		rabbit	rabbit	rabbit	rabbit
			cat		cat
		+Guinea pig		opossum	horse
				guinea pig	guinea pig
		+opossum		rat	opossum
			turtle	turtle	turtle

* Crile's work is based on
a correlation between
basic metabolic rate and
brain weight.

+ James, 1934, 1939.

he found that Chimpanzees could solve various problems using boxes, string, rakes or sticks. The Chimpanzees he considered exhibited "insight" or the "ah-ha" response. Kohler typified the gestalt revolt against the rather limited stimulus-response structures of the behaviourists at the time.

Bitterman (1967) in a review, provided a detailed analysis of the various contributions of animal theorists to learning beginning with a full treatment of Thorndike and Morgan and ending with Skinner and Bitterman. It is apparent from his treatment of the subject, that the animal species generally used for experimental purposes, the white Norway rat, is a mere appendage to test the hypotheses stemming from one or other of the rival learning theories current at the time. Only in the 1950's does there appear an interest in the rat as an animal in its own right, and an extending interest to cover a much wider variety of animal species.

The Pavlovian Respondent Conditioning method was brought to the U.S.A. and popularised by workers such as Liddell, Gantt and others who developed a variant procedure for conditioning known as type II or avoidance conditioning. See figure 2. Work with the sheep and the pig carried out since the late 1920's after Liddell's original maze experiments (see figure 1) were of this type. The sheep was placed in a harness and an electrode was fixed on its leg. Various stimuli were then introduced to the animal to enable

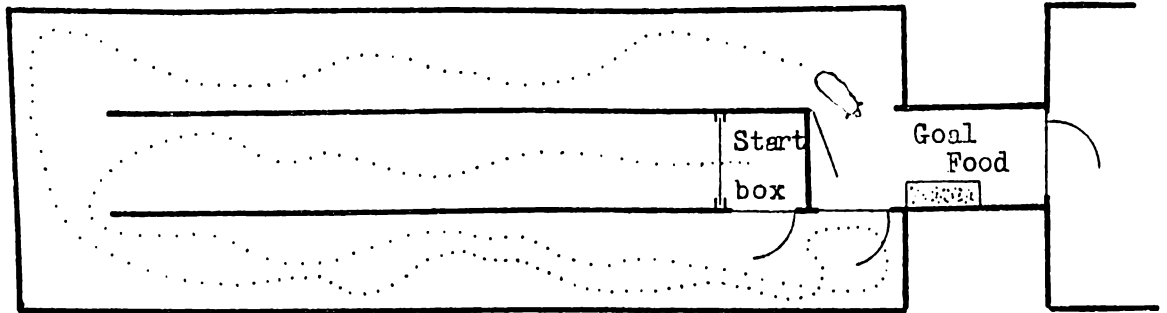


Fig.1. An alley maze used to test the intelligence of sheep
(after Liddell, 1954)

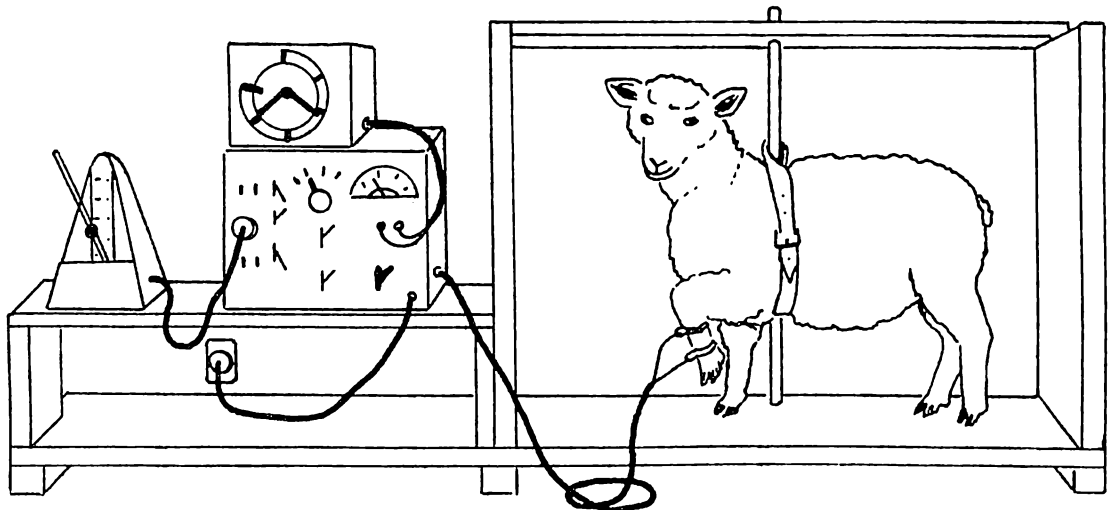


Fig.2. Apparatus used to establish conditioned reflexes in sheep
at the Cornell University Behaviour Farm
(after Liddell, 1954)

it to flex the appendage and avoid shock. Liddell (1954) gave reasons for the shift from maze work to conditioning as follows. It was obvious that the experimenters had inadequate control of the experimental situation. They were interested in the physiology of the thyroid gland and not learning, at the time. Liddell found later that he had little control of the behaviour of a sheep which had become neurotic as a result of the conditioning procedures. Although most recent Pavlovian type studies have been related to the investigation of animal temperament (Murphree et al, 1967), the method was used by Barnes et al, (1967) in work on the changes of ability between protein-deficient pigs and normally fed litter mates.

Work within the Pavlovian tradition has continued in the U.S.S.R. on the higher nervous activity of various animal species. An interesting variant method to sample the extrapolatory reflexes of animals has been devised by Krushinskii, (1960). He considered the ability to extrapolate, that is the ability "to form associations between phenomena in the outside world, which bear a cause and effect relationship to each other, as one of the most important criteria of rational activity". Three experimental procedures were described to test this in animals having simple forms of higher nervous activity; i.e., rabbits and birds.

Another approach to animal abilities which is a variant of the Pavlovian approach is that of Skinner, (1938). When he was recording the entry and exit of rats to a nest site Skinner initiated a mechanical method in which the animals themselves operated levers to record their behaviour automatically. He studied the rate of lever pressing for rats or key pecking for pigeons in the "Skinner Box" for various ratios and intervals of food reinforcement and how quickly such responses were extinguished after the food magazine was disconnected. Such procedures have been labelled "Operant conditioning" to distinguish them from the approach of Pavlov.

Yerkes, beginning in 1900, worked successively on lower forms of animals, then on the crab, the turtle, the frog, the dancing mouse, the rat, the worm, the crow, the dove, the pig, the monkey and man. He then went on systematically to the study of anthropoid apes. He took over the method of multiple choice developed by Hamilton, (1911) and used it extensively. The animal had to learn which of a number of boxes had the food in it. Hunter, (1913) used a delayed response technique whereby an animal could see where the food box was placed but was not allowed to go to it until after various periods of time.

Lashley, (1930) attempting to avoid the delays between an animal making a choice and its receiving a reward in a test of visual discrimination developed the jumping stand. It is practical

for rats. Kluver (1933) used a pull-in technique for animals with good manual dexterity, while Gardner, (1937) used three boxes, one covered with a black cover cloth for the domestic animals. Although it seems clear that the formation of simple discrimination habits does not distinguish between phyletic levels, by the use of 344 object discriminations, Harlow (1949) produced evidence of learning sets in monkeys. The solution of each new discrimination was not preceded by several trials at chance level as the test series progressed. Facility in the formation of learning sets has proven to be one of the most sensitive tests yet devised for measuring problem-solving ability in different species.

It has also been considered by Warren (1966) that as cats and monkeys learn to solve repeated reversals of the same discrimination habit with progressively greater efficiency, a comparative analysis of intertask transfer might be a profitable means of studying phylogenetic differences in mammals. From a review of this work and from studies of their own of the rate of improvement in a series of discriminations and reversals, Rajalakshmi and Jeeves (1965) developed the concept of the Reversal Index which they defined as "the relative difficulty of reversal learning as compared to that of the original learning." It would be determined by the following ratio.

Trials (or errors) to criterion on reversal learning

Trials (or errors) to criterion on original discrimination learning.

They list the Reversal Index for humans as 0.32; monkeys = 1.33; cats = 1.82 and rats = 2.89. This has generated much work on the Reversal Index or successive discrimination reversal (SDR) and Gossette (1968) summarised the work with 7 mammalian and 10 avian species and concluded that this methodology yielded systematic inter-species performance differences that were phylogenetically and taxonomically meaningful.

The selection of a single task for the testing of a variety of species was illustrated by the work of Fink, (1954). In his arrow maze (figure 3) there were four possible routes and these were alternated for the animals tested in a fixed order, 3, 2, 4, and 1. The same sized maze, 4 foot by 4 foot was used for all species tested and the minimum number of trials possible was 40 runs; i.e., 10 perfect runs in each of the four alleyways. The number of trials taken to reach 10 perfect runs was the major criterion of success though time and actual pathway were important. Fink compared the results from his work with those of other workers using different methods as shown in table 4.

This brief examination of the various approaches used to examine the ability characteristics of animals allows one a wide choice of methods. A combination of methods could also be possible.

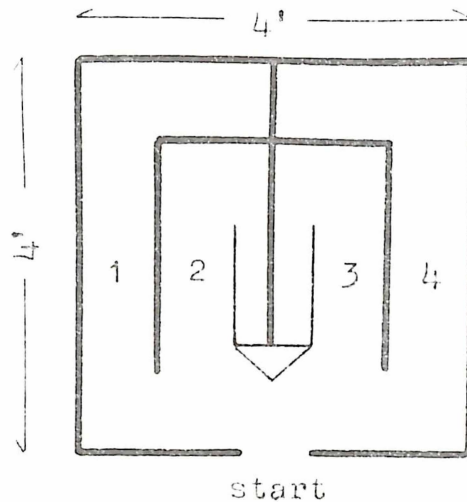


Fig. 3. The Arrow Maze designed and used by Fink, 1954.

For the purposes of this study we have taken the work of Hebb, (1949) as our model. Hebb, in his discussion of intelligence, examined the evidence from patients suffering from brain injury and surgery and concluded that there were grounds for distinguishing between two components of intelligence, Intelligence A and B. One is related to heredity and one more to experience. It was while Hebb was attempting to assess the contribution from experience that he had some rats blinded at birth and others at maturity. Observations of these animals suggested the possibility of a rat "intelligence test". The early test and the rationale for it was first reported by Hebb and Williams in 1946.

In its way, the Hebb-Williams maze or the Closed-field Test as it is normally called, is a synthesis of a number of earlier approaches. Hebb looked closely at the human intelligence tests and argued that all the material in them, be they figures, words or shapes, were familiar to the testee. Therefore in any work with

animals there would need to be adaptation periods and training trials to make the subject under test completely familiar with the nature of the tasks in hand. Once the animal was familiar with the experimental procedure and the elements of the maze, this could be rearranged in novel ways in the test sessions. The daily change of the detour or "umweg" problems as used in this test allay the original criticisms levelled by Kohler at the puzzle-box or maze approach to animal ability. Yet in most respects the apparatus can be referred to as a maze. It draws heavily on the traditions of the early American animal (rat) psychologists. Because of the adaptation periods used, it also partly answers the criticisms made of comparative psychological studies by the ethologists; i.e., that the laboratory tests conceived are too restrictive and sterile for the production of the full behavioural range which animals normally exemplify in their natural surroundings. Sheds and yards are part of the normal environment for domestic animals.

Not only was Hebb able to show differences between his two groups of blinded rats but the same apparatus was used very successfully with dogs raised in restricted and normal environments, (Thompson and Heron, (1954)). This Hebbian model presented the best possible procedure for our work for theoretical reasons and because some of the ground work had already been done with

dogs. Although it is not strictly a multivariate approach to animal "intelligence" it does allow for a number of separate analyses of the data produced; the speed with which learning or elimination of errors occurs; the use made by each species of visual cues and the overall error scores.

Other practical considerations were also important in our choice of method. Sheep and pigs had already been subjected to some degree of instrumental and avoidance conditioning, with rather limited results by way of a scoring device for abilities. We were to be dealing with large animals, the sheep, the cow and the pig and we needed apparatus in which each species could be tested with the minimum of adjustment or change of the apparatus. Though Pavlovian harness may be interchangeable for the sheep and the pig, harness would have to be developed for the cow. What if the work was to be extended to the horse or the goat? Problems of scaling and expense had also to be considered. To this end the closed-field apparatus presented us with the most flexible technique, the minimum expense, the possibility of future use as an outside laboratory, and no problem of storage of the equipment after the early work had been completed.

More important still was the realisation that the apparatus could have a double function; i.e., it could be used as an open-field test for experimental trials of emotionality and it could

also be modified easily to become the closed-field test for the assessment of the ability characteristics of the animals concerned. Schaeffer, (1968) also used his test apparatus with rats for this double purpose though we were not aware of this until sometime after this study had begun. We would be breaking new ground in testing all but the pig for the first time in such equipment. Further discussion of the work in which the open- and closed-field tests have been used will be found in a later section, the present study on page 69.

Large animals.

In this study the term 'large animals' has been defined as the animals of economic importance to New Zealand's primary industries during this decade; i.e., the cow, the sheep, the pig and to a lesser extent the dog. Horses were not included in this study for three reasons, (1) they were not readily available (2) because of the time factor and (3) the apparatus' costs would have been sharply increased, with the additional height required.

It is of interest to consider our objectives in terms of the four reasons given by Ratner and Denny (1964) for studying animal behaviour; (a) to gain information about the animal itself; (b) to gain information about the animal as an economic unit; (c) to use one animal form as a model for understanding other animal forms and (d) for the purposes of comparative analysis.

We are interested in the animal itself (reason (a)) because of the dearth of information about the behaviour of domestic animals. As 84% of New Zealand's overseas income is directly dependent upon pastoral production and these animals are essential to the functioning of this system, they are important to study as economic elements (reason (b)). As all of these subjects were tested in both the closed-field and the open-field for the first time the results are of interest for comparative purposes (reason (d)). Few species have been subjected to tests

in the open-field; e.g., only mice, rats, hamsters and pigs, though arena type tests have been used with sheep and dogs. With the closed-field test a wider range of animals has already been tested. Thompson and Heron (1954) worked with dogs in their 17 foot square maze. Livesey (1966) compared rats, rabbits and cats in the Hebb-Williams maze. Pollard and other workers have run rats and cats (1961), possums, (1967), ferrets (1969) and are at present doing work involving hens and several other species and recently Zimmermann (1969) has tested infant rhesus monkeys. This study will enable additional information to be gathered from the domestic stock.

Finally, it has been the understanding of the behaviour of the white rat which has led us to take the open-field and the closed-field as the model for our apparatus (reason (c)). The success of this study may give some indication of the real importance of the use of one species for the understanding of another.

Another interest in the study of farm animals arises from their essentially social character. The sheep, the cow and the pig are social animals forming some sort of herd or flock. Not only are they reared in social groups but they are maintained that way under normal farm management conditions. Though each animal was run individually in our tests they were tested in experimental groups of 6, 9, 12, 15, 18 or 21. We suggest that the discovery

of facts about the social processes and its inter-relationship with the performance of animals could be added as a fifth reason for their study.

The literature survey which follows indicates the studies already conducted on the sheep, cow and pig relating to the two aspects of behaviour under discussion.

CATTLE:

Hafez, Schein and Ewbank (1969) in 50 pages of review on the behaviour of cattle included one page on the discussion of temperament. After stating the problems involved in the objective definition of temperament which is equated with nervousness or skittishness they briefly reviewed a number of approaches made to the study of temperament in cattle.

(a) Latency of ejaculation. This is the time between mounting and ejaculation shown by bulls in an enclosure with a cow in oestrus. Hale and Almquist (1960) indicated that stimulus pressure; i.e., the sum total of sexual stimulation on the bull must be maintained at an adequate and a constant level during such a test, which appeared rather inadequate for the assessment of temperament in bulls.

(b) Restraint time. This is the time taken to fasten an animal to a post. Such a test involved several factors related to learning and habituation rather than temperament in the animal under test. The dexterity of the human handler is also involved.

(c) Pavlovian concepts of temperament. According to Pavlovian traditions, the temperament of cattle is related to the strength of nervous system processes; i.e., excitement and tranquility. (See Table 5). If both of these forces existed in strength then the cows would be of the strong type; if not they were of the weak type. These weak animals displayed a melancholic temperament and were subject to mental breakdowns. If, in a strong animal, these two forces were unequal the animals were unbalanced with a choleric temperament, being subject to fits of rage and expressions of extreme emotions. When the forces of excitement and tranquility were balanced in strength, the animal might be sanguine and lively or phlegmatic and quiet depending on which force can tip the balance. A practical example of this Pavlovian typology for bulls was provided by Smirnov-Ugrjumov (1945). Barishnikov and Kokorina (1959) related temperamental differences in higher nervous activity in cows to their levels of milk and milk fat yield, the character of their lactation curves, peculiarities of the milk let-down reflex, the speed of milk let-down as well as a number of other minor characteristics. They concluded that it was most desirable to breed cows with strong, equable, mobile type of higher nervous activity as they produced more milk and milk fats, evenly throughout the lactation period with the minimum of daily fluctuation.

TABLE 5: THE PAVLOVIAN CONCEPT OF TEMPERAMENT. (after Baryshnikov and Kokorina, 1964;
and Kudryavtzev, 1962.)

Frequency of occurrence in herds	FORCE Excitement and Tranquility	TEMPERAMENT	Reaction to environmental changes	Body build	Milking potential
High in improved herds	BALANCED	sanguine, lively, gay, versatile	shows good adaptation	strong build	highest of any group
High in improved herds	STRONG TYPE BALANCED	phlegmatic, quiet and inert	shows slow adaptation	strong build	good
Not high	NON-BALANCED	choleric, impet- uous non-inhib- ited	shows drast- ic drops in milk yield	strong build	seldom high
Low	WEAK TYPE	melancholic	adapts with difficulty	poor build	low

Another typological approach was that of Fraser's (1957) where he described the six types of bulls and these are shown in Table 3. The typological approach to the temperament of cattle is subject to the same criticisms as Fuller (1948) has made to similar work with dogs (see page 14).

(d) Temperament ratings. Some attempts have been made to rate temperament in cattle. Tulloh, (1961) provided a rating score of one to six based on a description of each particular temperament. He provided for a range from docile to wild and aggressive animals, (see Table 2). It was not considered that stubbornness gave a good indication of temperament as both docile and aggressive animals were found to be stubborn at times.

Scott (1958) made preliminary investigations of the effect of temperament on the inhibition of milk production. He showed that the two are related but he relied on the farmers' rating of their own animals for his assessment of temperament.

Dickson et al. (1968) in a more recent study of 27 Holstein herds used a one to four rating scale for assessing the temperament of 1,017 cows. (See Table 2). The milkers of each herd were asked to do their own ratings in this study.

Ely and Petersen (1941) threw a kitten onto the back of an unsuspecting cow as a test for temperament and recorded the inhibition of the milk ejection reflex. A modification of the

method was to explode paper bags every 2 minutes near the cow. Both Whittlestone (1951) and Phillips (1968) have used a slowly rotating black and white disc to inhibit milk let-down in cattle. This is a brief review of the typical approaches of earlier investigators to the assessment of temperament in cattle.

Hafez et al. (1969) do not cite any studies related to the assessment of the ability characteristics of cattle. However there are a number of such studies. Gardner and Nissen (1948) compared the performance of horses, sheep and cows with human aments and chimpanzees in a discrimination problem. They concluded that the domestic animals were superior to the others in initial learning. Several years before Gardner (1937) had tested 41 cows in discrimination problems where a dark cloth was used to cover food boxes. The rate of learning was rapid and the high milk producers were for the most part good learners. The Guernseys, Brown Swiss and Friesians made less errors than Jerseys, Shorthorns or Ayrshires. Breed differences in learning were more pronounced than age differences. Breland and Breland (1966) have shown how amenable the cow is to training but how impossible it is to speed up any reactions by increasing the food deprivation of these ruminants.

A number of more recent experiments have used the "T" or the "Y" maze to study the learning ability of cattle. Beauchamp et al. (1967) studied the calf's reaction to stimulus change while Dickson

(1967) measured the ability of heifer calves to associate a visual cue with a reward.

Wieckert et al. (1966) described a rather similar technique for measuring learning ability in calves. Other studies have reported on the possibility of training cattle in "cafeteria" stables in Holland (Brantas, 1968) and the reactions of dairy and beef cattle to an auditory signal to come to a food lot (Albright et al. 1966). Many farmers have made some attempts to train their own dairy cows in stalls and in the milking routine and numerous reports of these are found in farming journals. A full-scale study of the ability characteristics of cattle remains to be done.

SHEEP:

Sheep are seldom subjected to the close personal handling that is the lot of cattle in most farming systems. However with the growing interest in housing sheep and the importance of indoor lambing a new interest in the temperament of sheep could develop. Williams, (1967) writing of sheep which were to be housed indoors, talked in terms of "claustrophobic stress; i.e., being ill-at-ease with strange mates and seeking to escape to large fields or open hills. Thus housing does represent special hazards to nervous individuals. Yet with careful handling most sheep can be settled in happily to new situations. Fear is what they suffer from mostly in indoor housing."

A small open-field arena has been used with sheep a number of times during investigations of other factors than temperament. Cairns (1966) tested the attachment of a lamb to its partner after various periods of co-habitation. Lambs showed very strong following responses under these conditions. Liddell, (1956), Moore & Amstey, (1962) and others have used small rooms to score ambulation in lambs after conditioning experiments at various ages in the presence or absence of the mother. "Neurotic" and "normal" lambs show clear cut differences in both patterns and extent of ambulation.

Hafez and Scott (1962) explained why sheep had been so little used for studies in learning and intelligence. (i) Sheep have limited motor equipment and this limits the type of problems which they can solve. (ii) They show strong fear reactions to isolation. When discussing their sensory capacities they state that though a sheep is a highly visual animal it does not appear to use its sight as effectively as people. After their review they concluded that young animals were more amenable for testing; that some sort of detour problem or pathfinding situation would better suit sheep than a conventional maze and that the capacities of sheep were most likely to be fully expressed when they were used in the context of their flock and not as individuals.

Liddell, (1921) indicated that his basic interest was in the performance of thyroidectomised sheep. It was reasoned that lambs deprived of their thyroids should show a blunted mentality and a maze was built to test such sheep. It was 67 feet in length and 10 feet wide. It had a cinder floor and was surrounded by a timber fence. (See Figure 1.) From the start box the subject went down the centre alley and turned either left or right to return to the goal box where either the mother, the lamb or food was waiting. Learning was judged to be complete after three successful trials in succession. In a typical case a three month old lamb learnt the alternation problem in 5 trials while a 4 month old goat learnt it in 3 trials.

Because Liddell wished to have greater control over the behaviour of his subjects he became attracted to the Pavlovian method of the conditioned reflex. A laboratory was constructed under the guidance of Anrap, a former associate of Pavlov's. It was found that a sheep could be conditioned to establish a motor reflex by linking the sound of a metronome with a brief mild electric shock to the foreleg. This was known as type II conditioning (see Figure 2). The strength of the shock was so mild as to be barely felt by a moistened human finger. (Liddell, 1954). Though some of this work was related to the ability characteristics of sheep most of it was concerned with experimental neurosis. No sheep deprived of the thyroid have succumbed to

experimental neurosis. Of the 50 normal sheep suffering from such a neurosis none have been permanently "cured". The formation of conditioned reflexes by sheep indicate that their capacities are as highly developed as those of dogs or pigs.

Recently Sandler et al. (1968) described an operant feeding device for sheep and reported the effect on sheep of ingesting 20 mg. of dieldrin per kg. of body weight, on their vigilance behaviour. Three of the four sheep recovered to their pre-exposure response levels within ten days of the termination of the ingestion of dieldrin.

Much other evidence could be cited which indicates the capabilities of sheep for training. The biblical shepherd's skill in calling his sheep by name; the use of "Judas" sheep in the killing industry in New Zealand and elsewhere to lead mobs of sheep to the killing point; numerous comments from experimental workers who use sheep for research, and the trainers of performing sheep indicate the not inconsiderable capacities of sheep to learn and discriminate readily. As Hafez et al. (1969) conclude "they are highly responsive to new environmental requirements and readily adapt to modifications in patterns of reward and punishment".

PIGS:

Hafez and Signoret (1969) stated that most of the knowledge of the behaviour of swine has been gained from data collected incidentally during research on nutrition, breeding, physiology and management of the pig, or because the pigs were being raised in restricted quarters.

Pavlov tried to work with the pig (Liddell, 1934) but concluded that they were the most nervous of all animals and that "all pigs were hysterical". Other investigators however, have found the pig an amenable experimental subject.

A number of investigations into the temperament of pigs have been undertaken, and breed differences have been cited by farmers and experimental workers. Hodgson (1935) found evidence for genetic segregation in temperament in a series of highly inbred lines of pigs. Sows from one line became very aggressive while those of another remained placid.

The description by Marcuse and Moore (1944) of "Tantrum behaviour" appeared to be more related to the onset of experimental neurosis than a temperamental difference as it arose from modifications of the Pavlovian holding frame used when conditioning pigs. The study of Altmann (1941) which attempted to relate activity patterns of various sows undergoing experimental

conditioning to pathways made in pens running parallel to one another, suffers from the same criticism but must count as one of the first attempts to relate the temperament of pigs to an activity score, in this case the position of the pathway rather than an ambulatory score.

A serious attempt to score temperament in pigs was made by Dawson and Revens (1946). They were looking for a test which had the following requirements, (i) the animal would not be injured, (ii) the stimulus should be the same for all pigs tested, (iii) the pigs should be fully aware of the stimulus, (iv) the stimulus should cause a differential response between animals and (v) that no alarm be given by the stimulus to other pigs nearby waiting to be tested. To this end they used an electric spark which could be placed near to the feed trough, which could be turned on at will and which had stimuli for three of the pigs senses; i.e., a bluish-white light for visual receptors, a hissing, crackling sound for auditory receptors and a slight but distinctive odour. (See figure 4). The pig to be tested was driven into a pen and the drop gate was lowered by the experimenter. A two foot wide alley led to the food trough five feet away. The spark was set two inches from the far side of the 12" by 18" food trough, half an inch above the trough height. Dry meal was fed. Five seconds after beginning to feed the spark was turned on and left

going until the pig returned to feed again. As the pig started to eat the spark was turned off for 10 seconds and the trial was repeated. Three trials were carried out each day for two days.

Of the 42 pigs tested five did not leave the food trough though three flinched during one or more of the trials. Four pigs of the 42 left the trough and would not return. The rest were ranked by a return to the trough score of 1 to 563 seconds. Most of the pigs reduced their reaction time to the spark by 90% on the second trial and adjusted very quickly to the sparking device. No correlation could be found between the results and average daily weight gains, nor weight of offspring of the sows which had been tested. They make suggestions for improving the design of the apparatus, the nature of the food offered and ways to eliminate obstructions to the behaviour patterns shown in the test.

An open-field built at Iowa State University has provided results for two studies with pigs. Beilharz and Cox (1967) reported on a genetical analysis of open-field behaviour in an arena 10 ft by 10 ft. The floor was marked in two foot squares and 1853 pigs of the Duroc and Hampshire breeds were tested over a period of a year. Half of the sires of these litter mates had been subjected to scrotal irradiation of 300 roentgens at the age of 6 months. The pigs were tested at the age of 48-52 days and had not been isolated from litter mates before that time. Squares

crossed in two minutes ranged from one to 100 with an average of 22 per minute. A positive correlation with the season of the year indicated that pigs were less active in the hotter summer than in the late autumn. No other interactions tested were significant.

McCann (1966) similarly using X-irradiated and non-irradiated swine, sought a test for the generality of Denenberg's emotional reactivity hypothesis to pigs. Of the two breeds tested Durocs proved to be the most active breed in the open-field. Both avoidance learning and early experience given between days 7 and 11 of age decreased the activity in the open-field. The effects of early experience were apparent from the open-field data though evidence for a monotonic relationship as postulated by Denenberg (1964) between stressfulness of early experience and emotionality was not found. McCann considered that high emotionality was reflected in high ambulation, the reverse situation to that found in rats.

Several recent studies have considered the varying reactions of different pigs to "stress". Transporting pigs by vehicle and penning strange pigs together were more stressful to some breeds than others (Cena, 1965). Sybesma (1969) developed an endless belt which forced pigs to keep walking as a method of rating stress in pigs under test.

The ability characteristics of pigs have come under some scrutiny. The early studies of Yerkes and Coburn (1915) showed that the pig was able to learn by spatial discrimination the correct response when faced with five choices in four different positions of a problem-solving situation. The marked effect of the first habit established for the subsequent location of food was shown by Myers (1916). Despite the lack of success Pavlov had with the pig, Moore and Marcuse (1945) successfully conditioned pigs and described salivary, cardiac, and motor indices of conditioning. More recently Barnes et al. (1967) used only Pavlovian techniques to distinguish between two groups of pigs, (a) pigs with early food deprivation and (b) normally fed pigs. They wished to assess the influence of protein deficiency in early life on changes in learning behaviour. Both the experimental and the control pigs conditioned rapidly to a mildly painful electric shock paired with a change in light intensity and the acquisition time was the same for both groups. When extinction trials were run however, the animals fed well during early infancy extinguished the response in a few trials whereas the malnourished animals continued to act as if they anticipated the shock. This reaction occurred 18 months after complete rehabilitation of diet and weight.

The ready adjustment of pigs in classical and operant conditioning procedures has been turned to useful practical consideration by Baldwin and Ingram (1967, 1968). They taught pigs

to operate a switch which would provide short bursts of infra-red heat or hot air. The pigs were able to determine their own optimum environmental temperature. The exploitation of other animal preferences in the same way is clearly a possibility (see Figure 5).

Breland and Breland (1961) after an early belief that Skinnerian techniques could be applied equally successfully to most if not all animal species found that some animals "misbehaved". Trying to teach pigs to drop a coin into a hamper proved to be a most difficult task and several approaches had to be made to achieve any degree of success. However in most tasks the pig, being 'intelligent' and a good generaliser, an animal which has occupied a variety of niches in the past and one having omnivorous food eating capacities, was readily trainable by operant methods of conditioning. In Harlow's terms (1949) pigs readily "learn how to learn".

With the recent realisation that in many basic physiological systems the pig parallels man, the breeding of miniature pigs for research has progressed rapidly. Such pigs are small and docile to handle. It has been upsetting to find that despite the similarity of the structure of the eye to man's, the pig's ability to learn discrimination based on form, colour or size is poor. In his early studies, Wesley (1955) found that if the pig could be delayed for 5 seconds, two feet from a black or white stimulus

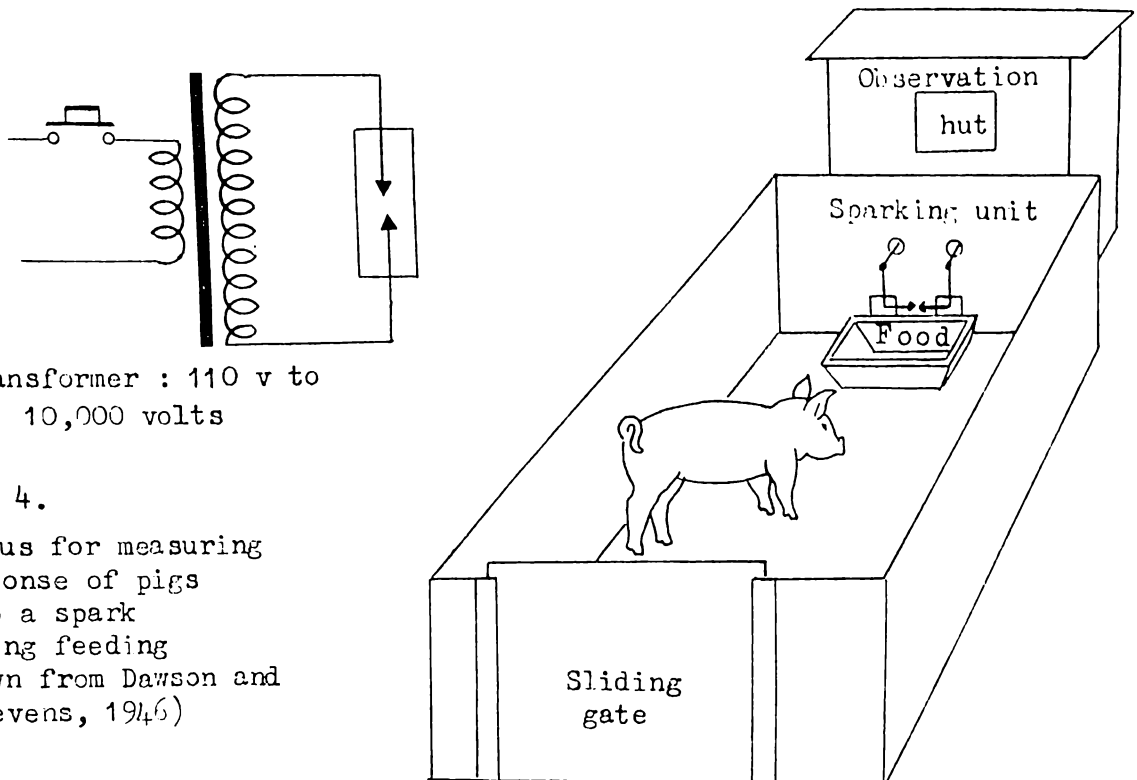
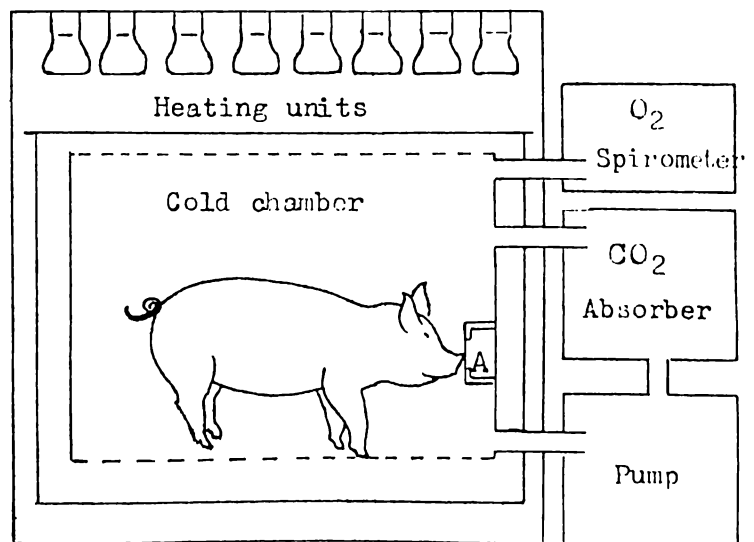


Figure 4.

Apparatus for measuring
response of pigs
to a spark
during feeding
(redrawn from Dawson and
Revens, 1946)

Figure 5.

Apparatus designed to
enable pigs to select
optimum temperature
requirement - an
application of
Skinnerian techniques.
(after Baldwin and
Ingram, 1967)



A = Heat control button

card, one of which was rewarded with food, three out of 16 pigs could learn to make a correct choice. Stopping the animal four feet from the cards or allowing the animal direct access to them was without effect.

After an analysis of the sensory cues employed in early teat-seeking and suckling, all of which are non-visual it was concluded that it would be difficult to train pigs to find food by forcing them to make visual discriminations. A full discussion of this work is provided by Klopfer (1966).

Fink, (1954) used his arrow maze (see figure 3) to test the ability characteristics of pigs and their ratings in comparison with other species is shown on Table 4.

Weikert and Barr (1968) used a "T" maze for learning studies in young pigs. These pigs were forced from the start box after 10 seconds and records were kept of the decisions made and the times required to complete the maze. Poland China and Yorkshire pigs and their crosses were used. They concluded that pigs differ in their ability to respond to and remember a visual cue; that crossbreds executed the maze more quickly than the pure-breds; that those in large litters spent less time in the maze than those in small ones and that none of the pigs achieved a constant response to visual cues.

Karas et al. (1962) developed a shuttlebox for avoidance learning in pigs. The box was six feet in length and two feet wide. A five inch wooden barrier was placed centrally on the

metal grid floor. After the pig was introduced a buzzer sounded for 6 seconds and if the pig did not shift compartments, shock of 700 volts was applied for 1/50th of a second each second. Kratzer (1969) reviewed the results from this work and gave additional evidence that Durocs were better performers than the Hampshire at 21, 40, 80 and 150 days of age; that younger pigs learnt faster than older pigs; and that heavier litter mates were better learners than their lighter siblings.

Braude (1948) gave practical examples of the pig's capacity for training. In Denmark pigs were trained to move out and dung and urinate in specially designed pits on hearing a bell. Others moved to specific feeding places within a week.

From this survey of the studies undertaken with sheep, cattle and pigs we concluded that sufficient work has been done to show that each of these species would respond to an arena type apparatus. Those workers who have used such apparatus in the past have recorded meaningful data. A large dimensioned field would allow for flexibility of procedures and design and such an apparatus appears to provide the best objective approach to the studies of both the temperament and ability of the domestic animals.

Stress conditions: Because farm animals are social animals

running animals singly in the test apparatus might well be a "stressful" experience, particularly for sheep. Liddell (1925) described the 'alarm reactions' of sheep in his long runway type maze and Marcuse and Moore (1944) described tantrum behaviour in pigs used for conditioning experiments. Liddell's subsequent work was related to a full exploration of the stress reactions of sheep under a variety of experimental conditioning procedures and its effect on maternal and other behaviour, (Moore, 1968). The definition and description of stress however presented some difficulty.

Almost any change in the external environment, physical injury or emotional upset is potentially capable of producing deleterious effects on the animal concerned, but within limits the adaptive mechanisms of the body provide it with the flexibility to accommodate most of these changes. The definitions and terminology most useful for this study draw their historical origin from three areas of investigation.

Studies of the social behaviour of animals were given impetus by the work of Schjelderup-Ebbe (1923) with hens. He described carefully the encounters in a flock of chickens and found evidence for a "peck-order" or dominance hierarchy

in smaller flocks. His study led to considerable work in this field and Guhl's monograph (1953) summarised the work to date. With the intensification of poultry units and the keeping of hens on deep litter and in battery cages, much practical interest has developed in the field of population density, social relationships in the flock and their influence on the growth and production of the animals concerned. Early papers of McBride and his co-workers explored some of these concepts in hens and pigs and this work was given full theoretical treatment by McBride in 1964. Meanwhile the social interactions of other animals were more fully explored; the red deer by Darling (1937); dairy cattle by Schein and Fohrman, (1955), Guhl and Atkeson, (1959), Kilgour and Scott (1959), Beilharz and Mylrea, (1963), Dickson (1967); sheep by Scott, (1945); the white rat by Barnett (1963) and the hen by Wood-Gush, (1965).

Ecological studies, particularly on population dynamics provided an additional source of evidence. Murie (1944) worked on the population dynamics of wolves and Wynne-Edwards (1967) and his co-workers studied the sage-grouse and their territorial spacings which control population fluctuations. A number of laboratory studies have been undertaken, by Calhoun (1962), Christian, (1950) and others. A review by Christian and Davis

(1964) indicated that there was growing interest in this area of social interaction. There was some evidence to implicate the adreno-corticotrophic mechanisms as a mediator of long term stress in social animals.

In addition we have **Selye's** classical concepts relating to stress developed over a period of years and his description of the General Adaptation Syndrome, (1947, 1950, 1954, 1970).

At a recent Poultry Symposium (Carter, 1967) several speakers discussed stress in birds and Brown nominated such diverse things as sonic booms, surgical trauma, and situations involving fear, apprehension, anger or anticipation as able to elicit stress in animals. He described stress as the generic term for these immensely dissimilar events which have the common property of stimulating adreno-corticotrophic hormone secretion, and this was determined by the measurement of plasma corticoids. Amoroso in the same symposia suggests a definition and mnemonic of stress as "Situations That Release Emergency Signals necessary for Survival". McBride, (1968) provided similar definitions of stress as "the stimuli from outside the organism which produce an alteration or deformation in the animal". He reserved the term strain for the resultant effect in the individual. We have adopted this terminology for our study in the hope of standardising general usage.

Using domestic animals for his examples McBride examined the situations due to management or mismanagement which can lead to stress on the subordinate animal. Social stresses are those which emanate from non-specifics in the immediate vicinity. They are inter-animal stimuli within a group and are generally agonistic, a term popularised by Scott (1945). Agonistic behaviour is regulated through the competitive system of the social hierarchy known as the 'bunt', 'hook' or 'peck-order'.

The organisation of an animal group into herd or flock presupposes a concept of spacing. The basic vectors postulated by Schneirla (1963); the tendency to Approach (the A vector), and the tendency to Withdraw, (the W vector) are useful to understand the dynamics of social spacing. Animals manipulate space mainly through the W vector as intra-animal aggressiveness. Normally if space is sufficient for the needs of the group, the threatened animal will disperse, but if the animals are restricted in space, these interactions constitute social stress and strain will develop in subordinate animals. McBride has developed a useful model to aid the understanding of these processes in domestic stock. (See figure 6.) Some of the preliminary observations concerning the social behaviour of cattle and the stress arising from management of dairy herds have been recorded. (Kilgour, (1969) and Donaldson (1970)).

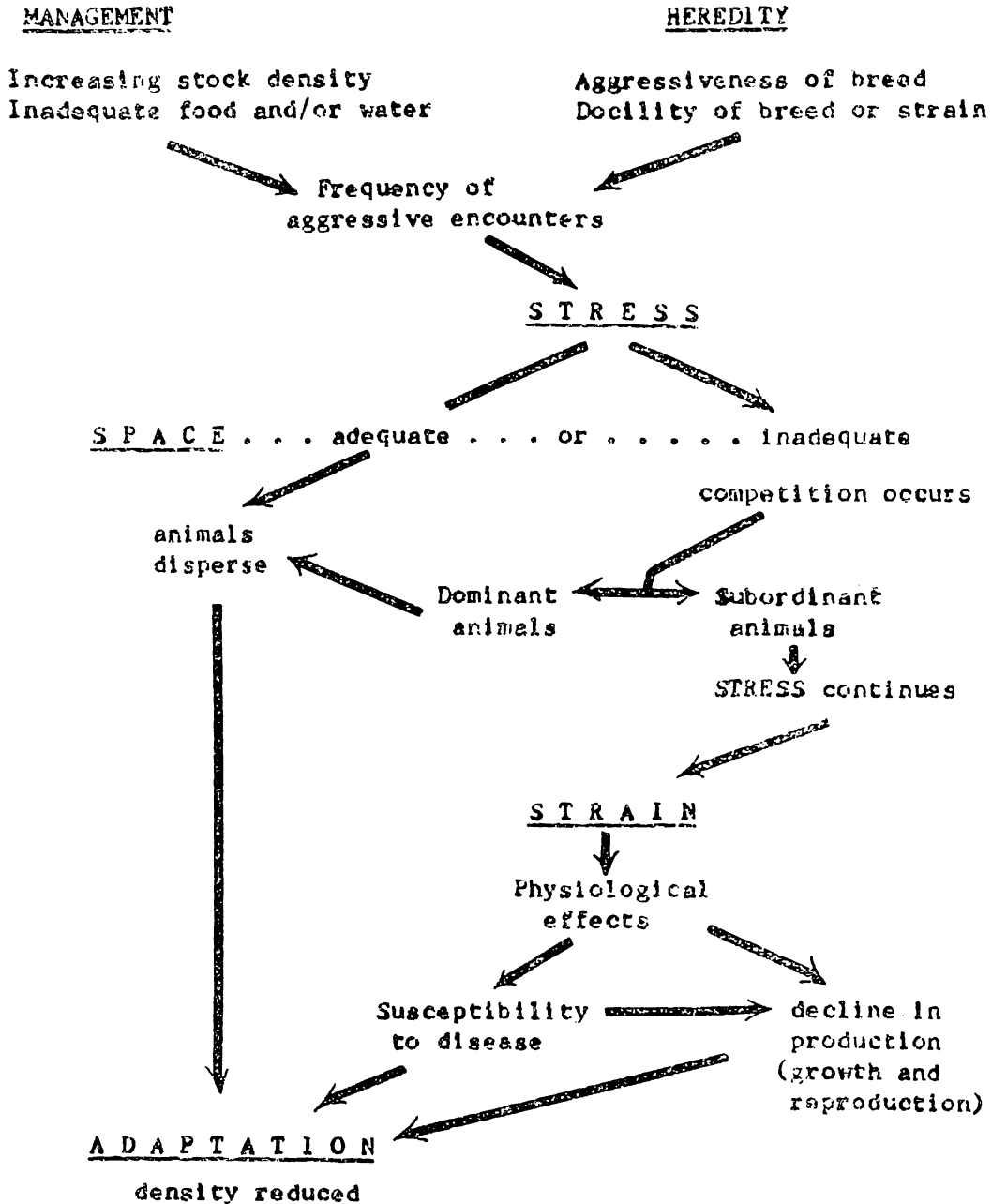


Figure 6.
A model of the causes and results of "social stress" in domestic stock. (after McBride, 1968).

The nature of the handling and testing procedures for both the open- and closed-fields meant that the subjects under study were frequently restricted and that social stress would be one of the factors influencing the results from such a study. Stress from other sources such as the deprivation schedule adopted, would also contribute to social stress as would the procedure of running them singly rather than in pairs or groups. In this latter case the A vector would be thwarted. No additional actions other than the simple experimental procedure seemed necessary to provide conditions of "stress" for the subjects in this study.

Such stress is assessed by two basic methods, both used in this study. A detailed examination has been made of the subject during the tests for striking features of behaviour; e.g., sheep under pasture conditions seldom show overt agonistic butting but this behaviour was frequently observed in our subjects. Certain behavioural patterns occurring during the test which appeared "irrelevant" in their context, made us suspect the presence of types of "displacement activities" especially in the sheep. Huxley (1914) first recorded Crested Grebes "displacement" wing preening while Lorenz (1935) noted that fighting cocks may suddenly stop and begin pecking the ground in the middle of a contest. Tinbergen (1940) and Kortlandt (1940) provided full and independent discussion of this behavioural phenomenon which has been termed "displacement activity". From a study of birds and fishes it was considered

that displacement activities arose under three conditions, (i) if two drives counteracted one another; e.g., the tendency to attack and the tendency to flee; (ii) if the fighting partner should suddenly flee before expected or (iii) if some anticipated stimulus did not occur but the drive had been aroused.

A wide ranging list of actions fall into the category of displacement activities including foraging movements, food begging, body care or preening movements, like scratching, sexual movements, incubation and sleep. It was claimed that such behaviour in a given species could be predicted, was consistent, and could be used as an indicator of some sort of conflict or stress. Some evidence for displacement activities has been provided for cattle by studies of Schein and Fohrman, (1955); Dalton et al. (1967); for sheep by Liddell, (1925); for dogs by Flashman (1967) and for humans, Kehrner and Tente (1969). Kilgour (1969) discussing the pertinence of this concept for the behaviour of domestic species, concluded that with cattle and sheep "displacement grazing" is common at times of conflict or stress.

As well as the behavioural indications of stress, an attempt was made during this study to evaluate the animals' reactions by a physiological test for stress. Blood plasma samples were

taken from a number of animals and these were tested for levels of cortisol using a spectro-fluorometric method (de Langen and Whittlestone, 1970) adapted slightly from the technique of Mattingley, (1962). The role of adrenal activity in stress responses has been well established (Ganong, 1963; Mason, 1968). This is an elaborate technique and a useful additional indication of stress in subjects under test.

As we wished to record the initial behavioural reactions of the animals to a strange environment in the open-field test, this was conducted on the first three days before the closed-field testing began. The social stress reactions of the subjects generally occurred in the closed-field testing during the adaptation period and early training trials.

To conclude: the testing procedures used with single sheep, cattle and pigs, animals of highly social species, provided in our opinion the stressful conditions required for this study. Our procedures simulated many of the normal farm activities with stock in pens and yards. Therefore we would be able to assess under a controlled situation some of the handling conditions stressful to domestic stock.

It is now possible to discuss the formulation of these concepts into the experimental programme which forms the body of this research.

THE PRESENT STUDY

Setting: The site chosen at the Ruakura Agricultural Research Centre was situated between a road and a railway and had a slight fall for drainage, and the maze, which was oriented approximately North-South, had a farm raceway as access and was 150 yards distant from the regular handling area for experimental animals. The site was $\frac{1}{4}$ of a mile from the piggeries, seen in the background of Plate 1, and $\frac{1}{2}$ a mile from two dairy herds on the experimental station. Sheep were always available at this Centre as were a number of dogs. Plate 1 shows an aerial view of the site and the completed apparatus with a legend to label specific features of the closed-field.

Apparatus: The original Hebb-Williams maze was constructed on a table top and was oblong rather than square, (1946). Designed for rats it was 30 in. by 36 in. and 4 in. high. Rabinovitch and Rosvold (1951) modified and standardised this test and fixed on a 30 x 30 in. area divided into a five in. grid pattern to give 36 squares. Most rat mazes were built either three ft. or 30 in. square, while those for opossums and larger animals have been 6 ft. (Pollard et al. 1965) or 12 ft. (Warren et al. 1961) though Thompson and Heron's maze (1954) was 17 ft. by 17 ft, $2\frac{1}{2}$ ft. high and was divided into 49 squares: i.e., a 7 x 7 grid pattern. Livesey (1966) used a 6 ft. by 5 ft. maze for testing rats, rabbits and cats. A summary of the sizes, the procedures, the

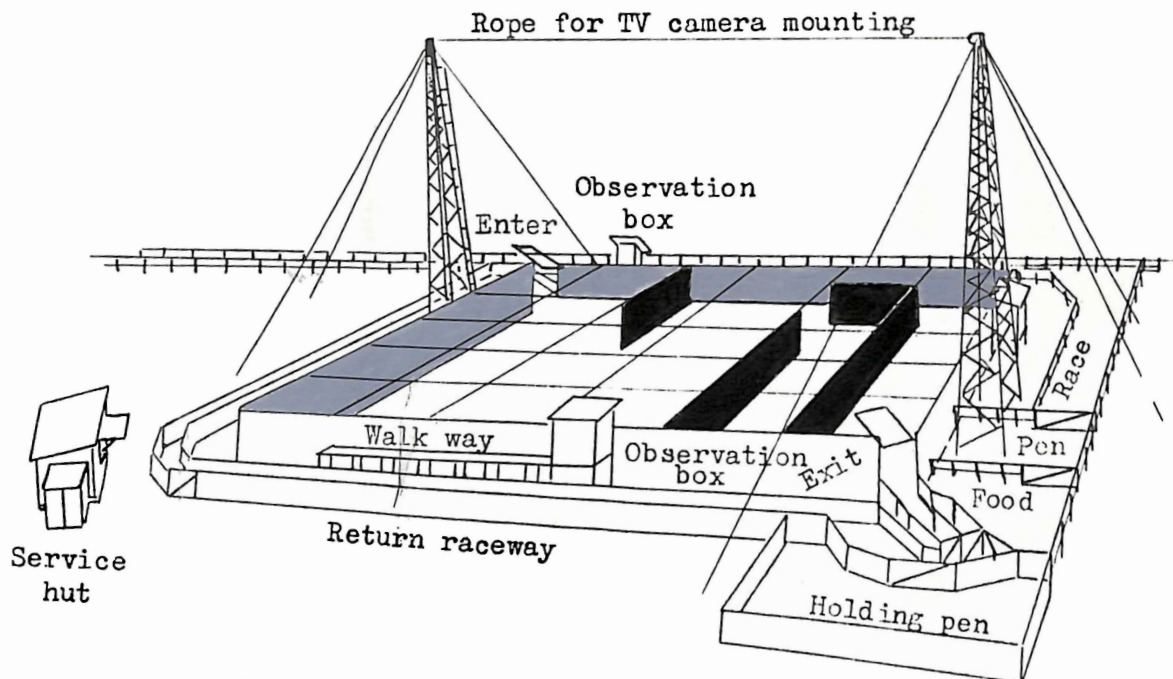
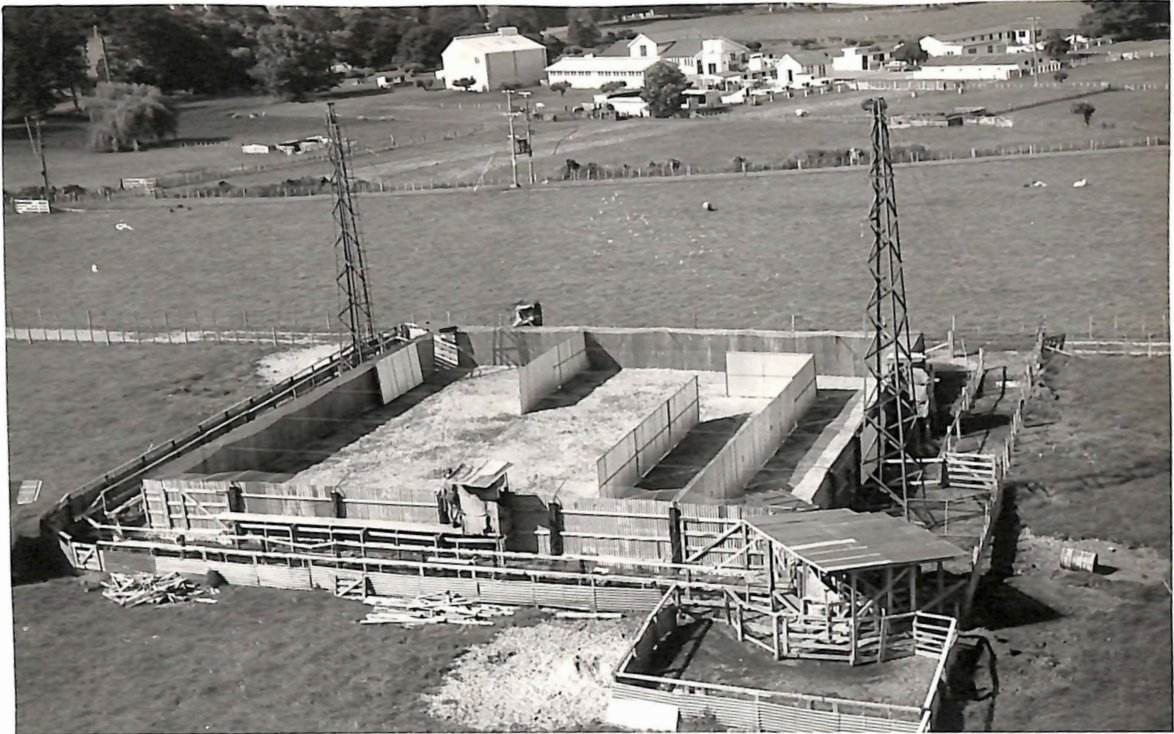


Plate I

The apparatus used for Open-field and Closed-field Studies showing problem XII.

Above : Photograph Below : Identification sketch.

species tested and other facts about the closed-field test is provided in Table 6.

The sizes of open-fields have varied from one experimenter to another as is shown in the sample summarised in Table 7. Hall's (1934) original field for rats was 8 ft. in diameter with walls 2 ft. high. Broadhurst (1957) used two arenas, one 6 ft. and the other $32\frac{3}{4}$ in. in diameter. Others using circular arenas have been Tobach and Schneirla (1962), 30" diameter; Ader et al. (1967) 5 ft. in diameter, etc. Square open-fields ranging in size from 18 in. by 24 in. (Bindra and Thompson, 1953) 30 in. square, (Tees, 1969) 45 in. square, (Corman and Biondo, 1969) to 4 ft. square, (Denenberg, 1963) have been used. Beilharz and Cox (1967) built a 10 ft. square arena for testing pigs.

It was clear that apart from the 17 ft. enclosure used as a closed-field for dogs and the 10 ft arena for the open-field with pigs most of the apparatus built has been for small animals and was 2, $2\frac{1}{2}$, 3, 4 or 5 ft. in size. How big should we make our apparatus for cows? Having watched the 6 ft. closed-field apparatus in use with rats at the University of Canterbury (Pollard, 1961) and watched the flow of these animals we decided to scale up by a factor of 12 and make our apparatus 72 ft. by 72 ft. Several other points were also considered in this decision; (a) the distance the subjects would have to travel in

Table 6 : A summary of some of the closed-field testing procedures used by various investigators.

Species	Field Size	Square size	Runs per day	r ^a	Depri- vation	Authors	Problems p ^b	scoring
			Training	Test			training test	method
rats	30"x36"x4"	---	for 2 wks	4p x 3r a day	food	Hebb & Williams(1946)	1A-1L ^c	dr ^d
rats	30x30"x4"	5"x5"	9r a day	7r or 10r	food	Rabinovitch A-F ^e	R&R,1-12 ^f	ez ^g
rats	30"x30"x4"	5"x5"	2 days in 60 sec	per p		& Rosvold (1951)		
rats	30"x30"x4"	5"x5"	9r a day	10r a day	water	Ison & Taplin (1966)	A-F 1A-1L	ee ^h
rats & cats	72"x72"x12"	12"x12"	9r a day	8r a day	food & water	Pollard (1961)	A-F 3v & 3nv ⁱ	ee & ez
cats	36"x36"x6"	6"x6"	8 of 9 in 2 days					
cats	12'x12'x2 ¹ / ₂ '	2'x2'	1r a day	8r at 2p a day	food	Warren et al	A-F R&R,1-12	ez
rat, cat & rabbit	72"x60"x12"	12"x12"	5r x 2p a day	5r x 2p a day	food	Livesey (1966)	A-F R&R,1-12	ez & ee
possum	72"x72"x12"	12"x12"	9r a day	8r a day	food	Pollard & Lysons(1967)	A-F 3v & 3nv	ee
dogs	12'x16'x2'		for 2 wks	3r x 4p a day	food	Phin (1946)	1A-1L	dr
dogs	17'x17'x2 ¹ / ₂ '	29"x29"	1p a day	6r x 1p a day	food	Thompson & Heron (1954)	5p 18 tests	ez _j & ee
dogs	12'x12'x2'	2'x2'	2r x 2p for 9 days (in 5 min)	2r x 2p a day for 6 days	food	Werboff et al.(1969)	A-F R&R,1-12	ez
infant rhesus monkeys	48"x48"x?	8"x8"	5r in 10 min	8r x 2p a day	food +cloth	Zimmermann	A-F R&R,1-12 ^k M.I.	ez

Key: a. r = runs b. p = problems c. =1A-1L = Hebb-Williams problems (see Figure 10)
d. dr = deviation rating e. A-F = Rabinovitch & Rosvold Training Problems
f. R&R,1-12 = Rabinovitch & Rosvold Problems 1-12 (See Figures 12 & 13)(See Figure 11)
g. ez = error zones h. ee = entry in excess of shortest pathway.
i. 3v & 3nv = Pollard's visual and non visual problems (See figure 14)
j. ts = time scores k. M.I. = Mirror image retest.

Table 7 : A summary of some of the open-field testing procedures by various investigators.

Species	Field Shape/size	No. of squares	Time (mins)	Reference	test days	test age in days	Type of activity and scores used
mice	12 gal. tub	12	2	Lindsey <u>et al.</u> 1963	2	30,100	a:d/u.
mice	36"x36"x24"	4	5	Henderson 1967,1968	2	70	a:d.
mice	36"x36"x?	36	3	Hegmann & de Fries 1968	2	40	a:d.
mice	36"x36"x?	81	3	La Barba 1967	3		a:d:ga.
mice	25"x25"x13	25	5	Hostetter 1966			a.
mice	30" dia x ?		2	Ader <u>et al.</u> 1967	1		d:aw:pc:
mice	30" dia x 24"		4	Tobach & Schneirla 1962	10		a:d/u:c:w:j etc.
rats	30" dia x 24"		4	Tobach & Schneirla 1962	10		a:d/u:c:w:j etc.
rats	96" dia x 24" zones		2	Hall 1934	14		e:d/u.
rats	72" dia x 12 $\frac{1}{2}$ "	6	2	Broadhurst 1957	5	110	a:d/u.
rats	32 $\frac{1}{2}$ " dia x 12 $\frac{1}{2}$ "	3	2	Broadhurst 1957	5	110	a:d/u.
rats	48" dia x 18"	49	2x5	Latane 1969	2	120	a:d:f.
rats	33" dia x ? zones		5	King 1968	2	63	ga: positions score
rats	72" dia x 12 $\frac{1}{2}$ "		2	Ivinskis 1966	2x4	90	w:d/u:a:r etc.
rats	60" dia x ?	7 $\frac{1}{2}$ sq.in	2	Ader <u>et al.</u> 1967	1	120	a:aw:pc.
rats	48"x48"x?	25	3	Denenberg 1963	3	50	a:d/u.
rats	45"x45"x18"	25	3	Levine <u>et al.</u> 1967	1-4	80	a:d/u:r:v etc.
rats	45"x32"x32	20	4	Pare 1964	4	80	a:d/u:r:s etc.
rats	24"x18"x16"		10	Bindra & Thompson 1953	1	100	d/u:e.
rats	40"x40"x18"	25	2	Becker 1969	11	90	d:a.
rats	48"x48"x12"	16	10	Leavitt 1969	4	70	a.
rats	45"x45"x21"	25	5	Morrison & Thatcher 1969	1	50	a:d/u:r:g etc.
rats	36"x36"x12"	144	3	Doty and Doty 1966	2	23-620	a:d
hamsters	32"dia x 15"	19	2	Swanson 1966	4	65,95	a:r:s:w etc.
hamsters	24"x24"x12"		3x15	Jowaisas 1969	1	110	f:w:k:s:d/u etc.
pigs	10' x 10'	25	2	Beilharz & Cox 1967	1		a
pigs	10' x 10'	25	2	McCann 1966	1		a

a = ambulation: aw = adrenal weights: c = circling: d/u = defecation/urination: e = eating time:
 f = freezing: ga = general activity: j = jumping: pc = plasma corticosterone: r = rearing:
 s = sniffing: v = vocalisations: w or g = washing, grooming.

the return raceway from the goal box to the start box after each run, and (b) the weight and size of the baffles which would be needed for setting up the problems from day to day. It was considered that a 12 ft. by 6 ft. barrier made of aluminium would be as much as could be conveniently handled by two persons.

The size of the test arena was finalised as follows:-

Overall length and breadth = 72 ft.

Basic grid size = demarcated by high tensile tie wires 12 ft. by 12 ft.

Approximate wall height = 7 ft. after allowing for floor materials.
Total number of internal squares = 36. This should allow for ease in scoring errors of ambulation in the open-field.

The discussion of Pollard et al.(1965) on the performance of rats in the small and the large maze was relevant here. It became obvious that by using the same sized testing apparatus for sheep, pigs and cows, the cow would be at a disadvantage. Each time a cow turned around in the arena there was a strong possibility that she would break a square boundary and commit an error, whereas a sheep or pig would be able to turn around even a number of times within the prescribed 12 ft. without breaking a square at all. Thus the relative scaling of the arena compared to the size of the species being tested was an important parameter for our consideration.

Construction: The arena was constructed to a timber frame supported on 12 ft. half-faced strainers. These were anchored into the ground by a tie wire at $3\frac{1}{2}$ ft. above ground level. The support was held rigid by taut overhead high tensile no.12 gauge wire which was strained back to the same ties in the ground. The tie wires were interlaced and held at each cross point by a small brass nipple and nut with two grooves holding the wires at right angles. By loosening the nut the wires could be moved across one another about 1 ft. in each direction to enable the baffles to be inserted with ease, and at the same time held the apparatus rigid. These wires also defined the basic maze grid for the correct placement of baffles and the delineation of squares for error scoring during the open- or closed-field testing. Allowing for sag over the 72 ft. arena, all wires were at least 80 in. above the floor level. Three by 2 in. timbers near the ground, and at $3\frac{1}{2}$ ft. and 7 ft. allowed corrugated iron to be nailed on to the inside. This iron was let 6 in. into the ground to prevent the entry of subterranean rooted plants. The corners were constructed in the form of 2 gates so that they could be opened out for ready access to the internal area, though when closed they made up a proper part of the internal wall structure. This also allowed the entry and exit of animals from any corner of the maze. The completed interior iron was coated with a rust-proof paint which was flat

grey (K-16). The internal barriers were made up in 12 ft. sections and painted similarly. As these original baffles weighed 138 lbs, the iron was later stripped off and replaced with aluminium. Sixteen baffles were made in all.

A feed-back raceway similar to that designed for rats by Radloff, (1964) was constructed to enable the subjects to return from the goal box to the start area and this was wide enough (4 ft.) to take a cow. After completing the first 3 experimental groups, 2 feed boxes were constructed to enable more animals to be run during one experimental period. This area was roofed to prevent the direct glare of the sun and stop rain falling into the food boxes in wet conditions. Plate 2 indicates the need for this area to be covered. Plate 3 illustrates the entrance gate.

Two 40 ft. pylons were erected slightly to one side of the start gate and goal boxes to enable all movements of the animals to be monitored by a closed-circuit television unit but as a result of various difficulties it was not possible to have this apparatus in operation during the three year study.

The floor of the maze was originally pasture. This was cropped off closely by sheep and three inches of pumice sand was spread across the soil surface. This was covered again with 3 to 5 inches of heavy wood shavings. Each new season an additional

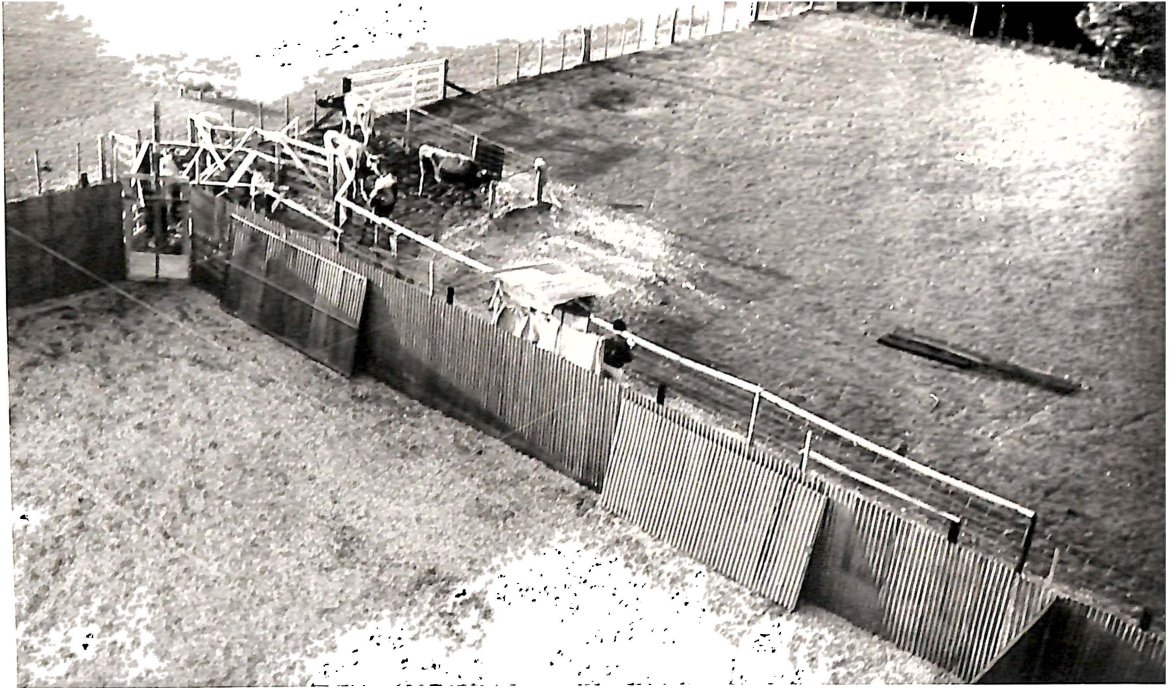


Plate II A view from 40 ft above the closed-field at the TV camera mounting showing exit gate, two cows feeding, four cows in the holding pen and the 12' x 12' squares marked by the wires and used for scoring the animals pathway.



Plate III A ewe enters the field on problem I on day I. The start gate is lowered to prevent retracing of steps on the training trials on day I, II and III.

8 cubic yards of shavings were added to the floor. Even in the wettest winter experienced, pugging has not been a problem. Pig tracks were the severest test. In heavy rain the floor has been covered with up to 2 in. of water which has run off above the level of the pumice sand.

To enable accurate plotting of the movement of the stock during the trials, 3 small platforms were constructed and weather-proof hides were built to allow independent persons to plot movement along 2 co-ordinates without disturbing the animals concerned.

As the trials progressed slight changes were made to the apparatus to streamline the handling and to aid the smooth flow of the subjects under study. A compressed air system for controlling start and goal box gates and the various raceway gates was installed in October 1969. Details of this system are given in Figure 7. Compressed air with the pan and tilt system is planned for the overhead TV camera. The advantages of such a system are (i) its ease of initial construction; (ii) its ease of subsequent modification; (iii) its ease of repair if some failure of the mechanism should occur; i.e., if a hose pipe should be cut this could be repaired on the spot. The system was rather costly but easy to maintain.

Working on the same principle, that repairs should be carried

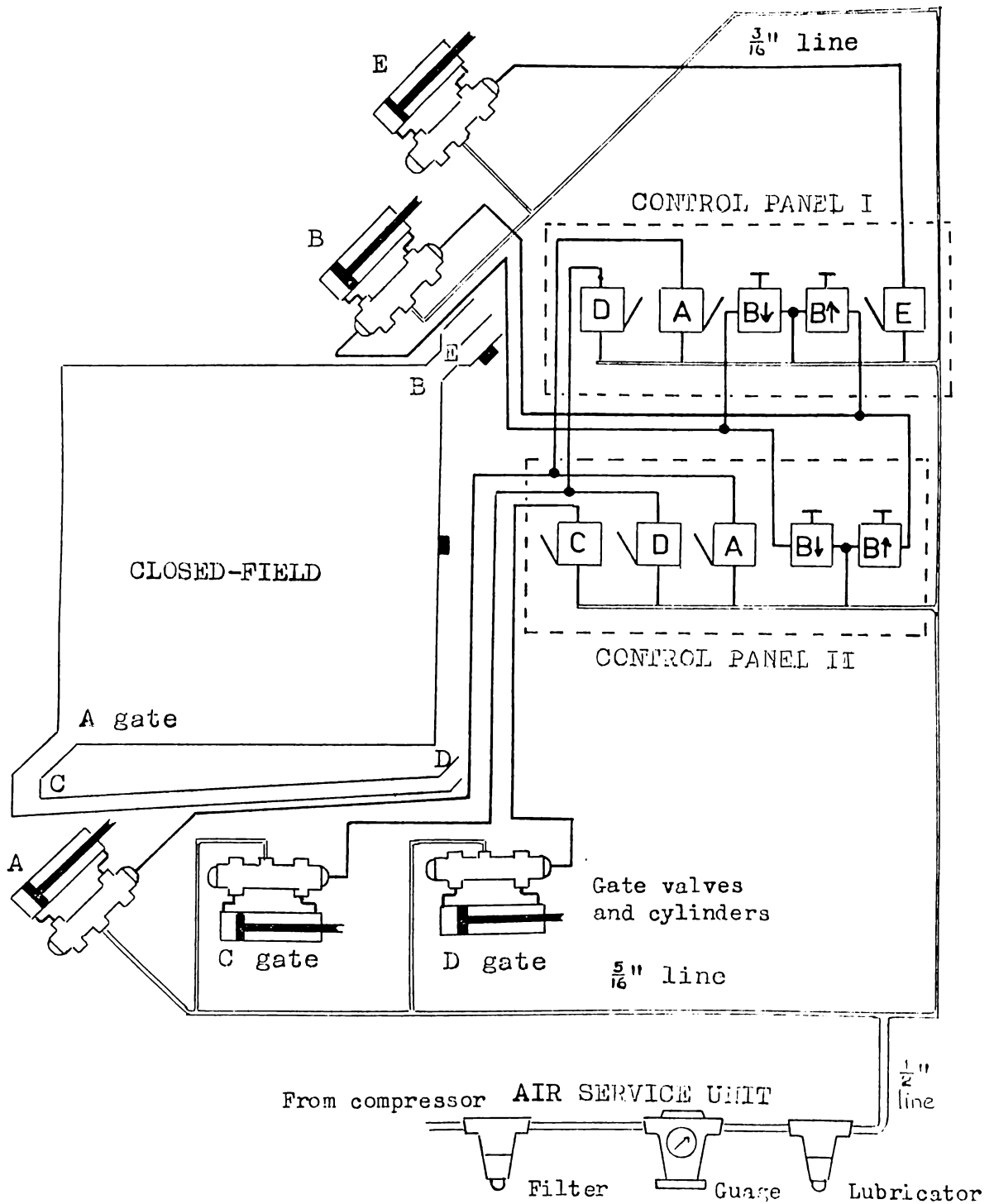


Figure 7.

COMPRESSED AIR DIAGRAM

out immediately by the operators on the job, the return raceways were constructed of wood. If a cow broke any of the railings it was possible to effect immediate repair.

In the winter, mud was a serious problem outside the maze where, unfortunately, pumice sand was not compacted above the soil level before wood shavings were used. The organisation of various drains and soak holes partly solved this problem but each time a wet spot developed in the return raceways the whole area was dug out to a depth of 2 ft. and completely filled with wood shavings. Wood shavings on the main floor allowed easy collection and disposal of animal droppings, especially cow dung. They also allowed regular raking to obliterate the tracks and trails left by the subjects. There were disadvantages in shavings on windy days when whirlwinds sometimes caught up pieces of wood chip and swirled them all over the animal running at the time. On frosty mornings the shavings had to be very carefully raked to avoid tracks becoming plainly visible.

A small building near the south-east corner of the apparatus housed the compressor pump and was the point of entry for electric power. A mirror placed on this building allowed the person controlling the animals at the goal box to see the return raceway, hidden by the south wall of the maze. If an animal stopped near the entry point the next animal of the run could be appropriately

delayed by gates C or D. In the early period of the study the animals were followed from the goal box to the start in the raceway itself. Later a small timber walk way was constructed between the maze and the return raceway low enough to ensure that the head of the experimenter was not visible to the animal inside the arena.

The start and finish gates were hinged horizontally rather than on the side and lifted up and down with a counter weight which could be adjusted for speed of operation. This assisted in the early training runs when the finish gate could be lowered manually after the subject had half its body through the exit gateway, thus terminating the trial.

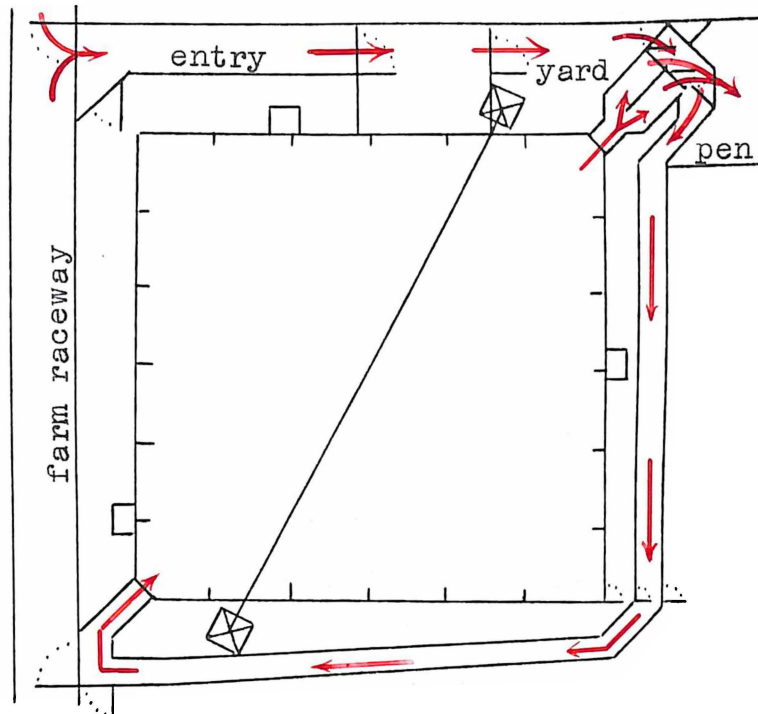
In general the apparatus has stood up well to three years' hard work. Pigs were the animals which found weak points in the apparatus and several weeks of repairs and slight modifications had to be made after they were first run. The floor has stood the test of time and only in 2 small areas has there been any sign of pugging. The adjustable food boxes have had to be repaired several times as the cows tend to knock them and break them. The control gates in the food box areas and in the raceways, particularly gate D have had to be repaired several times after cows have backed into them or attempted to jump across them, or have pushed against them with their full weight. Two cows and four sheep have jumped the 4 ft. high sides of the

return race-way.

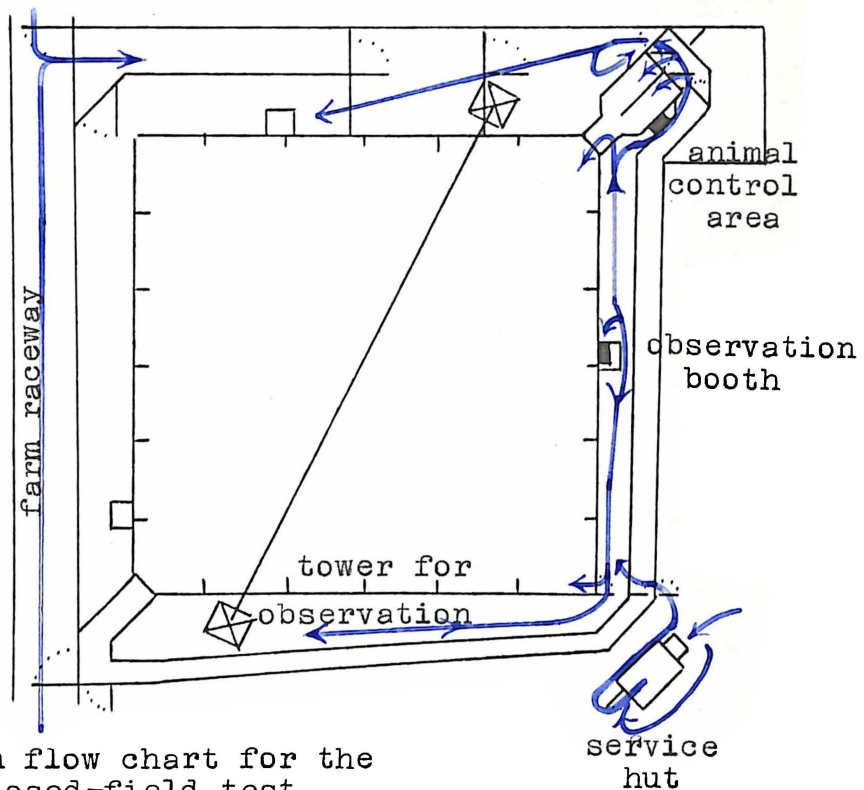
If the planning and construction of any large apparatus is carefully done, this should be reflected in the ease of access and operation of the unit. Figure 8 contains 2 flow charts showing the daily movement pattern of the animal subjects (in red) and the patterns for the human operators (in blue) below. Animal entry was from the farm raceway to the holding yard. Subjects were taken one by one to the starting point and on completion of each trial entered one or other of the food boxes. They were then run again until the requisite number of runs had been completed when they were directed into the final holding pen. This pen was close to the goal box area and provided an additional incentive to social animals to return to their flock mates, especially sheep.

While one person was bringing the animals from the yards, the other set the compressed air system in motion. The observers took up their positions and the operator began with the first animal subject.

Similar flow charts are shown for the open-field test in Figure 9.



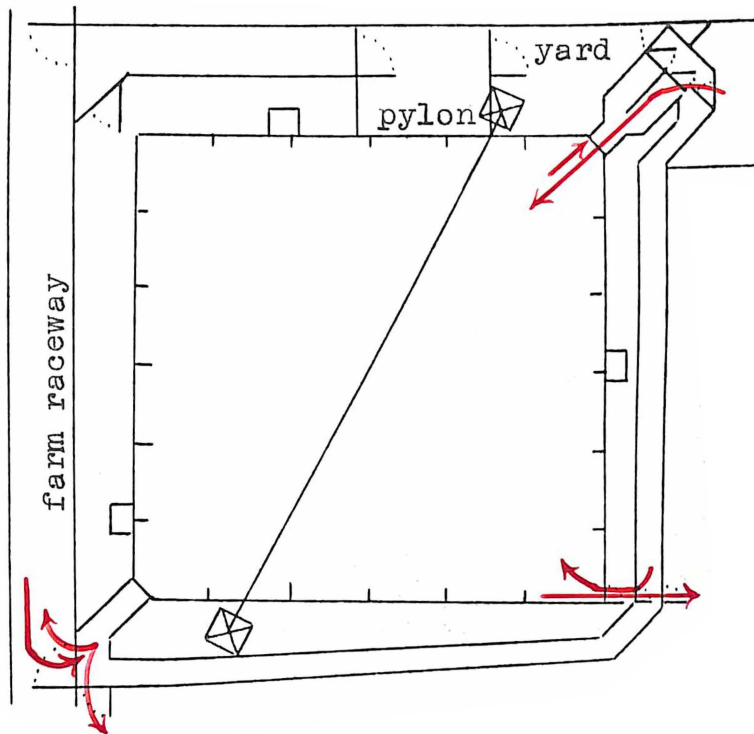
An animal flow chart for the closed-field test.



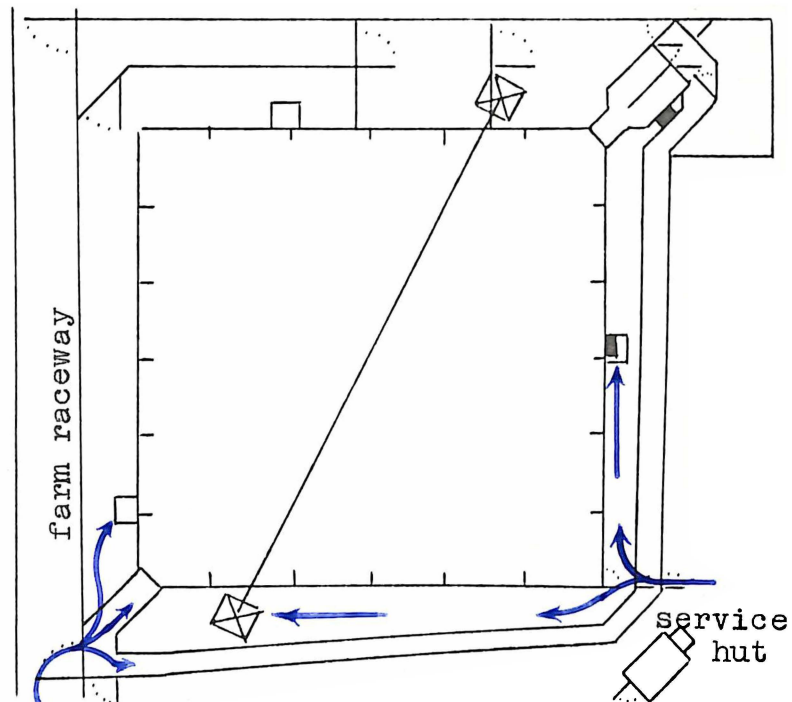
A human flow chart for the closed-field test.

Figure 8.

Flow charts showing the patterns of movement of animal subjects (above) and human handlers and observers (below) during the daily running of the closed-field test.



An animal flow chart for the open-field test.



A human flow chart for the open-field test.

Figure 9.

Flow charts showing the patterns of movement of animal subjects (above) and human handlers and observers (below) during the daily running of the open-field test.

THE EXPERIMENTAL PROCEDURE.

The Open-Field Test.

Hall (1934) in his original work tested the rats in the arena for 14 days. He recorded the activity, defecations and urinations for a period of 2 minutes each day unless the rat was eating at the central food trough when it was allowed further time. An examination of Table 6 will show that the procedures adopted have varied considerably from experimenter to experimenter. Trial time has varied from 2 to 5 minutes for mice; 2 to 10 minutes for rats and up to 15 minutes for hamsters. Tests have been carried out for from one day only, to 10 or 11 consecutive days. The pig trials were carried out only once, for 2 minutes.

Elimination and ambulation responses were the most common behaviour scored during the trials, though rearing, washing or grooming, squealing, sniffing and other behaviour has been used by some workers. Physiological measures such as plasma corticosterone, adrenal weights and adrenal ascorbic acid depletion have occasionally been used.

A small preliminary trial of 5 cows was run. Exact times were noted for elimination responses and vocalisations and the ambulation score was recorded for minute intervals. From a close examination of these results over a 15 minute period for several days, it was found that no unusual or significantly

different behaviour was being sampled after the first 5 minutes and that for cows the biggest daily variations occurred in the first 3 days. Later in the study some longer trials were run with sheep but these will be discussed in the appropriate section. The decision was therefore made to put the domestic animals into the open-field for 5 minute periods for 3 consecutive days.

Three scores were recorded for cows and sheep: (a) an ambulation score; (b) a defecation-urination score and (c) a vocalisation score. Because of the difficulty of recording (b) and (c) only an ambulation score was used for pigs. All testing was done **after** 9 a.m. in the morning.

The Closed-Field Test

The different procedures and problems adopted by various workers using the Hebb-Williams Closed-Field Test are listed in Table 6. The number of problems used varies from 6 to 24, though a recent study used only 5 of the IA to IL series designed by Hebb and Williams (1946), (Davidson, 1969). Some workers have used the 12 of Rabinovitch and Rosvold (1951) and then used them again in mirror image form. Reid et al. (1968) have provided 12 additional problems from their study. The number of trial runs per animal per day has varied from 8 in the test series to 5 or even fewer. Lavery and Belanger (1960) suggested

a shortened form of the original test. Basic choices had to be made both as to the problems to be used and the basic criteria and procedure to be followed.

The Selection of Problems.

The original Hebb-Williams problems are shown in Figure 10. These problems were not structured by a basic grid pattern, but Rabinovitch and Rosvold (1951) standardised all their problems to a 36 square grid except 2; i.e., D of the training problems has two barriers run diagonally across 2 squares of the grid and Test problem I had all of its barriers fitted mid-way in the squares rather than along the edges. The training problems A to F of Rabinovitch and Rosvold are shown in Figure 11, while their test problems are shown in Figures 12 and 13.

Pollard in his discussion of acceptable scoring problems for visual and non-visual animals analysed the various problems of Rabinovitch and Rosvold and found that they fell into three classes. Direct visual solutions were available to the subject in problems 1, 2, 4, 8 and 10. They were not available in 3, 5, 9, 11, and 12, while problems 6 and 7 were ambiguous. Utilising these standardised problems where possible, Pollard redesigned them so that they could be used as pairs, one of which could be solved by a direct visual approach and the other not, though the actual pathway used by the subjects was the same. This provided the test with much greater flexibility and we have followed

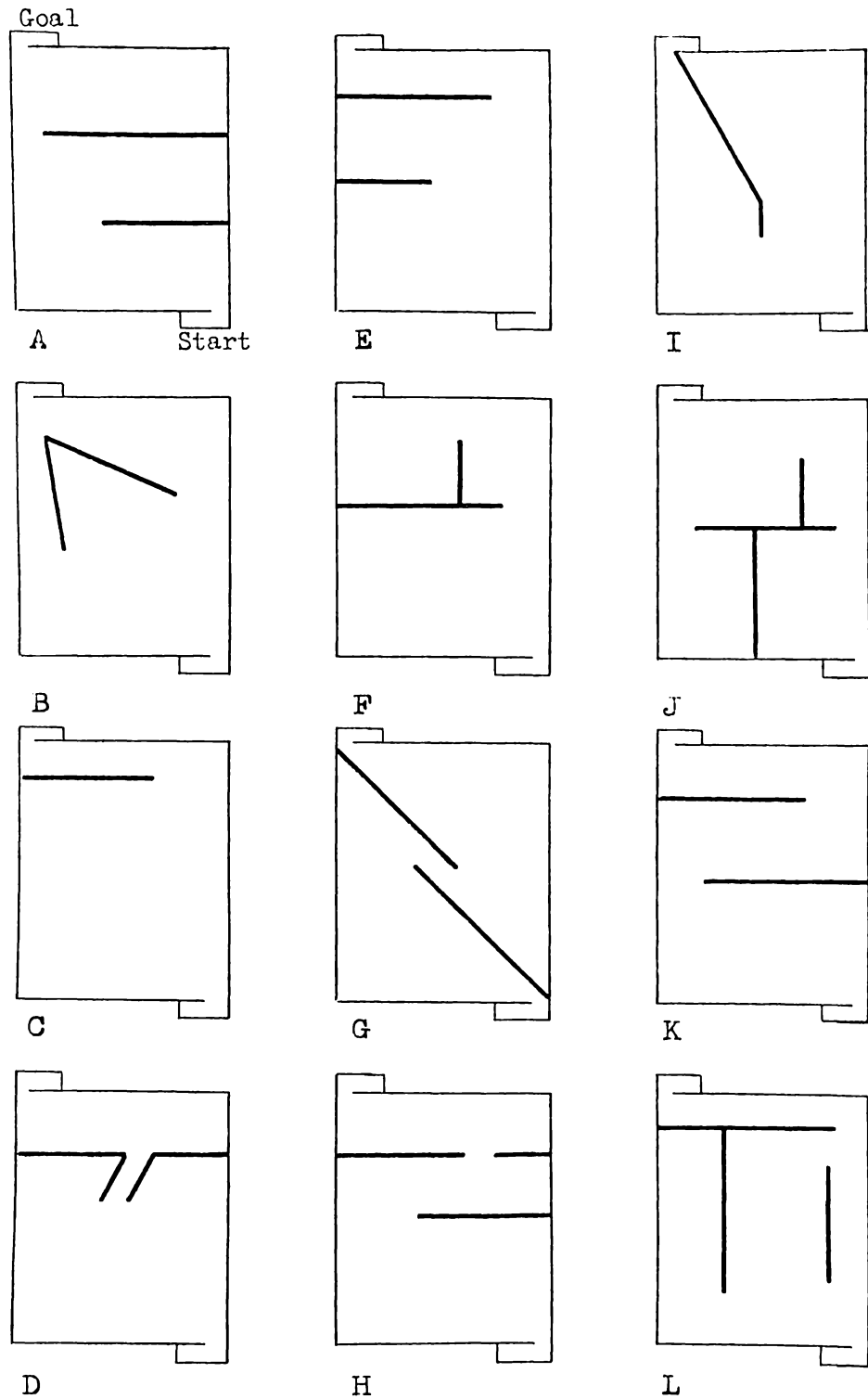


Figure 10 Twelve problems used in the Closed-field Test
(redrawn from Hebb and Williams, 1946)

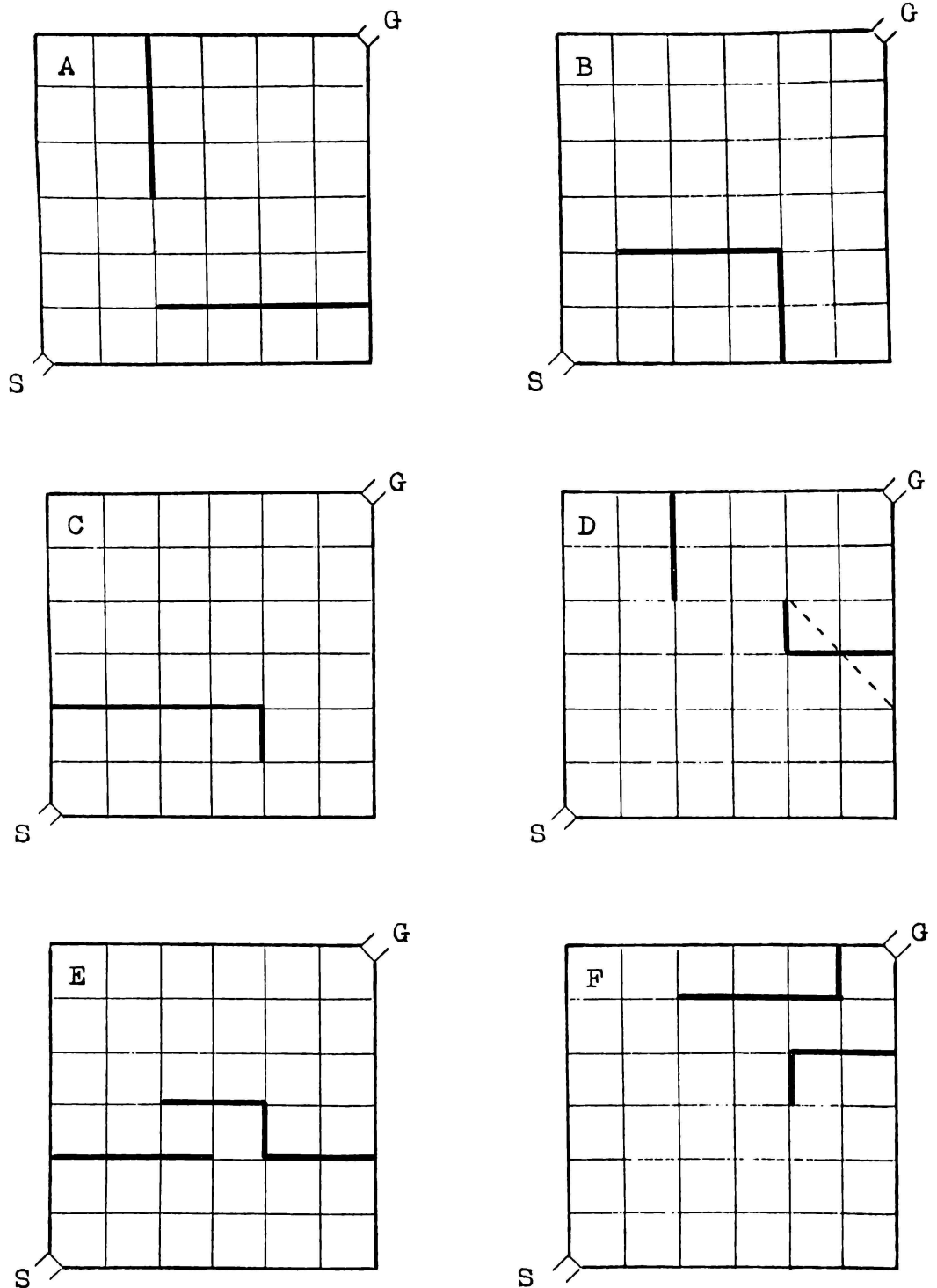


Figure 11 Plans of six problems A to F devised by Rabinovitch and Rosvold, 1951 for training animals to criterion before beginning the test series. With one slight modification to D, these were adopted for this study.

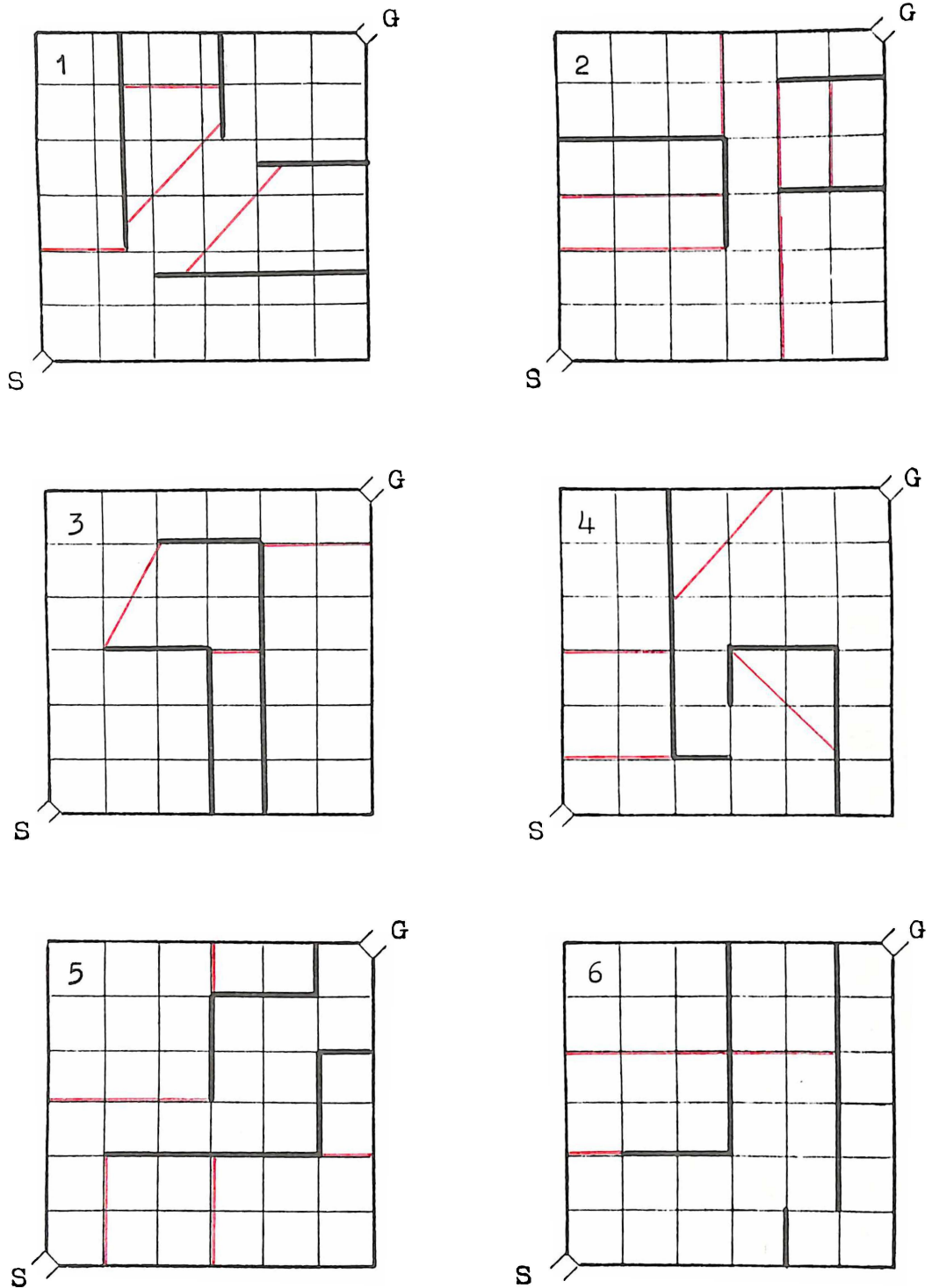


Figure 12 Problems 1 to 6 as standardised by Rabinovitch and Rosvold with corresponding error zones in red lines.

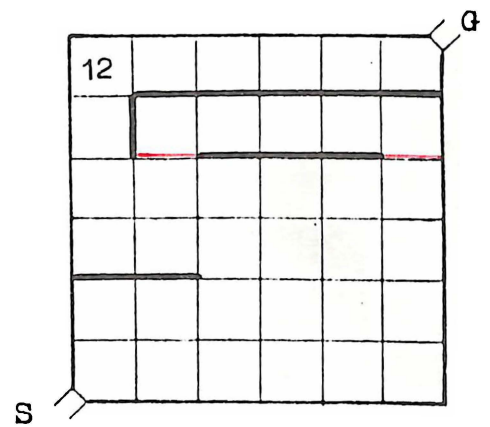
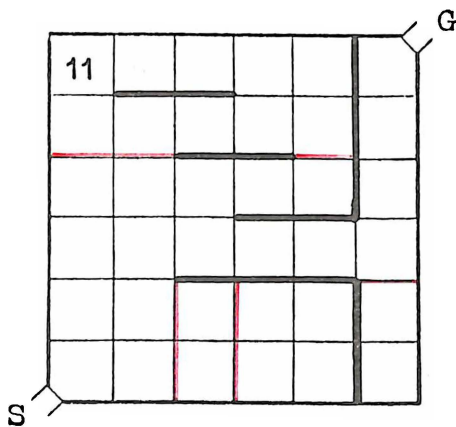
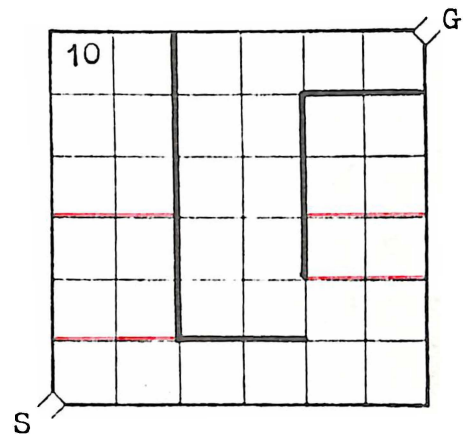
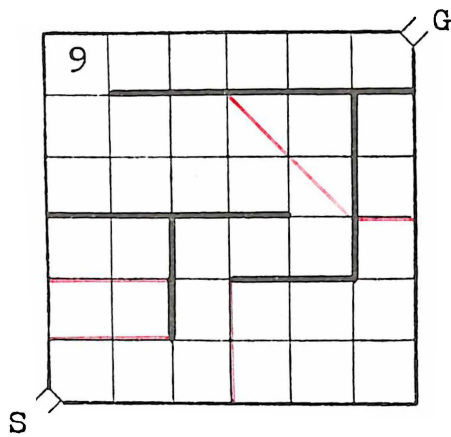
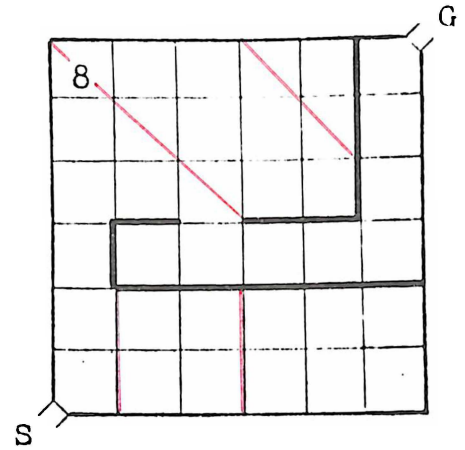
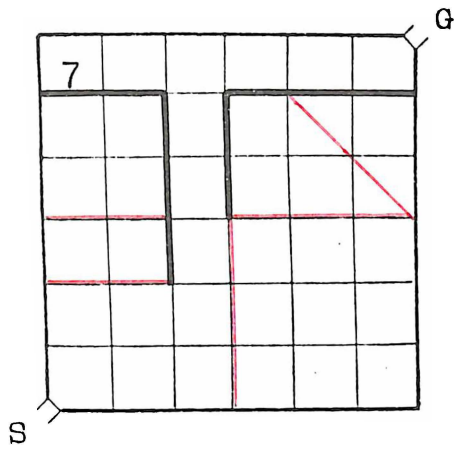


Figure 13 Problems 7 to 12 as standardised by Rabinovitch and Rosvold with corresponding error zones in red lines.

this precedent. Because of using an outside testing area, very wet days upset the animal's performance so an additional 6 problems, i.e., another 3 pairs bringing the total number to 12 were designed. This presented a visual and non-visual form for each problem. Figure 14 shows the problems of Pollard (1961) adopted for use in this study and Figure 15 illustrates 6 additional new designs. Every attempt was made to keep these designs the same as or similar to those of Rabinovitch and Rosvold (1951).

A recent study of Reid et al. (1968) provided designs for another 12 basic tests which have been used for rats and would be possible alternatives. They are shown in Figures 16 and 17. Some of these problems required 25 baffles to make up the barriers and because of this they were not used in the present study. Figure 18 shows a variety of problems from different sources. Problem B illustrates one of the designs used by Thompson and Heron (1954) for dogs. These problems were built on a 49 square grid and only one of the problems is illustrated. C and D are the visual and non-visual forms of an additional problem of Pollard (Preston et al. 1969). A, E and F were designs used at Ruakura. A was used for testing the propensity of sheep to follow tracks in the preliminary trials before the major study. The dotted line shows the sheep track. E was devised by the Ruakura shepherds as the most difficult problem for sheep using a total of 15 baffles, and F was used as a test

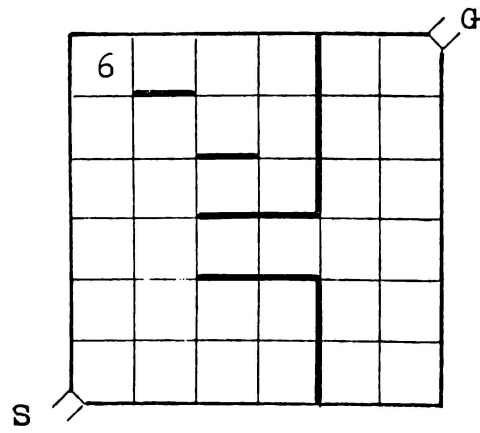
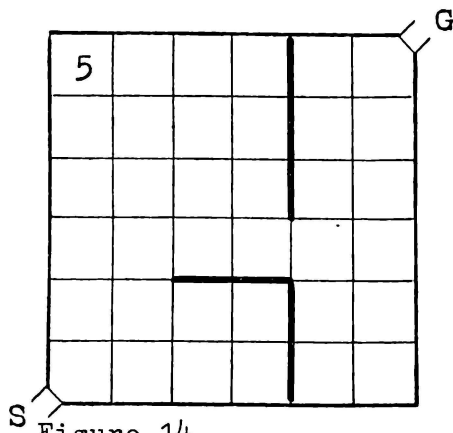
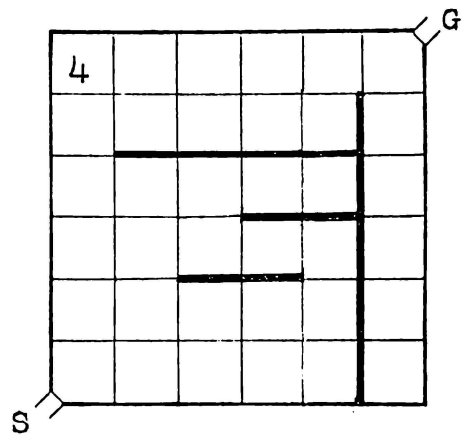
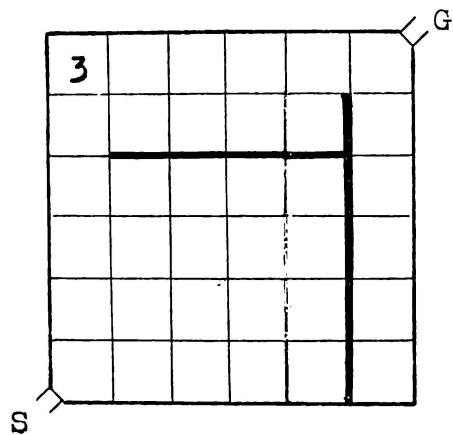
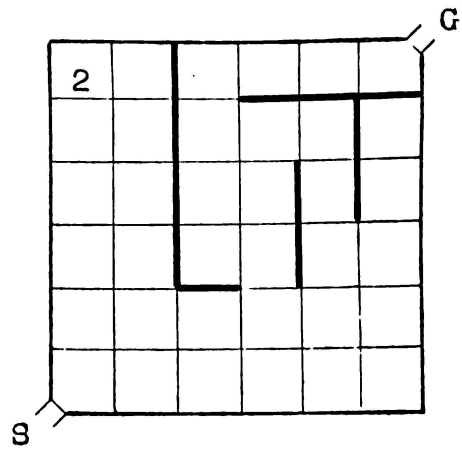
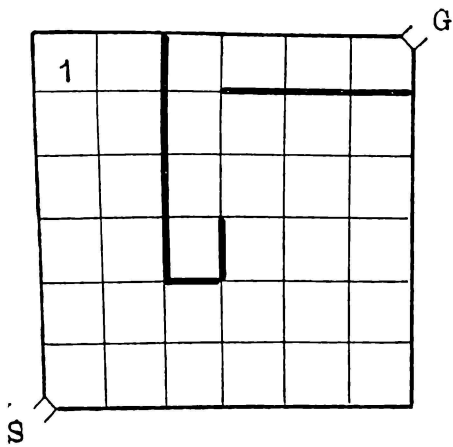


Figure 14

Plans of test problems 1 to 6 modified by Pollard (1961) from Rabinovitch and Rosvold, with the visual form on the left and the non-visual on the right. These were used in this study.

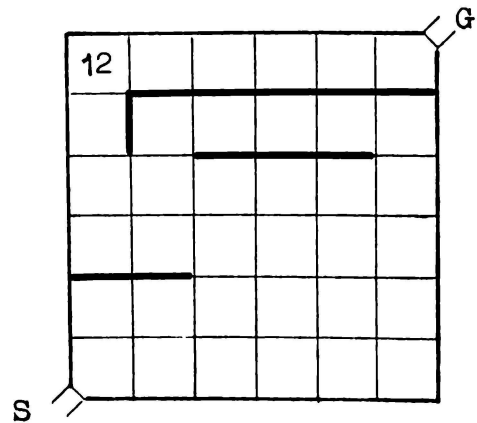
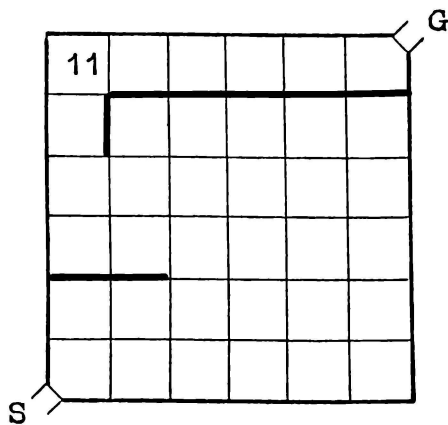
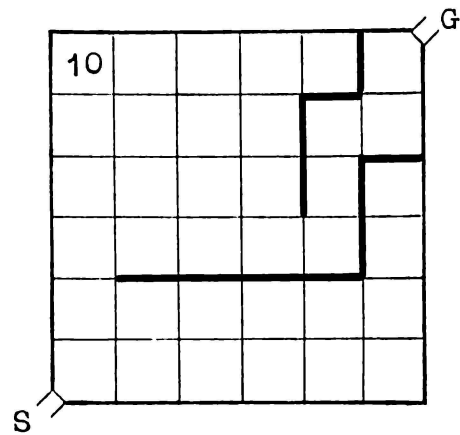
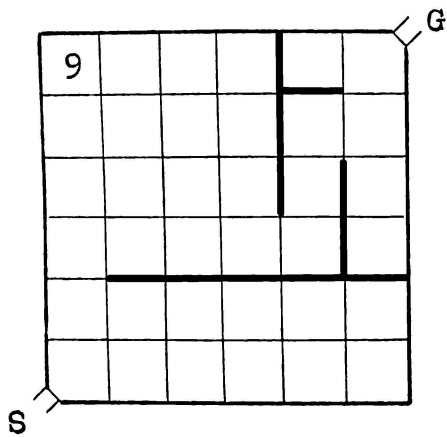
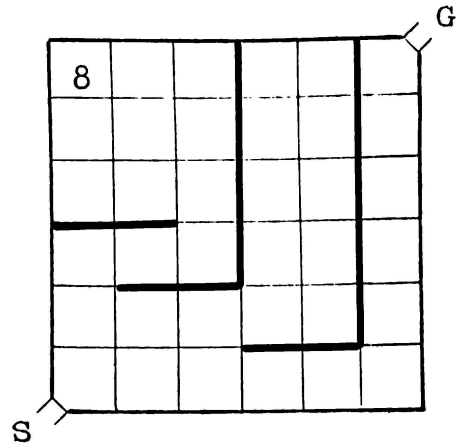
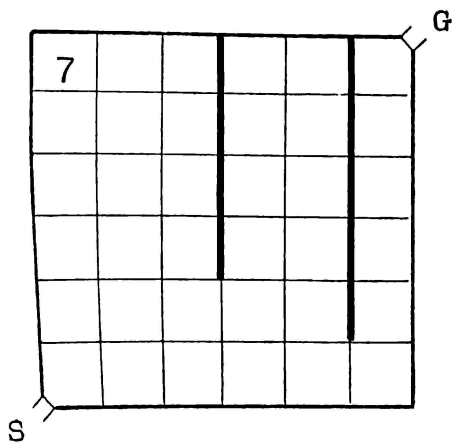


Figure 15

Plans of test problems 7 to 12 modified from Rabinovitch and Rosvold for use in this study. Visual forms are on the left and non-visual on the right.

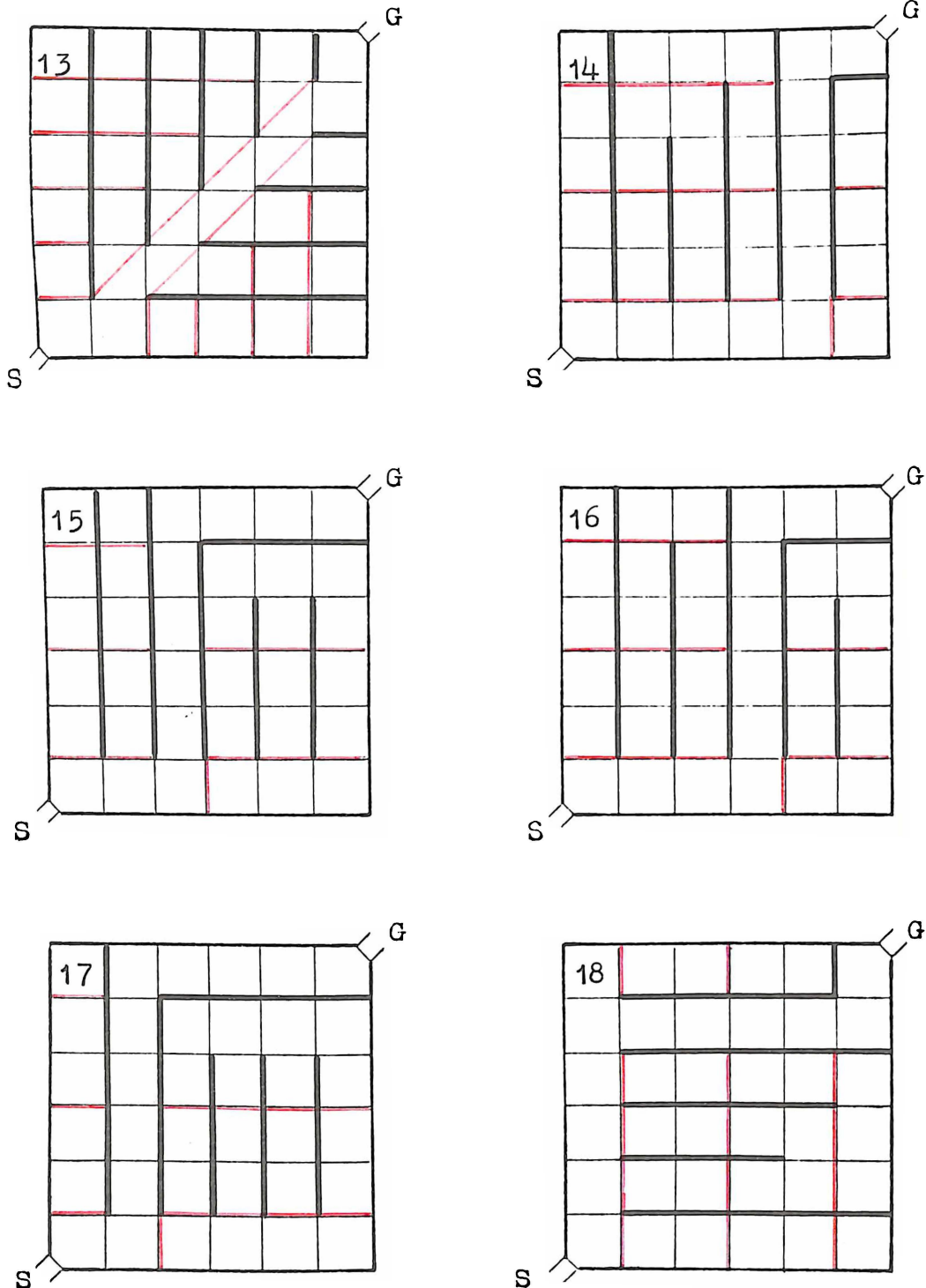


Figure 16

Plans of problems 13 to 18 used by Reid, Gill and Porter, (1968), with error zones in red.

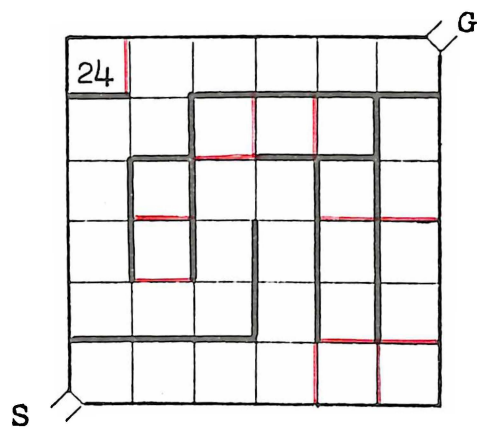
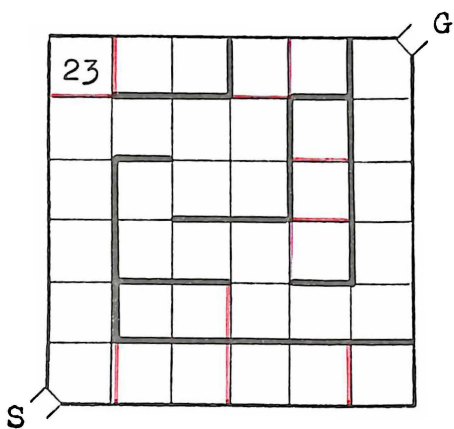
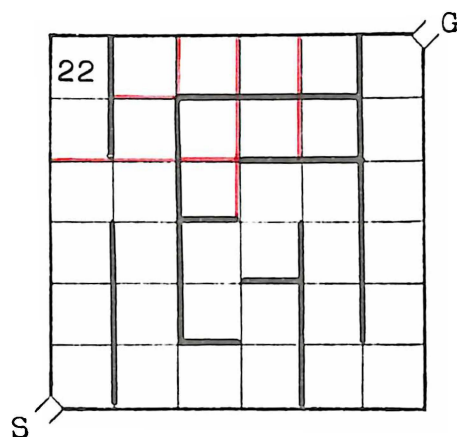
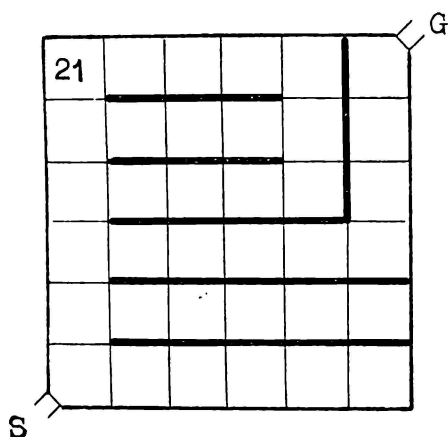
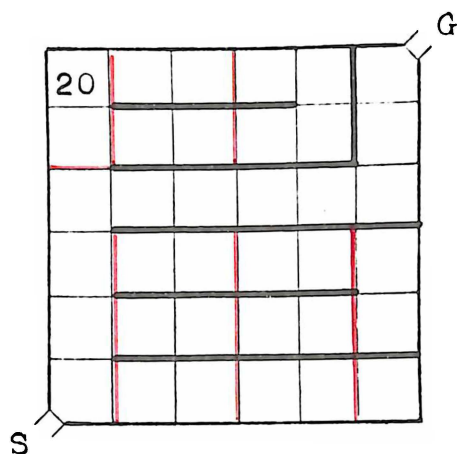
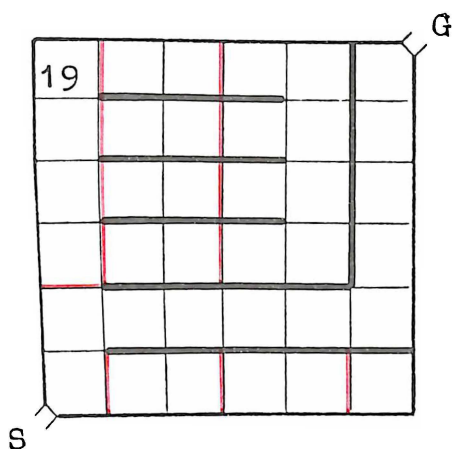


Figure 17.

Plans of problems 19 to 24 used by Reid, Gill and Porter, (1968)., with error zones in red.

Other problems used in this study or mentioned in the literature. (a) The test for track following used in this study; (b) A forty nine square unit by Thompson and Heron, 1954; (c) and (d) Problems 7 and 8 used by Preston et al, 1969; (e). Problem designed by shepherds as a hard problem for sheep using 15 baffles; (f) Problem used for testing visiting psychologists.

for visiting psychologists, some of whom were familiar with the problems of Rabinovitch and Rosvold (1951).

An examination of the training problems A to F of Rabinovitch and Rosvold indicated a certain logic of design. Problem A has blind alleys which lead off close to the start box area and aid the animal subjects in avoidance of errors in this part of the maze. Problem B provided experience with a move to the left and C followed next day with a move to the right. Problem D allowed for errors to be made in the central and side portions of the closed-field and E brought in the complete detour from the straight line which was to be experienced during the test series. Finally, problem F allowed for the making of errors in the vicinity of the goal box.

In a similar way, Pollard's selection of problems took the animal through the centre area of the maze in problems 1 and 2; then to the left in 3 and 4 and finally through the centre in 5 and 6. To this was added a movement to the right in problems 7 and 8; another centre solution in 9 and 10 and a movement to the left again in problems 11 and 12. There are therefore, three solutions with a central orientation, two with a left swing and one with a right, giving three central and three side type problems each with a visual and a non-visual form. Our debt to the standardised problems of Rabinovitch and Rosvold (R and R), is also shown in that problem 1 and 2 approximate

closely R & R 4 or 10; problems 3 and 4 are different; problems 5 and 6 are similar to R & R 11; problems 7 and 8 are similar to R & R 6; problems 9 and 10 to R & R 5 and problems 11 and 12 are based on R & R 12.

To summarise, the problems were chosen to include, or were modified from, those most useful from Rabinovitch and Rosvold. This included six which had been modified by Pollard. No problem selected required more than 16 individual 12 ft. baffles for its erection.

Daily test runs and training criteria

The procedures of Rabinovitch and Rosvold were followed closely. During the training period all animals were given 9 runs per problem per day. The day before training problem A was used, the animal was given 5 runs through the open field. Eight runs per problem per day were given during the test problems. Because of the large size of the maze, 9 runs in 60 seconds was impossible as a criterion for changing from training to test runs. The precedent of Pollard in using a performance criterion based on errors rather than time was followed. When all animals ran 8 out of the 9 training runs correctly on 2 consecutive days the test series was begun. The first full cycle of the A to F training problems was always to be completed prior to this. If criterion was not reached, A was begun again on day 7 and so on.

Most experimental sessions were begun on a Wednesday. For the first 3 days the apparatus was used as an open-field test. The subjects were completely deprived of food on Saturday and Sunday and on Monday each animal was given 5 runs. On Tuesday morning the training trials were begun and the baffles were erected to make up problem A. The subjects were given 9 runs a day through problems A to F and if they had all reached the criterion of 8 out of 9 runs correct on days 5 and 6, then the test series was begun on the following Monday. By this time 3 animals could be handled in the apparatus at any one time; (i) one feeding, (ii) one running in the return raceway and (iii) one running in the internal arena. Only 8 runs were given per animal during the 12 test problems.

The dual use of the apparatus in the first 3 days, to score behaviour in the open field while at the same time providing the subject with its early orientation period, has been followed by few other investigators (Schaeffer, 1968). It is suggested that this might become standard technique in the future because of the value of emotionality scores for each subject under test.

Scoring:

All scoring was done manually from the hides, as it was not possible to have the closed-circuit-television unit in

operation during the study. The pathway of the animal was scored by reference to the 12 ft. by 12 ft. overhead wire grid. During the closed-field testing the baffles making up the problems followed this grid and gave further orientation to help the scoring.

As well as the ambulation, the elimination and the vocalisation scores in the open-field, other behaviour was recorded, e.g., pawing the shavings or jumping up against the external walls or exit gates. Some pigs chewed objects from the floor. Careful check was kept of the time of runs, both in the open- and the closed-field. Each time the animal stopped running this was recorded on the pathway, as was defecation or urination. The score sheets provided entries for the species, the identification, the time for each run, the change of pathway, the weather and space for other behaviour. These sheets were based on those developed by Pollard. (See Appendix I).

If the subject failed to find the exit in the closed-field test several score sheets might be used for the one animal. The scoring of the dogs, which were particularly disturbed by the presence of human recorders, was done from the top of the 40 ft. pylon, but from time to time a dog would look up to the observer even at this height. This tended to inhibit the free running of some of these subjects.

The experimental subjects:

From the literature survey it was clear that apart from rats, mice and hamsters, and the 2 recent studies on pigs, few animals have been subjected to the open-field test. With the closed-field test an increasing number of species has already been tested. Thompson and Heron (1954) tested dogs in their 17 ft. by 17 ft. maze. Livesey (1966) compared rats, rabbits and cats and Pollard and co-workers have run rats and cats (1961), opossums (1967) ferrets (1969) and their present work involves hens and other species.

During this study 83 cows, 145 sheep, 63 pigs and 15 dogs were tested. Attempts were made to run some cats but they were not readily available for experimental purposes. A trial with young children was also run. Table 8 shows the order in which the species groups were tested in this study, together with some other relevant comments about each group.

(a) Sheep. Of the 24 rams tested 21 were from the Ruakura Research station. The remaining 3 were chromatin-positive-Klinefelter syndrome rams provided by Massey University of Manawatu. The performance of the "Klinefelters" was within the range of normal animals (Kilgour and Bruere, 1970). Closed-field tests were made of 18 bottle-fed lambs and 18 mother-reared lambs matched for age. All the ewes were drawn from experimental flocks with preference given to those sheep

Table 8 : A summary of the dates of the test and the species tested in the closed-field test.

Date	Trial No.	Species	No. tested	Remarks.
<u>1967</u>				
5-9-67				apparatus completed
6-9-67/6-10-67	I	ewes	12	two subordinates died
24-10-67/22-11-67	II	cows	9	
		pigs	4	one lame
4-12-67/22-12-67	III	rams	10	5 Romney-5 South-down
				reported to ANZAAS.
<u>1968</u>				February, 1968
10-2-68/29-2-68	IV	lambs	22	11 bottle-fed; 11 mothered
28-3-68/10-5-68	V	pigs	8	Trials for reversal index
6-5-68/24-5-68	VI	cows	10	
17-6-68/4-7-68	VII	cows	11	
13-7-68/2-8-68	VIII	rams	11	
		lambs	11	6 month retest
11-8-68/30-8-68	IX	ewes	14	1 ewe died
8-10-68/24-10-68	X	ewes	16	
12-11-68/29-11-68	XI	ewes	16	
5-12-68/9-12-68	XII	children	19	limited series only
<u>1969</u>				
7-2-69/24-2-69	XIII	lambs	18	9 bottle and 9 mothered
3-3-69/21-3-69	XIV	ewes	18	
8-4-69/26-4-69	XV	ewes	8	
		cows	10	
6-5-69/23-5-69	XVI	cows	6	
		pigs	9	
30-6-69/18-7-69	XVII	cows	6	
		rams	4	3 "Klinefelters"
28-7-69/9-8-69	XVIII	cattle	8	2 yearling bulls, 6 cows
		ewes	7	mirror image retest
2-9-69/26-9-69	XIX	pigs	9	
4-11-69/21-11-69	XX	pigs	9	
24-11-69/13-12-69	XXI	pigs	11	
8-12-69/23-12-69	XXII	dogs	5	
		cat	1	
<u>1970</u>				
12-1-70/30-1-70	XXIII	dogs	10	
Total subjects tested			312	
total number of runs			45,480	

which had recently been bought from farmers as flock replacements. The age range of the subjects tested was as follows : 36 lambs; 32 two-year olds; 18 three-year olds and 24 four-year olds. The rams were 3-4 year olds. Plate 4 shows a ram displacement grazing in the closed-field during the early testing period, and Plate 3 (page 77), a ewe moving past the start gate into the maze.

Cattle

In contrast to sheep which were available at any time of the year and were therefore tested under all seasonal variations, dairy stock was only available at the end of the milking season. Every attempt was made to test these animals as many months before their projected calving dates as possible. A few dry cows were available. As the Ruakura herds consist largely of monozygotic twins up to 20 pairs have been included in the analyses. No attempt has been made with the present equipment to test either older bulls or steers. Table 9 shows the ages of the dairy cows at testing.

Table 9 : Age of dairy cows at testing.

<u>Conditions</u>	<u>Ages of cows</u>								<u>Total</u>
	2yr.	3yr.	4yr.	5yr.	6yr.	7yr.	8yr.	Over 8yr.	
dry cows	7	4	2	1	0	0	1	1	16
in calf	3	5	13	11	6	8	4	5	55
total	10	9	15	12	6	8	5	6	71

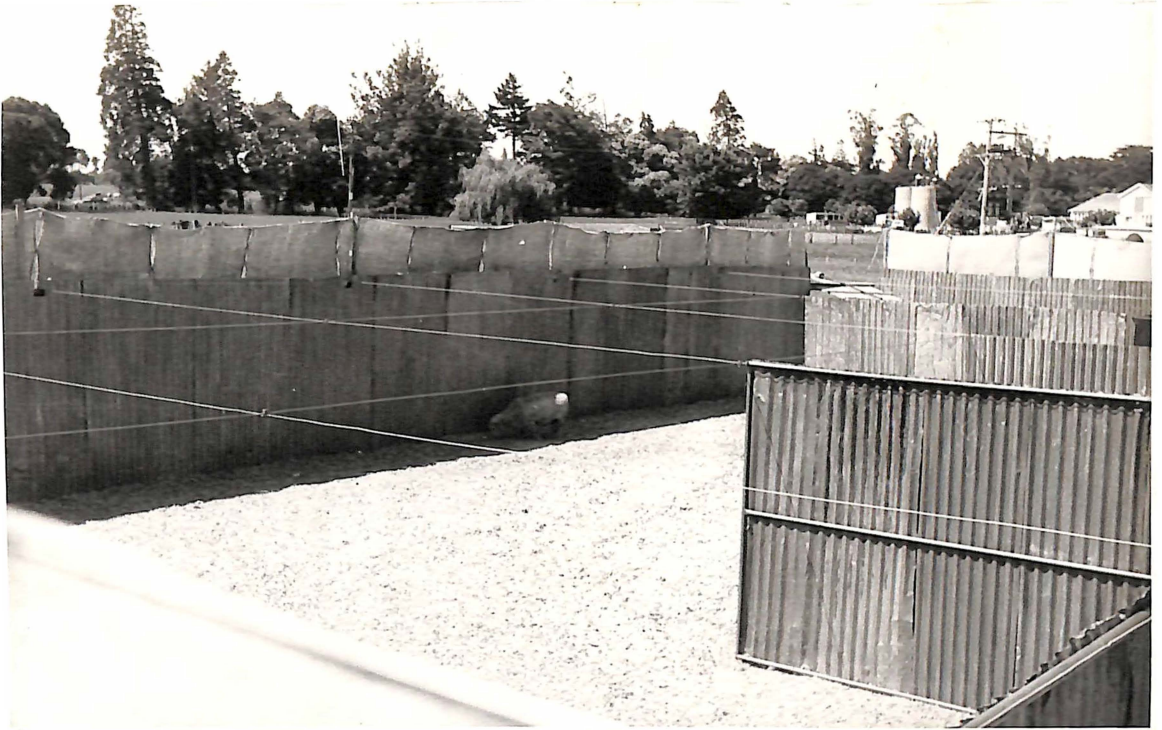


Plate 4 A Southdown ram showing 'displacement grazing' behaviour during a trial on problem II on the Closed-field test.

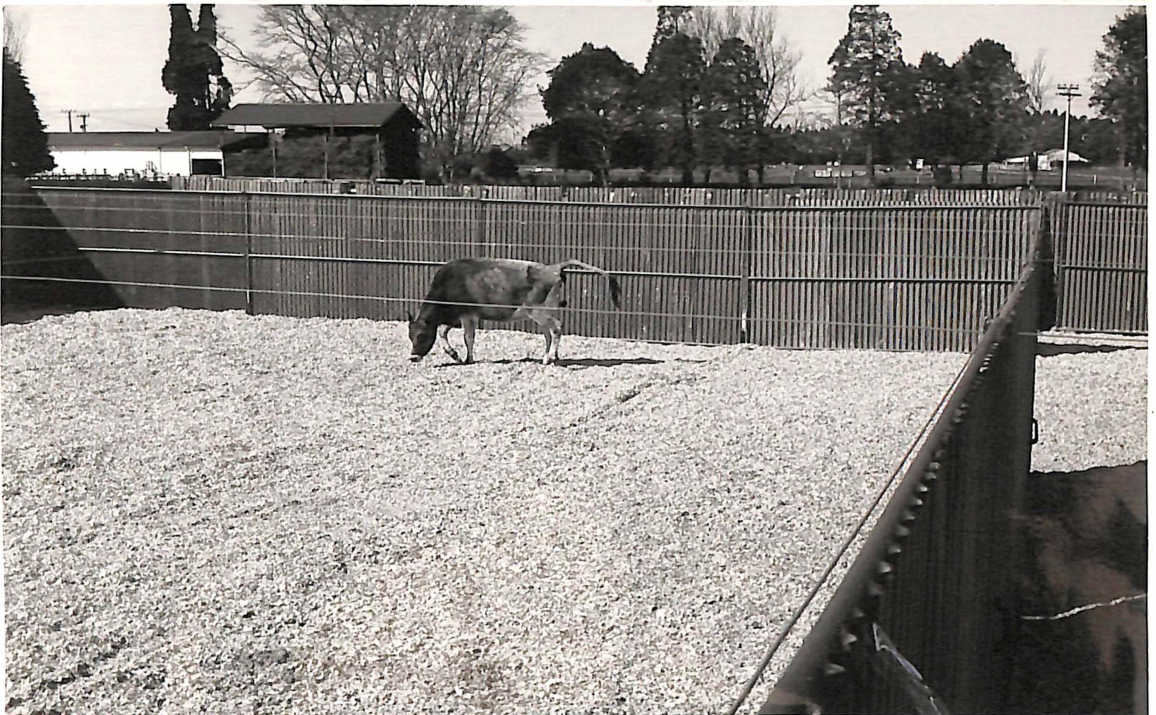


Plate 5 A dairy cow pawing the shavings and defecating during the first day's training trials on problem A.



Plate 6 One of the bitches runs very freely and quickly in problem 12 of the closed-field test.



Plate 7 A cat moves without hesitation in problem E of the training series. Some cats scaled the 7 ft walls of the enclosure and escaped.

distance of several feet. A system of raddles and codes was developed to aid this. The coloured raddles were identified as follows :- R= red; B= blue; G= green; Y= yellow, and the position on the body was coded as follows: N= nose; H= head; S= shoulder; B= back and T= tail. Thus RHBT = red head blue tail and NHNT = no colour on the head or the tail, while GNBSNT = green nose, black shoulder, no colour on tail. As the largest group run in any experimental period was 22 animals, adequate combinations were available.

All dairy stock at Ruakura have numbers branded on the rump and the numbers of identical twins follow one another, e.g., 7171 and 7172 would be twins of a pair.

The pig identification was by ear clips shown in Figure 19. Because of the flopping ears of the pigs, raddles were used as an additional means of identification. These raddles had to be renewed every second day, especially in wet weather.

Both the dogs and the children were sufficiently different to be immediately recognisable.

The weather:

Most cattle were tested during the winter months and apart from the mud and periodic driving rain or severe cold spells, the weather appeared to have little influence on the performance

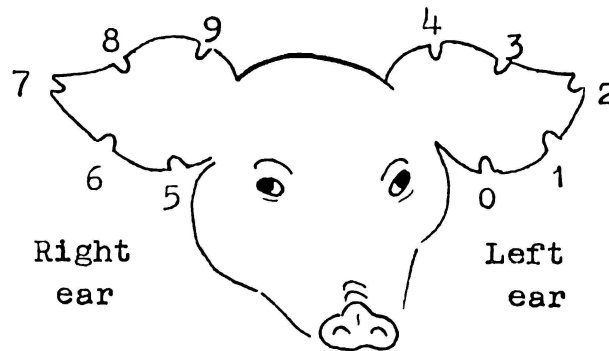


Figure 19.

Chart of earmarks for Ruakura pig identification.



Plate 8 A pig eating moist meal in the exit pen before being moved into the return raceway for the next run in the closed-field. At the top left a second pig, having just completed a run, moves to the adjacent feeding trough.

of the subjects. On one occasion only was the rain driving so heavily that cows in the closed-field moved to the walls or baffle barriers for protection.

In the summer the galvanised iron enclosure and the shaving floor had highly reflective qualities and temperatures frequently rose above 90°F. Pigs and sheep tended to keep in the shadow under these conditions. To avoid these problems experimental sessions in the summer were begun at 6 a.m. in an attempt to have all animals completed before the heat of the day.

SPECIES MOTIVATION and the DEPRIVATION SCHEDULES.

Although Breland and Breland (1966) stated that ruminants were difficult to motivate, it was quickly realised on beginning the work in the closed-field test that even severe regimes of food deprivation might have little effect on behaviour. Pigs on the other hand and dogs to a lesser extent soon settled into the routine and worked very well for a food reward.

Sheep:

Almost 2% of all sheep die rather than shift from a grass diet to diets of a pellet nature; e.g., sheep nuts (Tomaszewska, 1967). All the sheep used in this study were fed on Tomoana sheep nuts[†] for a period of several weeks.

All sheep were allowed one week to make the adjustment and only those which had done so were used. Some sheep lost up to 20% of their body weight during this period and that of the early adaptation trials; i.e., over a period of 2 weeks. During

[†]The Composition of Tomoana sheep nuts:

Protein 20% (min) Fat 8% (max) Fibre 8% (max) Salt $1\frac{1}{2}$ % (max)

Ingredients include :

Linseed meal	Wheat meal	Dried brewer's grains
Barley meal	Molasses	Dried milk solubles
Fish meal	Copra meal	Wheaten pollard
Pea meal	Minerals	Wheaten bran

the weeks of testing, however, the top third of the animals in the experimental group regained the lost weight. Table 10 gives an indication of changes in weight during the test period in sheep.

During the closed-field trials the sheep were offered a choice of food; freshly cut grass, sheep nuts and good quality hay. Different sheep ate different foods and some showed a shift of food taken during the 3 weekly experimental period. Generally the sheep "discovered" food in the food box during the orientation in the maze and return runway and 95% of these animals were eating well by the third day of training.

That deprivation was essential to the performance of the animals was demonstrated accidentally on a few occasions when sheep escaped from their holding pen during the night and gained access to pasture. Although in every case an attempt was made to run the animal concerned, in no case was this successful. One day however, after a group of trained sheep had been returned to the pasture for 2 weeks, a TV camera team wanted photographs of sheep in the closed-field test. Sheep were removed from the pasture at 5 a.m. before they had begun their first daily grazing cycle and penned until 10.30 a.m. when the cameramen arrived. They ran very well and solved a new problem which had been specially designed for the occasion.

Table 10 : A sample of typical weight changes of experimental subjects during the period of open- and closed-field testing. The first weight was taken on the second day of training and the second weight on the last day of testing, 17 days later.

Sheep

weight 1. lbs	90	108	86	140	119	91	120	106	113	121	112	110	118
weight 2. lbs	100	118	93	145	120	90	118	100	106	112	100	95	100
diff. in lbs	+10	+10	+7	+5	+1	-1	-2	-6	-7	-9	-12	-15	-18

Average weight loss was less than 7 lbs per animal or 6% of original body weight.

Cattle

weight 1. lbs	645	740	975	638	685	750	1060	1095	1080
weight 2. lbs	691	761	990	634	671	725	1016	1037	1010
diff. in lbs	+46	+21	+15	-4	-14	-25	-44	-58	-70

Average weight loss was 25 lbs per animal or 3% of original body weight.

Pigs

weight 1. lbs	207	100	221	120	110	81	115	120
weight 2. lbs	230	115	230	125	110	79	110	110
diff. in lbs	+23	+15	+9	+5	0	-2	-5	-10

Average weight gain was 2 lbs per animal or 1.7% of original body weight.

More difficulties were encountered in bringing the behaviour of sheep under the control of a food reward than with any of the other species tested. Yet despite these early problems of adjustment, all sheep in the closed-field test reached the criterion of eight correct runs out of nine on training days 5 and 6 and were thus ready for the test runs on day 7. More controlled experimental work needs to be carried out on the motivation of ruminants, particularly sheep.

Cattle:

In the first attempts to find a good food for hungry cows they were provided with freshly mown grass and nuts. During these early trials hay was also introduced and it was found that this was sufficient to motivate cows by itself if the quality of the hay was high. The cows worked well for hay and all animals reached criterion by days 5 and 6 of the training trials as was the case for sheep. Every care was taken to keep the cows in good condition as most of the animals under study were in calf. The daily intake for the cow as recommended was adhered to as follows : 16 lbs of hay per animal.

It was found most practical for cows to have hay in the food box at all times during the closed-field testing. The very consistent times of each run meant that a rather specific period of time only was spent at the food box. It was this time period which

limited the intake. If set rations were given and the cow had finished a ration before the next trial, she would push against gates and raceway and a number of major upsets were caused by cattle in this way. Gates were lifted off their hinges and railings were broken. The remainder of the hay for the day was fed to the subjects immediately after the day's trials were completed, and no further food was given until the next day.

Pigs:

The first session with pigs indicated that feeding nut type food to these animals could present some difficulties. Though nuts were readily eaten, it was found that as the tests progressed more and more of the pigs stored the nuts in their mouths and when they had entered the maze they threw out the solid nuts and started to root around for them in the shavings until they were recovered. A shift was made to meal fed in water and mixed to a porridge-like consistency. The pigs worked very well for this type of food and were able to maintain a set weight for periods of up to 6 months.

The daily ration for pigs was 22 ozs of meal porridge⁺ given almost completely during the experimental trial each day.

⁺Composition of fattening meal as follows:

Barley 71.6%	Maize 9.0%	Meat Meal 16.0%
Lucerne 3.4%	Vitamins A, D ³ , B ² , B ⁶ , B ¹ , B ¹² , E	Niacin
Bistan	Minerals Mg, S, Co, Zn, Fe, Sc, Ca	
80 gms crude protein per lb = 17.6% c.p.		
1360 Kilocalories digestible energy per lb.		
4% Iodised salt, Cu.SO ₄ 250 p.p.m.		

Water was available ad lib to all animals; sheep, pigs and cows. Plate 8 shows a pig eating from the food trough.

Dogs:

Dogs were starved for four days then fed small balls of human-quality mince meat at the rate of 156 grams a day. Although some protein bean powder was added to the meat for a trial it made little difference to the performance of the dogs or their condition during the test period. Plate 6 shows a dog during a run in the closed-field test.

Cats:

For the trial runs which have been made with cats, a commercial fish food has been used with success. It was given at a daily ration of 3 ozs per animal. Plate 7 shows a cat in the closed-in field.

Children:

Small round coloured sweets (about 3mm diameter) like smokers, were given to each of the children after each trial run and with the swapping for different colours and tastes, it proved to be a cheap and useful incentive. Total daily weight was 3.5 gms per subject.

THE DAILY PROCEDURE

The following is a description of a typical experimental procedure for one day. From a 6 a.m. or 7 a.m. start, depending upon the season, the gates leading to the access runway would be opened and the subjects taken to the maze and penned in preparation for the trials. Sheep were kept tightly penned but cows were allowed approximately 5 square meters each and the most dominant cows were evenly divided into the two holding pens available. The food which had been prepared the evening before in the case of pigs was placed in the food boxes. The compressor pump was checked for oil and started and the gates were placed in the correct position for the first run. The observers took up their positions in the hides and the operator allowed the first animal to proceed into the raceway. After the training period was over most animals found their own way to the entrance gate where they were timed as they entered. The track of the animal was recorded together with any other behavioural information and the weather for the day, on a sheet specific to each animal. On entry into the goal box, the time was taken and recorded against the correct run number, and the swinging race gate was shifted across behind the animal to allow the second subject to enter food box 2. A second animal was begun and a second score sheet was used. When the run had been completed a

third animal was started and when it had entered the closed-field proper, the animal from the first food box would be started in the return raceway, and the food replaced in that food box.

Three animals could be run in one batch. If the subject in the maze stopped or made serious error the subject in the return raceway could be delayed by closing either gate D or C until the run was completed. After the 3 animals had completed their 8 runs (9 for the training trials) they were removed to the finish pen and the next three animals tested.

At their peak performance with a visual problem, the 3 subjects would require about 20 minutes while in several cases the pigs would be completed in 10 minutes. In the early training runs, times of up to and longer than 1 hour were needed for the testing of pairs of animals with 9 runs each.

At the completion of each batch of animals, the food in each trough was cleaned out and replaced with fresh material and the floor of the arena was raked carefully to prevent the formation of tracks and pathways. At the finish of the series, the baffles were set up for the next day's testing, the compressor pump was switched off and the pressure released, the animals returned to their holding pens and the remaining food fed to them as needed. Any repairs to the apparatus arising from the day's work would be completed. The records for the day were entered on

the master sheet and the score sheets were filed after details of dominance, leadership orders, etc., had been compiled.

With this routine it was generally possible to run between 12 and 22 animals per month; i.e., one week for orientation and the open-field and 3 weeks for the closed-field test. Every attempt was made to keep one weekend in 4 free from work.

Scoring and data analysis.

Each day the score sheets were examined and the number of squares broken by the pathway of the animal was totalled and from this was subtracted the number of squares broken on the shortest pathway. The number of squares entered on the shortest route for each problem is shown in Table 11.

Table 11 : The minimum number of grid squares to be broken on the shortest pathway through each problem of the closed-field test.

Problem no.	A	B	C	D	E	F	1-2	3-4	5-6	7-8	9-10	11-12
No. of squares	11	11	11	11	15	11	13	11	11	11	11	15
	<u>training</u>						<u>tests 1-6</u>			<u>tests 7-12</u>		

In the 72' square arena these distances represent approximately 100 ft pathways and the point to point distance taken by the animal in correct solution of each problem is shown in table 12. The distance in the return raceway was 195 ft.

Table 12 : - Actual distances travelled by animals in the closed-field test on each of the problems when the correct path was used.

Training problems	A = 98 ft	Test problems	1 & 2 = 117 ft
	B = 101 ft		3 & 4 = 110 ft
	C = 109 ft		5 & 6 = 101 ft
	D = 98 ft		7 & 8 = 122 ft
	E = 123 ft		9 & 10 = 104 ft
	F = 101 ft		11 & 12 = 134 ft

These distances were more important when considering the time scores taken for each animal subject during each trial run.

Score sheets were compiled for each animal giving the excess entry scores as totalled (the raw score sheets) and these scores were transformed by using the square root of each error to scale down the large differences between subjects with low scores and the few animals with very high scores (the transformed error score sheets) - See Appendix I.

To obtain data comparable to that of Pollard's for other species (Pollard and Sampson, 1961) three indices were calculated from this transformed score for each animal.

A score of use of visual cues or visual ability, was calculated for each subject by comparing the scores made on the visual and non-visual forms of each problem. This was expressed as a percentage of the total error score and was called %P (P= problem). A very low score on %P meant that the subject had committed very few errors on the visual form of the problems

while a score of 50% meant that as many errors had been committed on the visual as the non-visual form.

Secondly, a score for the elimination of errors or for learning ability was calculated. The errors made in the first four runs were compared with the errors made on the last four runs for each of the visual and non-visual problems. The assumption was made that with good learners the errors would be largely eliminated by the fourth run. This was termed %R (R= runs) and a score of 100% meant that no errors were made after the fourth run while 50% meant that as many runs in error were made after the middle of the eight run series as were made before it.

A total error score for each subject was also derived. As Pollard (1961) had only run problems 1 to 6 with his animals, all our calculations were made on problems 1 to 6 and then 7 to 12 in separate groups.

As the time for each run had been kept, an analysis of this is also provided. The speed of the run for each species was averaged with a view to ascertaining speed changes during the eight run trial and normal running time to be expected from the species involved. The runs in which animals stopped for long periods were rejected from this analysis.

The distances from blind-alley walls at which animals stopped and retraced their steps were also calculated to give

an index of visual registration, an index important for farming practices.

Rank orders of ambulation, elimination and vocalisation scores were made for animals in the open-field and attempts were made to correlate these with temperamental ratings made by technicians very familiar with the animals, or with other estimates of temperament; e.g., plasma cortisol levels, taken immediately after testing. The scores from open- and closed-fields and their inter-relationship, together with leadership and dominance scores were also considered. Some attempt was made to evaluate the influence of age, sex, breed, and early experience on a subject's performance in the closed-field test. Some test-retest trials were conducted with a group of subjects to ascertain the reliability of the closed-field test results. Finally, the behavioural data recorded during the trials from both tests was examined and this is discussed in a separate section.

RESULTS AND DISCUSSIONSThe Open-Field Test

Forty four cows, 32 sheep and 28 pigs provided open-field scores during the course of their orientation to the closed-field test. Special studies of an additional 45 sheep were undertaken after the completion of all closed-field testing. Table 13 displays the comparative figures for the 3 species tested during the initial trials on the 3 scores recorded.

Table 13 : A summary of the Open-field test results from cattle, sheep and pigs.

Spec-ies	No.	ambulation mean S.D. range			vocalisation mean S.D. range			elimination mean S.D. range		
day 1 scores										
cows	44	39.4*	16.5	3-97	8.2	6.2	0-31	1.3	0.9	0-3
ewes	32	50.3	20.9	27-132	28.7	14.0	10-73	0.5	-	0-2
pigs	28	58.9	15.7	37-104	-	-	-	0.25	-	0-2
day 2 scores										
cows	44	25.5	13.9	2-53	7.0	7.2	0-28	1.2	1.9	0-3
ewes	32	51.7	21.8	15-111	31.8	14.3	4-71	0.5	-	0-2
pigs	9	52.4	12.7	34-70	-	-	-	-	-	-
day 3 scores										
cows	44	17.5	13.6	2-54	3.8	5.6	0-27	1.1	0.9	0-3
ewes	32	52.0	29.6	22-187	32.7	12.0	4-69	0.3	-	0-2

* mean number of 12' x 12' squares broken

Certain trends are noticeable from this summary. They point to some of the differences between the species, particularly sheep and cows. The mean ambulation score for cattle dropped appreciably between day 1 and day 3 from 39.4 to 17.5 squares broken. In contrast, the mean scores for sheep tended to rise from 50.3 to 52.0 squares. Very similar trends are shown for vocalisations : for cows a drop from 8.2 on day 1 to 3.8 on day 3 and for sheep a rise from 28.7 to 32.7 vocalisations over the same period. The elimination scores show little change over the three days for either sheep or cows. Unfortunately the scoring of defecation-urination responses and vocalisations for the pig were impractical, so these results are not available for comparison. The scores from each species will now be examined in more detail.

Open-field Scores : CATTLE

The results of testing 44 dairy cows in the open-field for 3 consecutive days are shown in table 14. As the open-field was designed to test the reactions of subjects to a strange environment, no prior orientation of the animals to the apparatus was desirable. It was not conceivable to pick the cows up and drop them into the arena as one might with a rat, so the subjects had to be driven through the entrance gate. The animals to be tested were brought into the adjacent yard

and left quietly for a period of approximately 30 minutes. On the arrival of the experimenter the subjects would get up and defecate almost immediately. In many cases they would defecate again before finally entering the arena. It became clear that because of these procedural difficulties the elimination score might be of rather limited value. In Table 14 elimination data are recorded as u or d for urination or defecation and the number of responses of each kind follow the appropriate symbol; i.e., u1 d2, means that on this day this cow urinated once and defecated twice.

The table shows that only 9 of the 44 cows did not either defecate or urinate in the open-field on their first day of entry. Of the 28 subjects which defecated, 4 did so 3 times and another 11 twice. On day 2, 29 animals were concerned; 3 defecated 3 times and 8 twice. On day 3, of the 31 cows, 9 defecated twice. Similar numbers of subjects defecated on each of the 3 days of the test; i.e., 28, 29 and 31 respectively. Fifteen animals defecated consistently over the 3 days and 18 others did so on 2 days. With 1 exception those subjects which defecated 3 times on day 1 continued to do so at least once on days 2 and 3.

The number of cows urinating on each of the 3 days was also similar in total; i.e., 11, 11, and 10 but only 1 cow urinated on each of the 3 days. Five cows did so on 2 days.

Table 14 : Open field scores for cows.

cow no.	Ambulation				Vocalisation				Elimination			
	day no.				day no.				day no.			
	1	2	3	total	1	2	3	total	1	2	3	total
1	97	53	31	181	4	10	0	14		d1		1
2	65	33	41	139	12	9	8	29	d1		d1	2
3	64	39	18	121	7	10	5	22	u1	d1	d1	3
4	62	53	13	128	31	27	18	76		u1d1	d1	3
5	60	31	5	96	9	4	4	17	d2	d1		3
6	58	19	7	84	16	11	3	30		u1d2	u1d2	6
7	54	52	31	137	14	8	5	27	u1		d1	2
8	50	51	59	160	0	0	0	0	u1d2	d1	d1	5
9	48	14	23	85	5	1	2	8				0
10	47	41	42	130	4	4	4	12	d3	d3	u1d2	9
11	47	27	19	93	8	2	4	14	d2		d1	3
12	46	32	54	132	0	0	0	0	d1	d1	u1	3
13	45	37	7	89	18	15	4	37				0
14	45	15	24	84	12	0	1	13		u1	d2	3
15	44	32	38	114	9	5	4	18	d2		d2	4
16+	44	3	3	50	20	19	21	60				0
17	43	26	18	87	15	28	27*	70	d1	d1	d2	4
18	43	19	14	76	10	4	4	18	u1	d1	d1	3
19	42	48	22	112	5	27	11	43	d2	d2	d1	5
20	41	19	6	66	11	7	2	20	d2	d2	u1d1	6
21	40	5	5	50	10	5	2	17	d1	u1d1	d2	5
22	39	19	19	77	7	5	1	13	u1d1	d3	d1	6
23	39	19	10	68	4	1	0	5	d2	u1d1	d1	5
24	39	13	7	59	16	1	2	19	u1	d1		2
25	39	10	4	53	0	2	1	3	d1	d1	d2	4
26	37	43	30	110	7	5	5	17	d1	d2	u1d2	6
27	36	16	11	63	9	4	2	15		u1d1	u1d2	5
28	35	17	5	57	15	7	0	22	u1d1	d1		3
29	34	11	9	54	13	6	0	19	d1		d1	2
30	33	33	23	89	2	2	1	5	u1d2	d1		4
31	33	15	8	56	8	6	2	16	d3		d1	4
32	31	21	17	69	12	17	4	33	u1d1	d1	d1	4
33	30	30	31	91	4	5	3	12	d1	d2		3
34	30	10	5	45	4	0	0	4	d2	u1		3
35	28	39	11	78	4	14	0	18	u1	u1	d1	3
36	27	30	16	73	2	0	0	2	d2	u1d2	u1d1	7
37	27	26	5	58	4	6	0	10	d1	d1	d1	3
38	25	19	25	69	1	8	6	15	d2	d2	d1	5
39	25	25	16	66	10	2	0	12	u1	u1d1	d1	4
40	25	12	7	44	5	2	1	8	d2			2
41	14	11	2	27	3	3	0	6	d3	d2	d1	6
42	11	39	12	62	7	9	7	23		d1	u1d1	3
43	6	12	15	33	0	0	0	0	d1		d1	2
44+	3	2	2	7	4	3	2	9	d1	u1	u1d1	4
ave	39.4	25.5	17.5	82.3	8.2	7.0	3.8	18.9	1.3	1.2	1.1	3.6

*showing signs of oestrus + not rated for temperament.

Only 3 of the 44 animals tested did not either defecate or urinate on at least one of the days involved. Generally, cattle defecate before they urinate if both types of response are to be shown.

As the early tests were administered during the orientation of the subjects to the raceway and arena, they could not be run rapidly and directly into the open-field. Later it was possible to redesign the raceway approaches so that animals could be driven directly from the outside raceway into the field. By this change we hoped to raise the elimination scores by having all these responses occur during the five minutes in the arena. No significant differences were shown in elimination scores in the results from these two techniques. In general it seems that the elimination response of cows showed a definite limit within a prescribed time period; i.e., 3 responses during a 5 minute period. Increasing the strangeness of the surroundings might increase the number of elimination responses.

On Table 14 the subjects are placed in order of the number of squares broken in the open-field on day 1 of testing. They range from 3 to 97 squares broken in the 5 minute period. Cows ambulated from approximately 25 feet to 1,152 feet in the trial period. The range for squares broken on days 2 and 3 is rather similar; i.e., 2 to 53 and 2 to 59 respectively. The

daily total of squares broken drops from 1,731 on day 1 to 1,121 on day 2 and 770 by the third day. This represents a 56% decrease over the 3 day period. Only 3 of the 44 cows tested increased their scores and this averaged only 8 squares or about 100 ft. The biggest drop was for the cow ranked highest on day 1 and represents 66 squares over the 3 days. The 3 day ambulation scores ranged from 7 to 181.

The cow which broke only 3 squares on day 1, froze on the spot in the field, after entering 3 squares. Though she did take several steps forward, one at a time, she immediately stepped backwards again and moved around on a small arc, not shifting position at all. This cow had to be literally dragged out of the field by 3 men after the trial was complete.

Rank order correlations using Spearman's rho, (Seigel, 1956) were calculated for the ambulation scores ranked for day 1, day 2, day 3 and the overall 3 day total. These correlations are shown in table 15 and are significant at the 1% level of confidence between day 1 and 2; day 2 and 3; and day 1 and the 3 day total score.

An examination of the vocalisation score shows that 3 cows were silent throughout the 3 days' tests and another 10 ceased to vocalise by day 3. Only 2 cows increased their vocalisation score during the test period and 1 of these was coming into oestrus on day 3 of the tests. Most cows showed appreciable decreases in this response. The day 3 overall

Table 15a: The correlations of the 3 scores of the open-field test for cattle by the Spearman rank correlation coefficient (ρ). (Siegel, 1956).

Day	Ambulation score			Elimination score			Vocalisation score		
	1	2	3	Total	Total	Total	3	2	1
	0.45**	0.65**		0.003	-0.10		0.57**	0.53**	
	0.38*						0.50**		
		0.74**		0.17			0.80**		
			-0.12				-0.21		
				0.33*					

Level of significance:

When $N = 44$, 5% level* = 0.304 ; 1% level** = 0.393.

Table 15b: The correlations of the 3 scores of the open-field test for sheep by the Spearman rank correlation coefficient (ρ).

Day	Ambulation score			Elimination score			Vocalisation score		
	1	2	3	total	Total	Total	3	2	1
	0.55**	0.38*		0.14	0.18		0.72**	0.57**	
	0.27						0.55**		
		0.77**		0.40*			0.88**		
			0.16				-0.04		
				0.29					

Level of significance:

When $N = 32$, 5% level* = 0.349 ; 1% level** = 0.449

total decreased from 361 on day 1, to 304 on day 2 and 166 by day 3. This is a 54% decrease over the trial period. The correlations between the daily rank orders for vocalisation parallel those for ambulation and indicate that the animals which vocalise most on day 1 continue to do so over the 3 days.

From this initial consideration of the data it seemed that both the ambulation and the vocalisation scores were measuring something meaningful which decreased at a similar rate over the 3 days. The next task was to see if there was an interrelationship between the ambulation, vocalisation and elimination scores. The scores of each of these for day 1 and for the 3 day total were correlated and in all but one case gave non-significant results (see Table 15). The rank orders of day 1 scores, for ambulation and vocalisation, were correlated at the 5% level of significance. As expected the elimination scores did not show a relationship with either ambulation or vocalisation.

The changes in scores from day 1 to day 2 and from day 1 to day 3, using the score on the first day, when the arena was totally strange, as a base line, were ranked for each animal and these changes for ambulation and vocalisation were found to correlate at the 1% confidence level ($\rho = 0.46^{**}$). (See Table 16). Animals which show the greatest drop between day 1 and day 3 for one parameter show similar trends for the other. The scores which are related for cows originate in the subjects'

Table 16 : Changes in the daily ambulation and vocalisation scores of cows in the open-field test. Using the Day I scores as baseline the results are shown as plus (+) or minus (-) for decreases or increases respectively.

Cow no.	day 1-2 (ambulation scores)	day 2-3	total	day 1-2 (vocalisation scores)	day 2-3	total
1	-44	-22	-66	+6	-10	-4
2	-32	+8	-24	-3	-1	-4
3	-25	-21	-46	+3	-5	-2
4	-9	-40	-49	-4	-9	-13
5	-29	-26	-55	-5	0	-5
6	-39	-12	-51	-5	-8	-13
7	-2	-21	-23	-6	-3	-9
8	+1	+8	+9	0	0	0
9	-34	+9	-25	-4	+1	-3
10	-16	+1	-15	0	0	0
11	-20	-8	-28	-6	+2	-4
12	-14	+22	+8	0	0	0
13	-8	-30	-38	-3	-11	-14
14	-30	+9	-21	-12	+1	-11
15	-12	+6	-6	-4	-1	-5
16	see below (not rated by milkers)					
17	-17	-8	-25*	+13	-1	+12*
18	-25	-5	-29	-6	0	-6
19	+6	-26	-20	+22	-16	+6
20	-22	-13	-35	-4	-5	-9
21	-5	0	-35	-5	-3	-8
22	-20	0	-20	-2	-4	-6
23	-20	-9	-29	-3	-1	-4
24	-26	-6	-32	-15	+1	-14
25	-29	-6	-35	+2	-1	+1
26	+6	-13	-7	-2	0	-2
27	-20	-5	-25	-5	-2	-7
28	-18	-12	-30	-8	-7	-15
29	-23	-2	-25	-7	-6	-13
30	0	-10	-10	0	-1	-1
31	-18	-7	-25	-2	-4	-6
32	-10	-3	-13	+5	-13	-8
33	0	+1	+1	+1	-2	-1
34	-20	-5	-25	-4	0	-4
35	+11	-28	-17	+10	-14	-4
36	+3	-14	-11	-2	0	-2
37	-1	-21	-22	+2	-6	-4
38	-6	+6	0	+7	-2	+5
39	0	-9	-9	-8	-2	-10
40	-13	-5	-18	-3	-1	-4
41	-3	-9	-12	0	-3	-3
42	+28	-27	+1	+2	-2	0
43	+6	+3	+9	0	0	0
44	not rated by milkers see below					
16	-41	0	-41	-1	+2	+2
44	-1	0	-1	-1	-1	-2

* oestrus on day 3

0.46**

reaction to the arena on the first time of entry. If the strangeness of the apparatus were increased by some method both ambulation and vocalisation scores might increase and together become an adequate measure of the animal temperament reaction. However, it is also possible that ambulation represents a particular animal's exploratory reactions to confinement within the arena while the vocalisation score might be a reflection of social isolation. Certainly the cow which was coming into oestrus on day 3 showed a not unexpected increase in vocalisations on that day.

Although both the vocalisation and ambulation scores declined in a rather parallel manner over the 3 days, the elimination scores did not.

Having shown that the day 1 scores of ambulation and vocalisation correlate, it is important to know if scoring these 2 behaviour parameters might provide an index of temperament or allow an operational definition of temperament. One score alone might be a better index of "emotionality" just as many of the investigators with rats have considered that ambulation is a better indicator of "emotionality" than elimination. As 2 independent dairy workers had been involved in the handling of most of the cows tested, it was possible to have their assessments of the temperament of the subjects tested. Nineteen of the animals were rated by both the observers. Working from Tulloh's

ratings of beef steers and Dickson's ratings for dairy cows, we made a compromise in suggesting a rating into 5 classes. The classes which were used are shown in Table 17. Because only 19 of the cows were common to the ratings of both dairymen, we have treated the ratings as separate groupings and tables 18 and 19 show the results. Rankings of the ambulation score are shown on the left and those of the vocalisation score on the right. Each of these is linked with the temperament scores of the dairyman shown from ratings 1 to 5.

A visual examination of the results indicates that subjects are very evenly scattered throughout each of the 5 groups. Quiet, docile subjects rank from 5 to 39 on the ambulation score and 2 to 41 on the vocalisation score, while scary agitated cows rank from 6 to 37 for ambulation and 9 to 38 for vocalisation. The results of the second dairyman show a very similar pattern, in Table 17. In this case only 22 of the animals were ranked, the others having been replaced by newer stock in the twin herd. The application of Jonckheere's test (1954) to the results confirms that there are no significant relationships between either ambulation or vocalisation scores and the temperament ratings given by either of the dairymen. In fact, the independent ratings of the 2 dairymen show a low level of correlation, significant only at the 10% level of confidence, when calculated by Burr's modification of Kendall's correlation (1960). Some

Table 17 : Description of categories for temperament ratings by dairymen.

Scale	Description
1.	Very placid, quiet cow, does not get ruffled, not upset by strangers, amenable to handling, docile, perfectly settled into the complete handling and milking routine. An ideal type.
2.	Quieter than average but can be upset by very unusual circumstances. May flick tail on odd occasion but generally gives very little trouble in yard or during milking.
3.	Average temperament. Generally quiet and manageable. May move at times during milking. May show mild upset with strangers and can be rather restless at times.
4.	Can be jumpy and nervous at times, not a consistently difficult cow for dunging, etc., but will be upset and dung periodically. Kicks occasionally, and can be quite disturbed by unusual happenings.
5.	Flighty, very scary, often reluctant to enter bails and hangs back. Defecates and urinates quite frequently. Is known to be difficult. Kicks at handler or milking claw, gives small bellows from time to time. Fearful and will tremble on being touched. Agitated with strangers and holds her milk back. Comes very close to being culled as a "nuisance" cow.

Table 18 : Showing the relationship between the temperament ratings (by milker A) and the ranked total Ambulation and Vocalisation scores on left and right respectively.

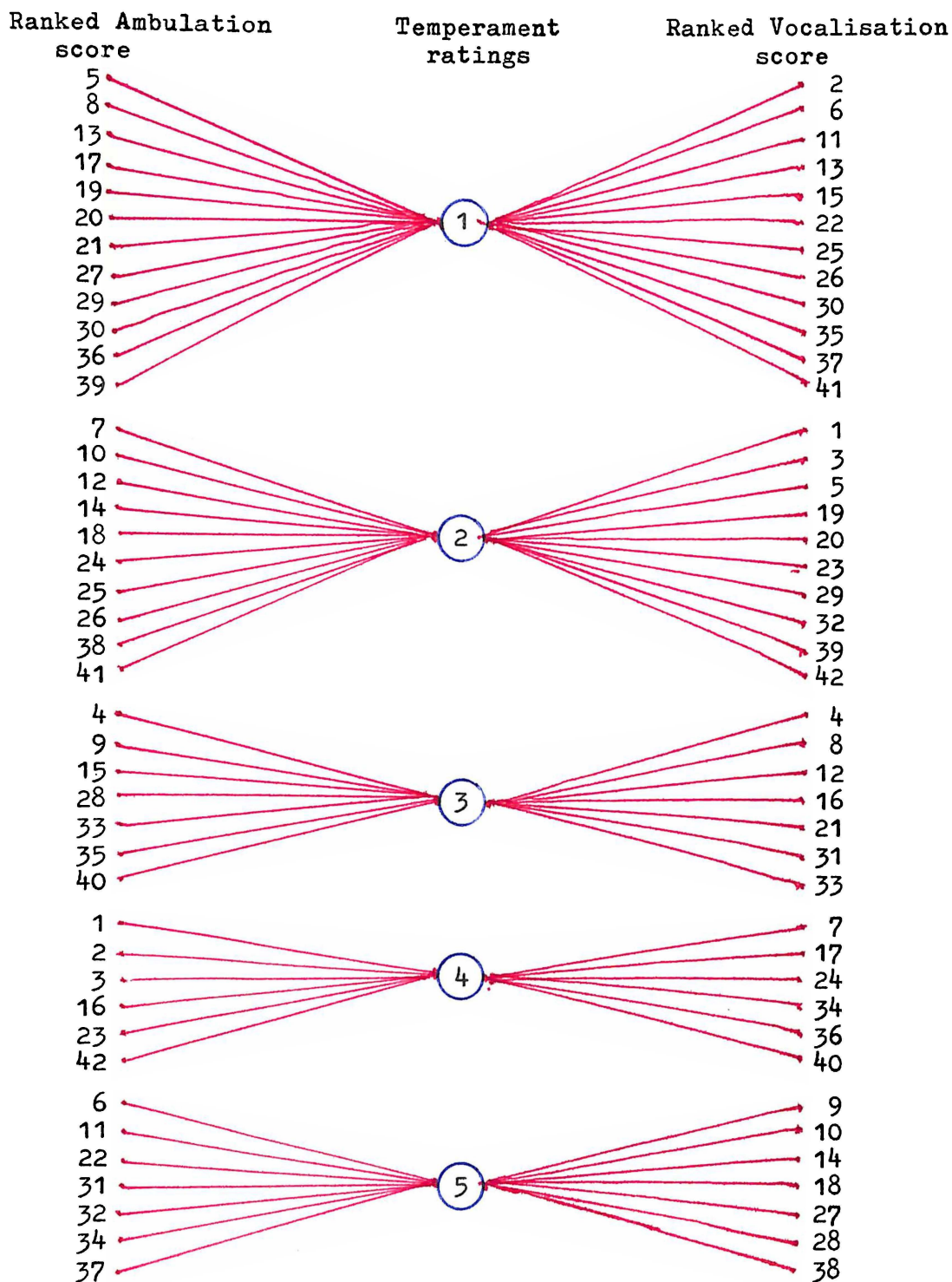
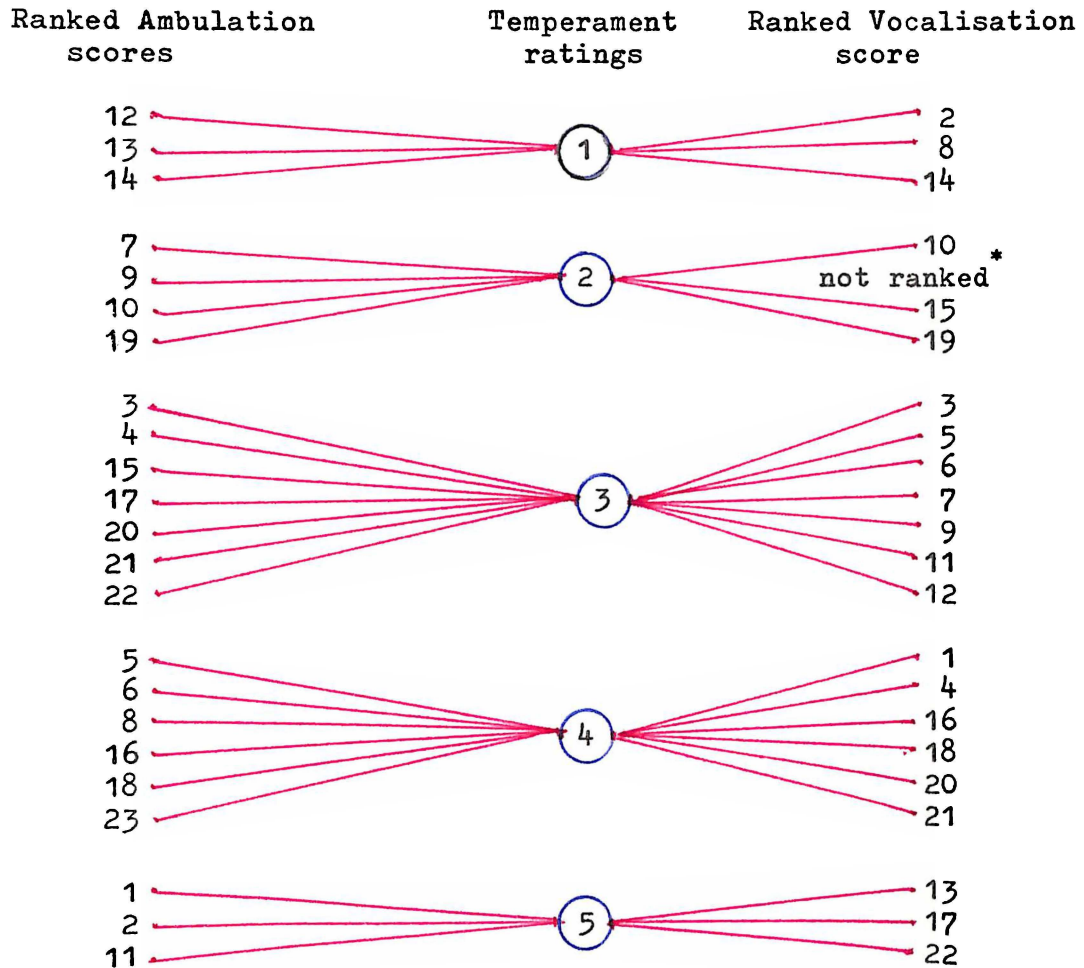


Table 19 : Showing the relationship between the temperament ratings (by milker B) and the ranked total Ambulation and Vocalisation scores on left and right respectively.



* This cow was showing signs of oestrus on day 3 and this gave her unusually high total vocalisations.

cows rated as 1 by milker A were classed in group 4 by milker B.

It is conceivable that age was an important factor in the dairyman's ratings of his animals. As years pass perhaps older cows become more and more familiar with the shed routine and remain placid whereas, in the relative strangeness of the open-field they gave unexpected evidence of a "real" temperamental response to the situation. Table 20 shows the ranks for age and production adjusted for age (see below) with the temperament ratings. Cows rated as having a placid temperament ranged from ages 2 to 10 years and those rated excitable ranged from 2 to 6 years of age. Again no significant differences were found with Jonckheere's Test.

Summarised on Table 20 is a variety of score ranks in the temperament groupings to allow ease of comparison. Ranks for day 1 ambulation and vocalisation scores are shown followed by the elimination score. The rank of a product of the ambulation and the vocalisation score for day 1 and the whole 3 days is shown. The age, the production of the cows in gallons of milk during the 1968-1969 season, adjusted to allow for the age differences of the dairy cows concerned by using the tables provided by the New Zealand Dairy Board for cows in the local region, is then shown. (37th Annual Report, 1961, table 3. p.101). This is followed by the production rank order. It is clear from this table that in all the score rankings animals are divided very

Table 20: The rank order of various open-field scores, age and adjusted production for each subject, arranged according to the temperament ratings of the dairy-men for the 42 cows.

Temp rating	day 1 Amb.	day 1 Voc.	total Elim.	day 1 Amb x Voc.	total Amb x Voc.	age yrs	Production gals	rank
1	3	3 $\frac{1}{2}$	5	2	2	2	9160	1
1	5 $\frac{1}{2}$	5 $\frac{1}{2}$	10 $\frac{1}{2}$	6	7	3	6067	14
1	11	8	10 $\frac{1}{2}$	12	9	3	5870	17
1	12	10	17	13	16	4	5558	20
1	13	14	17	18	19	4	5403	22
1	16	17	27	20	23	5	5253	24
1	22	19 $\frac{1}{2}$	27	24	25	5	5190	25
1	26	31	27	28	27	5	5117	27
1	28	31	27	31	30	6	4463	31
1	33	31	27	8	36	6	4257	32
1	34	40 $\frac{1}{2}$	27	32	35	6	1231	41
1	38	31	36 $\frac{1}{2}$	38	41	10	933	42
2	4	1	2	1	1	2	6558	9
2	5 $\frac{1}{2}$	10	10 $\frac{1}{2}$	9	3	2	6251	11
2	9	14	10 $\frac{1}{2}$	15	10	3	5901	15
2	18	17	10 $\frac{1}{2}$	19	13	3	5740	18
2	20	26	17	25	22	4	5621	19
2	31	26	27	26	24	5	5128	26
2	32	31	27	30	29	6	5012	28
2	35	36 $\frac{1}{2}$	27	36	31	8	4840	30
2	38	38	36 $\frac{1}{2}$	41	40	10	4215	33
2	42	40 $\frac{1}{2}$	41 $\frac{1}{2}$	42	42	14	2374	37
3	7	2	5	3	5	2	6628	7
3	14	7	17	5	6	3	6072	13
3	15	12	17	11	11	3	5319	23
3	19	17	27	16	18	3	3238	35
3	29	19 $\frac{1}{2}$	36 $\frac{1}{2}$	22	28	4	2808	36
3	36	26	36 $\frac{1}{2}$	29	32	7	1995	39
3	38	31	41 $\frac{1}{2}$	33	34	7	1573	40
4	1	10	5	4	4	3	7808	5
4	2	14	10 $\frac{1}{2}$	14	8	3	7705	6
4	8	31	17	17	17	4	6076	12
4	16 $\frac{1}{2}$	35	27	35	33	4	5446	21
4	30	36 $\frac{1}{2}$	36 $\frac{1}{2}$	37	37	7	3871	34
4	40	40 $\frac{1}{2}$	40	39	38	8	2257	38
5	10	3 $\frac{1}{2}$	1	7	12	2	7953	2
5	21	5 $\frac{1}{2}$	5	10	14	3	7914	3
5	23	22 $\frac{1}{2}$	5	21	15	4	7860	4
5	24	22 $\frac{1}{2}$	17	23	20	5	6579	8
5	25	22 $\frac{1}{2}$	27	27	21	5	6345	10
5	27	22 $\frac{1}{2}$	27	34	26	6	5873	16
5	41	40 $\frac{1}{2}$	36 $\frac{1}{2}$	40	39	6	4938	29

evenly throughout each of the temperament groups as provided by the dairymen. We might suspect that the cow-man interactions which seem to vary quite a lot from cow handler to cow handler are not providing sufficiently accurate ratings for valid comparisons to be made. However the culling of stock on the grounds of temperament is completely dependent on the assessment of the cowman concerned and is not related to any other objective assessment. The rank order of production shows that the placid quiet cows cover the whole range of production while the active type 5 cows are rather more related to the better producers. This might be explained by the fact that apart from their production these animals would already have been culled. This would give a slight bias to the groups of cows left in the herd with a 5 rating in terms of production level.

In discussing definitions of animal temperament it was seen earlier that genetic constitution was considered to be an important factor. This study allowed an analysis to be made of the open-field results of 20 pairs of monozygotic cattle twins with a view to assessing the importance of this constitutional basis for temperament. Table 2¹ sets out the results of ambulation, vocalisation and elimination together with the age and adjusted production records for each of the pairs of twins. Twin numbers follow consecutively in the Ruakura herds. The rank order correlations between days 1 and 3 for each score and

Table 21 : Data concerning 20 identical twin cows tested in the open-field.

cow no.	milker rating	ambulations				vocalisations				elimination total	production in gals.	age in yrs.
		1	2	3	total	1	2	3	total			
407	5	39	10	4	53	0	2	1	3	4	6345	6
408	5	19	19	19	77	7	5	1	13	6	4938	6
707	5	39	13	7	59	16	1	2	19	2	7647	4
708	5	11	39	12	62	7	9	7	23	3	6326	4
545	5	37	43	30	110	7	5	5	17	6	7914	6
546	5	47	41	42	130	4	4	4	16	9	7860	6
679	1	30	10	5	45	4	0	0	4	3	5403	5
680	1	25	25	16	66	10	2	0	12	4	4257	5
689	1	34	11	9	54	13	6	0	19	2	1089	3
690	1	47	27	19	93	8	2	4	14	3	825	3
699	1	58	19	7	84	16	11	3	30	6	4463	5
700	1	36	16	11	63	9	4	2	15	5	5558	5
419	4	14	11	2	27	3	3	2	8	6	3871	6
420	3	41	19	6	66	11	7	6	24	6	3238	6
683	4	43	19	14	76	10	4	4	18	3	7808	4
684	4	33	33	23	89	2	2	1	5	3	6076	4
665	2	27	30	16	73	2	0	0	2	8	5012	4
666	3	27	26	5	58	4	6	0	10	3	5332	4
7183	3	45	37	7	89	18	15	4	37	0	6363	3
7184	2	46	32	54	132	1	8	6	15	5	5901	3
705	4	97	53	31	181	4	10	0	14	1	5236	3
706	4	50	51	59	160	0	0	0	0	4	2170	3
351	3	33	15	8	56	8	6	2	16	4	6072	7
352	2	27	30	16	73	4	5	3	12	3	5740	7
059	1	43	26	18	87	15	28	27	70	4	5435	10
060	2	42	48	22	112	5	27	11	43	5	5005	10
739	1	45	15	25	85	12	0	1	13	3	5253	3
740	1	28	39	11	78	4	14	0	18	3	5369	3
541	1	64	39	18	121	7	10	5	22	3	5190	5
542	1	46	32	54	132	0	0	0	0	3	5117	5
6149	5	35	17	5	57	15	7	0	22	3	5873	4
6150	4	24	42	25	91	3	5	1	9	2	7084	4
695	2	37	37	11	85	7	10	0	17	4	3944	5
696	2	25	60	19	104	6	4	2	12	3	4067	5
7169	2	60	31	5	96	9	4	4	17	3	5621	5
7170	3	51	68	36	155	3	9	11	23	2	5950	5
333	3	16	8	38	62	7	5	17	29	4	4151	9
334	3	28	47	13	88	8	16	9	33	3	2905	9
907	1	51	35	32	118	9	11	11	31	4	4504	3
908	1	30	20	20	70	9	12	13	34	1	4007	3
					3510					737	149	

between the totals for each score follow the pattern shown earlier (Table 15a) though the relationship between day 1 ambulation and day 1 vocalisation in this case is not significant.

Hancock (1954) has summarised the results from early studies with monozygotic twins and provided a method of analysis to determine the twin efficiency value of various types of activity in these twins. This value is defined as follows: the twin efficiency value multiplied by 2, expresses the number of randomly selected animals 1 twin set can replace without the loss of statistical efficiency. Dick and Whittle (1951) suggested a formula for this calculation as follows:-

$$\text{efficiency value} = \frac{\frac{1}{2}(\text{mean square between sets} - 1)}{(\text{mean square within sets})}$$

Table 22 shows the twin efficiency values for a number of activities and measures as selected from Hancock, p. 213, and includes some behaviour data related to grazing and elimination. The values calculated from this study are included in this table below the ruled line. The data were calculated using raw scores, square roots and logarithms without showing any variations in basic twin values. At the most, one set of identical twins can replace 3 non-twins for work done in the open-field test. The scores for ambulation and vocalisation are rather similar to the efficiency value for urination in cattle though only 6 pairs of twins were used by Hancock in his calculation. It is

Table 22 : Twin efficiency values* (selected from Hancock, 1954)

Characteristics selected for study	Twin Efficiency value	No. of twin sets used.
milk	22	7
persistence of lactation	4	7
grazing time	72	6
loafing time	6	6
lying down time	3	6
distances travelled	3	6
no. of defecations	8	6
no. of urinations	1	6
no. of drinks	5	6
body temperature	37	7
respiration rate	15	7
dry matter intake		
content of faeces	5	12
total sperm	8	12
sperm concentration	8	12

Twin efficiency values : this study.

open-field scores		
Vocalisations	1.3	20
Ambulation	1.7	20

FORMULA for CALCULATION (Dick and Whittle. 1951)

$$\text{Efficiency value} = \frac{1}{2} \left(\frac{\text{mean square between sets}}{\text{mean square within sets}} - 1 \right)$$

* The Twin efficiency value, multiplied by two expresses the number of randomly selected animals one twin set can replace without loss of statistical efficiency.

considered that the index for monozygotic twins which relates to aspects of behaviour such as urination, or ambulation might be termed a similarity index and that efficiency ratio might be used for features of growth and production in twins such as length of lactation, growth rates etc.

The similarity index of the 20 sets of twins in this study indicates that a pair of twins can be used to replace 3 non-twin cattle and still maintain statistical efficiency.

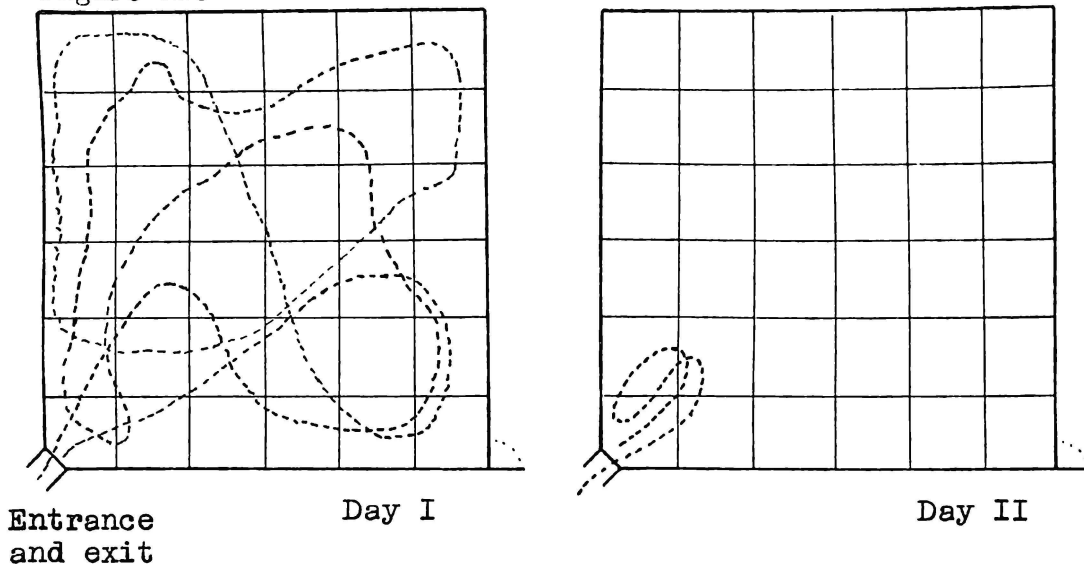
If the constitutional basis of temperament is paramount in the determination of behaviour at a later stage of life, then the open-field tests must be further refined to provide a better index of temperament. Otherwise it is clear that the early experience of the subject must seriously modify the basic constitution and provide a variety of expressions of later temperament even in monozygotic twins. In the case of the twins tested, many had come from other dairies to make up the initial no. 3 dairy herd in 1967 and had had a variety of background not always experienced by such twins. (Ewbank, 1967).

An analysis of the pathways taken by the subjects during the tests in the open-field showed that the procedures adopted by the experimenter on the first day of testing have important effects on the behaviour of the cows on subsequent days. The subjects seem to develop certain "expectancies" with regards to the entrance

and exit points of the arena. Though this can be partly controlled in the rat, where each subject can be placed by hand in the centre square of the field and after the trial is over can be lifted directly from the apparatus again, this is **not** possible with the cow. Figures 20 and 21 give 2 examples typical of the effect of the entrance and exit points on day 1 on the behaviour of the subject on day 2. Cow 402, with an ambulation score of 68 and a vocalisation score of 16 on day 1, maintained the vocalisation score on day 2; i.e., 19, but decreased the ambulation score to 9. Because 402 had been run into the arena and taken out from the one spot, gate A, she remained very close to this point on day 2. By way of contrast cow 5113 was run in the same gate but taken out the exit gate on the lower right corner of the arena. On day 2 she made straight for the exit point of the day before, then moved to the gate B and returned via the first exit point to wait near the start gate for the rest of the 5 minute period. The scores for each day are as follows in this case. Day 1 vocalisations = 2; day 2 vocalisations = 2; ambulation day 1 = 19 and day 2 = 23. The building of a circular arena with a number of entrance and exit doors might overcome this problem but such equipment would be expensive and of limited use for further studies. In general, the reactions of the subjects on the first day should be given most consideration in ratings of temperament, because of this procedural

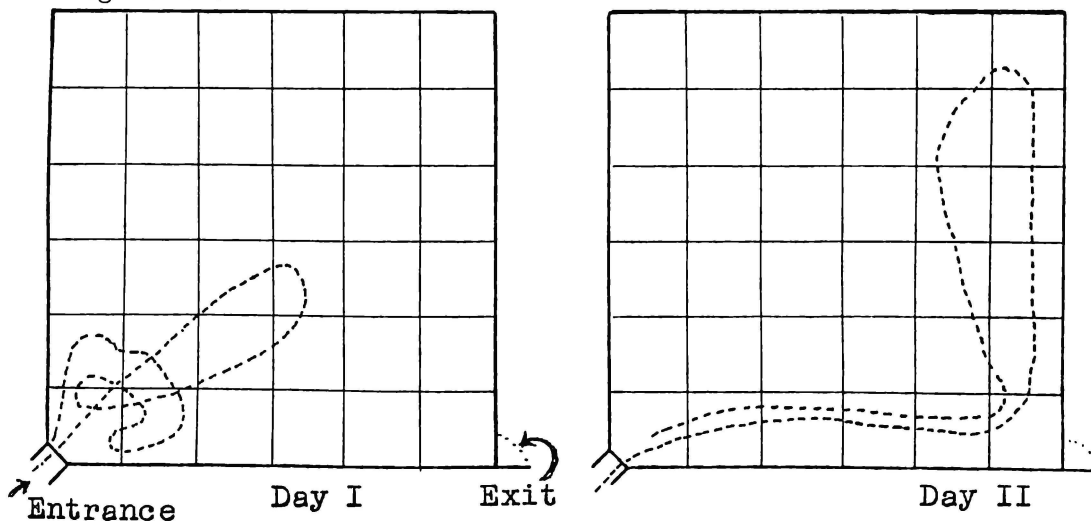
Figure 20.

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Tracks of cow 402 on day I and II in an Open-field
Ambulation path on day I on right; day II on left.

Figure 21.



Tracks of cow 5113 on day I and day II in an Open-field.
Ambulation path on day I on right and day II on left.

Cattle tracks on Day I and Day II in an Open-field showing the influence of entry and exit points of Day I on the performance of the cows on Day II. Above: Entry and exit point - gate A. Below: Entry point -gate A; exit point as marked.

effect. It is of interest that the one significant correlation between the ambulation and the vocalisation score was from totals on day 1 in both cases. Further work should attempt to increase the strangeness of the field for the responses on the first day to become more pronounced.

For the rat the rationale underlying the use of the open-field test is as follows (Denenberg, 1969): mammals exposed to strange or noxious stimuli will, in most cases, "freeze". This may make it more difficult to be seen by the predator. The reaction of ungulates to noxious or strange situations is not well documented. It might be expected that the rat and cow would give opposite reactions to strangeness in the open-field; i.e., high ambulation scores for the emotional animal. McCann (1966) suggested that this is so for pigs. The second consequence of exposure of the rat to strange stimuli is the triggering off of the activity of the autonomic nervous system and as a result, defecation and urination of the subject concerned. To obtain such scores the arena for the rat has to be distinctly different from its home cage. The open-field is greater in dimension and has not the odour trails of the home cage for the rat. For the cow, however, our dimensions are smaller than the paddock and larger than the normal yard. Though it is a strange environment so also is the area adjacent to the arena as well as the raceways and holding pens. It seems clear once again that additional

methods of adding strangeness to the open-field may be necessary for the large farm animals, before suitable indices of temperament can be reliably gathered. The use of the small rotating wheel containing black and white stripes to excite the cow and thus inhibit the milk-ejection reflex (Whittlestone, 1951) deserves consideration in this respect.

We have already indicated some of the problems of scoring vocalisations in the large social animals. During testing it appears possible to score two types of vocalisations, (a) those made as a direct result of being in isolation from the group and in a strange environment and (b) those made in answer to some call. The last animal to be tested, if left alone in the holding pen for a time before being tested, is likely to show increased agitation and it would seem wise to have a companion for all sheep, cattle and pigs up until the precise time of testing in the open-field. The separation of the individual cow at some distance from the herd is sufficiently stressful to increase the leucocyte count of the milk taken from the quarters of a dairy cow and to significantly increase the vocalisation score. (Whittlestone et al. 1970). Such animals become difficult to manage as a result of separation. The close proximity of the rest of the herd may have an important influence on the vocalisation score of an individual animal in the arena during the test period. These are all problems which arise when testing

social animals unless they have been imprinted on to human investigators rather than their own species.

During this study it was not possible to use a wider range of cattle including both sexes, castrated males, etc. It is conceivable that had such a wider range of cattle been tested a greater variation of scores may have provided a good indication of temperament whereas the test is not sensitive enough to differentiate adequately between the dairy cows in milk which have already been subjected to quite severe culling on temperament grounds.

A discussion of the specific behaviour recorded during the open-field tests is reserved until after the closed-field data have been discussed.

Open-field scores : Sheep

Thirty two sheep were scored in the open-field during their orientation to the closed-field test and the results are shown in Table 23. Though every attempt was made by two recorders to note all the urinations and defecations which occurred in the 5 minute trial, defecations in particular were difficult to ascertain in actively moving sheep. A mere flick of the tail was sometimes the only evidence for defecation and the defecation score cannot be considered accurate. Urination is a more precise behavioural act and was reliably recorded. It can be seen from the Table that urinations began to fall in frequency on the third day.

The total ambulation score and vocalisation score for each day of the test shows an increase for the 32 sheep under study though this partially reflects the very high scores of the number 1 ranking sheep. The day 1 total ambulation score of 1611 rose to 1664 on day 3 while the first day vocalisation score of 919 rose to 1046 by day 3. This is in marked contrast to cows for which the same scores dropped approximately 55% in the same period. The general rise in scores over the 3 days might be attributed to several factors; the infrequent handling of sheep on normal farms compared to cows, which are handled twice a day; the sheep's reactions to the strangeness of the environment; or the severity of isolation being greater for sheep than for cows.

Table 23 : Open-field scores for sheep (32 subjects)

sheep no.	Ambulation				Vocalisation				Elimination				to- tal
	day number				day number				day number				
	1	2	3	total	1	2	3	total		1	2	3	tal
1	132	111	187	430	64	67	46	177					0
2	77	74	70	221	38	43	36	117	u1				1
3	77	93	33	203	25	25	24	74					0
4	75	72	81	228	31	34	34	99	u1	u1d1	u1		4
5	72	37	38	147	29	27	44	100	u1				1
6	72	20	26	118	31	8	22	61			u1		1
7	67	83	47	197	36	32	36	104					0
8	65	43	72	180	19	38	40	97					0
9	58	86	41	185	73	71	69	213		u1	u1		2
10	52	74	59	185	27	25	34	86		u1			1
11	51	51	58	160	30	33	25	88	u1	u1			2
12	50	70	27	147	24	39	27	90			u1d1		2
13	50	42	33	125	31	26	31	88	u1	d1			2
14	48	59	75	182	39	39	44	122		u1			1
15	46	23	42	111	19	19	26	64		u1	u2		3
16	44	52	50	146	15	32	28	75	u1d1	u1			3
17	44	52	48	144	13	4	4	21	u1				1
18	43	68	83	194	15	28	29	72	u2	u1	u1		4
19	43	50	37	130	18	33	21	72	u1	u1			2
20	41	47	44	132	24	41	33	98					0
21	41	15	43	99	13	9	15	37	u1				1
22	38	39	52	129	27	34	35	96	u1	u1			2
23	37	38	45	120	24	30	31	85					0
24	36	44	22	102	33	24	18	75	u1	u1			2
25	35	40	72	147	32	41	55	128					0
26	35	27	36	98	15	9	20	44					0
27	33	46	28	107	29	46	45	120					0
28	32	43	57	132	25	23	31	79	u1				1
29	31	31	54	116	15	28	39	82		u1	u1		2
30	31	41	23	95	53	47	32	132					0
31	28	47	55	130	10	26	32	68					0
32	27	35	26	88	42	38	40	120		u1			1
	1611	1653	1664	4928	919	1019	1046	2984	u14d1	u13d2	u8d1		39
	50.3	51.7	52.0		28.7	31.8	32.7						

A separate test of 30 sheep which had been handled continuously in various experimental trials was undertaken in the open-field in an attempt to answer some of these questions.

The relationship between the daily scores for ambulation and vocalisation with one another and the 3 day total, and the inter-relationships of these 2 scores are shown in Table 15b. The 3 day total scores for ambulation and vocalisation show a correlation at the 5% level of confidence. Assuming the arena to be more unfamiliar to sheep than to cows such a result encourages the belief that attempts to add to the strangeness of the field for cattle might increase the significance of the relationship of these 2 scores for them also.

Using day 1 scores as a baseline the increases or decreases in the scores on day 2 and 3 for ambulation and vocalisation are shown in Table 24. The minus scores indicate an increase on the day 1 scores and a plus sign indicates a decrease on the day 1 scores as would be expected as the subjects adjust to the open-field. The fact that 18 of the 32 animals showed an increase in the ambulation score over the 3 days, and 21 sheep in the vocalisation score, provides a contrast with the similar analysis for cows. The correlation of 0.26 (Spearman's rho) between the 2 deviation score rankings is not significant and indicates that sheep are not showing comparable changes of the scores on both

Table 24 : Changes in the daily ambulation and vocalisation scores of sheep in the open-field test. Using the day 1 scores as baseline the results are shown as plus (+) or minus (-) for decreases or increases respectively.

Sheep no.	Ambulation scores			Vocalisation scores				
	day	1-2	2-3	1-3	day	1-2	2-3	1-3
1		+21	-76	-55		-3	+21	+18
2		+3	+4	+7		-5	+7	+2
3		-16	+60	+44		-0	+1	+1
4		+3	-9	-6		-3	0	-3
5		+35	-1	+34		+2	-17	-15
6		+52	-6	-46		+23	-10	+13
7		-16	+36	+20		+4	-4	0
8		+22	-29	-7		-19	-2	-21
9		-28	+45	+17		+2	+4	+6
10		-22	+15	-7		+2	-9	-7
11		0	-7	-7		-3	+9	+6
12		-20	+43	+23		-15	+12	-3
13		+8	+8	+17		+5	-5	0
14		-11	-16	-27		0	-5	-5
15		+23	-19	+4		0	-7	-7
16		-8	+2	-6		-17	+4	-13
17		-8	+4	-4		+9	0	+9
18		-25	-15	-40		-13	-1	-14
19		-7	+13	+6		-15	+12	-3
20		-6	+3	-3		-17	+8	-9
21		+26	-28	-2		+4	-6	-2
22		-1	-13	-14		-7	-1	-8
23		-1	-7	-8		-6	-1	-7
24		-8	+22	+14		+9	+6	+15
25		-5	-32	-37		-9	-14	-23
26		+8	-9	-1		+6	-11	-5
27		-13	+18	+5		-17	+1	-16
28		-11	-14	-25		+2	-8	-6
29		0	-23	-23		-13	-11	-24
30		-10	+18	+8		+6	+15	+21
31		-19	-8	-27		-16	-6	-22
32		-8	+9	+1		+4	-2	+2

rho= 0.26 ns

parameters measured over the first 3 days of testing. It is probable that isolation effects make for more erratic performance during this period.

While it was possible to ask the dairyhands to rate the cows for temperament, sheep are seldom handled to the point where such a rating would be possible. Instead attempts were made to take blood samples without unduly upsetting the sheep concerned at various times during the open-field testing procedure. These samples were then assayed for the presence of blood cortisol. The problem was to know when to take the samples during the testing to give the best assessment of upset and stress. The sheep were still showing increased reactions in both ambulation and vocalisation on average up till the third day.

A group of 30 sheep which had been subjected to almost continuous handling since birth was selected. They had, in contrast to the other sheep used, been involved in an experiment immediately prior to the open-field tests and had been used extensively in fertility trials for several years. In this group of sheep both the ambulation and vocalisation scores were decreasing by the third day of testing. A blood sample was taken from each of these subjects at the completion of the second day's trial. The whole procedure was done as rapidly as possible so as not to add to the stress of the animals. This handling stress

would be minimal for these experimental sheep which were well used to this type of treatment.

Another group of 15 sheep which had not been subjected to experimental procedures and were naive animals was selected. They were given repeated tests in the open-field until it seemed clear that their scores were dropping as they were becoming familiar with the testing procedure and arena. This trial was continued for 9 days. Taking the scores on day 1 as base-line it can be seen from Table 25a and Table 25b that 2 of the 15 sheep were still giving scores higher than the baseline for ambulation on day 9 and 3 sheep were vocalising more on day 9 than day 1. From an examination of the scores over the 9 days it can be seen that in general the mean ambulation and vocalisation scores rose above the day 1 mean on days 3, 4 and 5 and 6. This trend, together with the similar results from the first trial with sheep, indicates that for sheep under normal New Zealand farming conditions, the peak response to the open-field will not be adequately sampled by a 3 day testing procedure and that the sheep do not start to habituate to the apparatus until after about the fifth day. This of course can be modified by earlier experience as was the case with the 30 experimental sheep tested in the second trial. It can further be assumed that 70% of the sheep under test should have become familiar with the

Table 25a : Open-field scores for 15 naive sheep over a nine-day period together with the level of plasma cortisol taken before and after the day 1 trials.

A. <u>AMBULATION SCORES</u>												
Sheep no.	day number									rankings		
	1	2	3	4	5	6	7	8	9	total	total	day 1-3
1	71	66	66*	46*	44*	37*	42*	91*	42	504*	3	2
+ 2	61	34*	67*	82*	87	64	71*	50	43	559	1	3
3	58	81	88	76	47	56	64	43	23	536	2	1
4	49	16	35	48	17*	39*	47*	33*	15	229*	11	12
5	43	30	42*	30*	44*	80*	55*	62*	19*	405*	5	9
6	42	36	54	46	53*	53	56*	49*	42	431	4	5
7	42	34*	32	38*	46	41	44	58	15	350	9	10
8	40	48*	39*	43*	27*	23	15	11*	8	254*	14	6
9	39	43*	43*	88*	44	25*	35*	47	4	370*	6	7
10	39	42	39	41	37*	56*	43	34*	27*	358*	8	8
11	37	16*	35*	36	41	39*	34*	57	43	338*	10	13
12	37	50	62	29*	36	54*	50	26*	17	361	7	4
13	36	12*	33*	43*	28*	41*	16	48*	18	275*	13	14
14	27	28	37*	35*	34*	37*	26	35	20	279*	12	11
15	22	17	32	35	37	35	18	29*	9	234	15	15

* denotes scores greater than that recorded for day 1 or means of totals higher than the day 1 score.

+ sheep 2 was blind in one eye. She followed round and round the walls and kept vocalising.

Table 25b :

VOCALISATION SCORES

Sheep no.	day number										rankings		plasma cortisol		plasma corti-	
	1	2	3	4	5	6	7	8	9	total	total	day 1-3	pre-test	post-test	sols pre-post	difference
1	17	9	25*	15	32*	27*	29*	33*	22*	209*	2	4	2.7	4.3	+	1.6
+ 2	47	27	38	39	35	31	41	34	27	319	1	1	2.9	2.1	-	0.8
3	5	10*	10*	6	13*	0	13*	6*	4	67*	8	8	5.2	6.5	+	1.3
4	5	5	16*	18*	11*	15*	17*	13*	2	102*	6	7	2.5	4.6	+	2.1
5	0	1*	12*	1*	1*	1*	5*	9*	3*	33*	12	11	2.3	8.1	+	5.8
6	22	19	20	23	18	13	21	24*	7	167	4	2½	2.1	7.0	+	4.9
7	1	2*	3*	3*	14*	2*	6*	2*	1	34*	11	14	3.3	4.7	+	1.4
8	0	15*	19*	14*	6*	4*	6*	0	0	64*	9	6	3.9	2.9	-	1.0
9	0	0	18*	13*	23*	0	6*	13*	0	73*	7	10½	4.2	3.9	-	0.3
10	0	0	2*	0	1*	2*	1*	0	0	6*	15	15	3.7	4.2	+	0.5
11	0	0	12*	1*	2*	2*	7*	0	0	24*	14	12	4.4	2.7	-	1.7
12	0	1*	7*	4*	1*	4*	9*	3*	0	29*	13	13	2.9	5.2	+	2.3
13	17	19*	25*	22*	21*	17*	16	22*	18*	177*	3	2½	1.2	1.6	+	0.4
14	18	10	13	23*	21*	11	12	16	4	128*	5	5	6.6	9.4	+	2.8
15	0	1*	21*	14*	9*	0	10*	0	0	55*	10	9	3.8	4.0	+	0.2

* denotes scores greater than that recorded for day 1 or means of totals higher than the day 1 score.

+ sheep 2 was blind in one eye. She followed round and round the walls and kept vocalising.

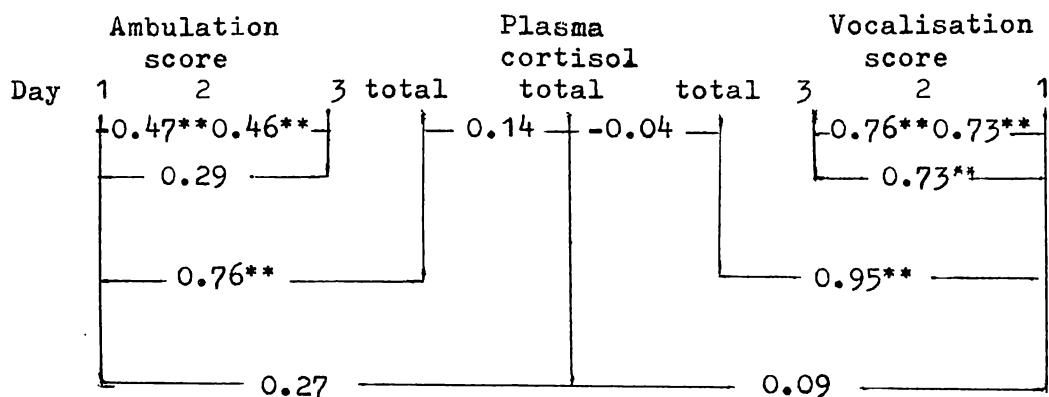
arena by the 9th day while a smaller percentage of animals was still giving persistently high scores after 10 days. Blood samples were taken from these 15 sheep both before and after the day 1 trial in an attempt to assess the changes in blood cortisol which occurred during the 5 minute test period.

Altogether 45 sheep were involved in the attempt to correlate the levels of plasma cortisol, the physiological index of "emotionality", with one of the behavioural indices sampled in the open-field test. The pre-test and the post-test levels of cortisol for the 15 sheep (naive) are shown in Tables 25a and 25b while the post-test levels on day 2 of the trial for the 30 experienced experimental sheep are shown in Table 26. The data for each of these groups were treated separately. Table 27 shows the results of the analysis of the levels of blood cortisol and the behaviour scores for the 2 groups of sheep. In the group of 30 experienced sheep sampled on day 2 at the end of the 5 minute trial, the vocalisation score and plasma cortisol rankings gave a minus correlation of 0.27 which is not significant, and the ambulation score and cortisol ranks were not correlated at 0.00. Neither the first day totals nor the 3 day totals were related to the cortisol levels in the blood after testing on day 2. In the second group of sheep, where pre-trial and post-trial blood samples were taken, 3 of the sheep showed decreased plasma cortisol levels greater

Table 26 : Scores of 30 experienced experimental sheep in the open-field and the post test cortisol level, on day 2.

Sheep no.	day 1	Ambulation score				Vocalisation score				blood cortisol post test	rank
		2	3	total	rank	day 1	2	3	total		
1	92	87	84	263	1	32	27	31	90	3.8 $\mu\text{g}\%$	13
2	92	69	44	205	3	41	39	40	120	3.7 "	14
3	84	51	19	154	9	31	8	0	39	6.7 "	2
4	83	59	51	193	4	50	38	37	125	5.9 "	4
5	75	65	41	181	7	38	35	33	107	3.1 "	20 $\frac{1}{2}$
6	73	32	14	119	20	0	0	1	1	3.2 "	18
7	69	34	58	161	8	8	1	7	16	3.1 "	20 $\frac{1}{2}$
8	67	54	65	186	6	1	2	4	7	3.1 "	20 $\frac{1}{2}$
9	67	28	27	122	17	23	7	1	31	5.0 "	6
10	65	73	82	220	2	28	22	23	73	3.1 "	20 $\frac{1}{2}$
11	63	48	19	130	16	19	6	2	27	4.3 "	9 $\frac{1}{2}$
12	63	20	21	104	24	13	2	1	16	6.0 "	3
13	62	82	43	187	5	32	39	23	94	3.5 "	16 $\frac{1}{2}$
14	62	46	34	142	11 $\frac{1}{2}$	14	8	0	22	3.0 "	23 $\frac{1}{2}$
15	61	37	23	121	18 $\frac{1}{2}$	11	11	7	29	3.6 "	15
16	59	49	43	150	10	0	0	0	0	5.6 "	5
17	57	41	18	116	21	19	12	4	35	2.7 "	27 $\frac{1}{2}$
18	52	55	35	142	11 $\frac{1}{2}$	4	0	1	5	4.9 "	7
19	51	56	33	140	13	10	3	3	16	4.7 "	8
20	50	21	19	90	27	6	3	1	10	2.9 "	25
21	48	55	29	132	15	38	22	24	84	2.3 "	29 $\frac{1}{2}$
22	45	49	44	138	14	41	2	3	46	4.0 "	11 $\frac{1}{2}$
23	44	35	8	87	28	29	11	5	45	4.0 "	11 $\frac{1}{2}$
24	41	46	19	106	22	32	30	7	69	3.0 "	23 $\frac{1}{2}$
25	39	25	22	86	29 $\frac{1}{2}$	28	11	18	57	2.8 "	26
26	38	31	34	103	26	1	7	3	11	3.5 "	16 $\frac{1}{2}$
27	37	28	39	104	24	14	2	0	16	7.8 "	1
28	36	51	17	104	24	2	4	0	6	2.3 "	29 $\frac{1}{2}$
29	36	34	51	121	18 $\frac{1}{2}$	2	11	4	17	2.7 "	27 $\frac{1}{2}$
30	25	27	34	86	29 $\frac{1}{2}$	18	9	7	34	4.3 "	9 $\frac{1}{2}$

Table 27 : A summary of correlations (Spearman's rho) between measures of plasma cortisol and various behavioural indices of emotionality as recorded in sheep in the open-field test.



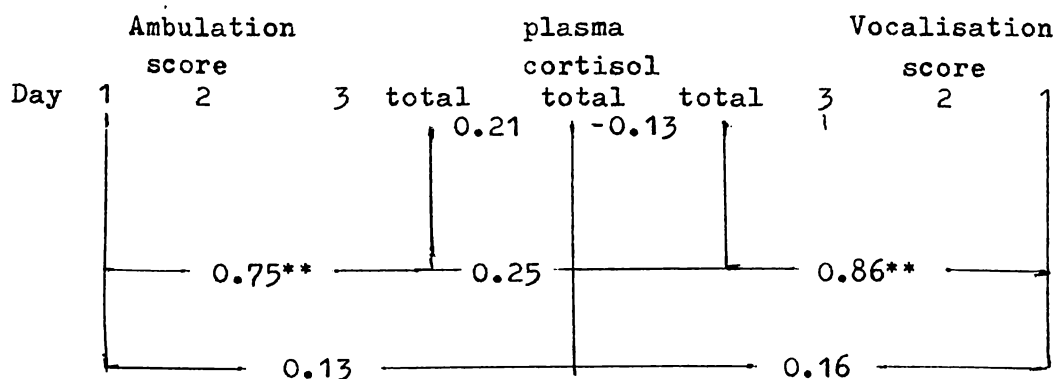
Correlations. Day 2 ambulation v plasma cortisol = 0.00

Day 2 vocalisation v plasma cortisol = -0.27

Level of significance:

when N = 30 5% level * = 0.36; 1% level ** = 0.46.

(a) Open-field results from 30 experienced experimental sheep.



Correlations. Cortisol levels, pre-test v post-test = 0.03

Cortisol levels, difference v post-test = 0.88**

Level of significance.

when $N = 15$ 5% level $*$ = 0.51 ; 1% level $**$ = 0.64.

(b) Open-field results from 15 naive ewes.

than the ± 0.3 micrograms which was the level of reliability of the spectrofluorometric test used, and 11 animals showed gains. When the pre and post-trials are subtracted and these differences are ranked and this is compared with the rank of the post-test score, a correlation of 0.88^{**} is obtained, significant at the 1% confidence level. No other significant correlations were found. No relationship between the levels of plasma cortisol and the overt behaviour of the sheep in the open-field could be established. Neither were the ratings of the scorers, using a 1 to 5 scale according to how excited or fearful the sheep appeared to be, significantly correlated with levels of blood cortisol. These ratings tended to be based on the speed with which the subject moved and the patterns of startle reactions given by the sheep to various features, such as the corners of the arena.

Although it is clear that the ambulation and vocalisation scores were both showing an increase over the 3 days of trials, a characteristic which distinguishes the sheep from the cow, this is not reflected in the physiological measurement of stress which was taken during the trials, i.e., the level of circulating plasma cortisol.

The possibility still remains that the defecation response of the sheep might reflect their "emotionality". It is difficult in a short objective sample of behaviour to ascertain this

reaction properly unless special bags were fastened to the animals to collect the faeces, or a hard floored testing arena was available from which droppings could be counted or weighed. Such bags could be used in future studies though they will need to be attached to the subject as it enters the arena. From numerous attempts of other workers to relate open-field scores to plasma corticosterone in rats it can be concluded that provided the early experience of the animal has been adequately manipulated, discernible and significant differences can be obtained, between control and experimental groups. In these studies the level of circulating corticosterone has been positively related to both defecation incidence and ambulation scores after the day 1 test in the open-field. (Levine et al. 1967). With only one day's testing in the open-field the ambulation results were not statistically significant (Hess et al. 1969). Severe stress, such as shock however, provided higher levels of plasma corticosterone 15 minutes after termination of the shock for rats that had been handled in infancy compared with controls (Levine, 1962). The adequate sampling of the corticoids poses a problem of design. If only a 3 minute period is used in the open-field then the responses of the mechanisms are barely perceptible, but if the animal is maintained in isolation for a further period before blood is taken this will add an additional stress factor arising from the isolation or strange environment

in which the animal is being held. In our case if the sheep were placed back in the flock for a set interval the group had to be disturbed again for the sampling procedures. Later experimental work with rats partially avoids this by placing the animals to be assayed back into the home cage for a pre-determined period of time.

In a recent summary, Denenberg (1969) discussed the validity of the open-field test as a measure of the construct of emotionality. His reasoning was as follows: "If the open-field performance does measure emotional reactivity, then a relationship should be found between open-field performance and some measure of adrenal physiology". He expected "high activity scores, low defecation scores and low adrenal steroid levels to be associated" p.856. With 4 days of testing in the open-field, 36 rats were sacrificed after each day's testing. The results from the plasma corticoid assays paralleled the scores for defecation and the scores for ambulation after day 1. Denenberg admitted that the interpretation which he draws is only related to work within the general area of early experience research.

Ader, (1969) attempted to make this validation more general and substantiate the relationship between "emotionality" and adrenal activity. Anderson and Anderson (1938) using adrenal weights and Pare and Cullen (1965) using Adrenal Ascorbic Acid depletion reported insignificant correlations between these 2

scores. Ader found that the elevation in plasma corticosterone levels in response to open-field testing is greater when the testing stimulation is carried out during the trough rather than the peak of the 24 hour corticosterone cycle. After testing rats in the open-field for 4 days at intervals of 1 week he found no evidence for the behaviour changes which occurred being paralleled by changes in the plasma corticosterone levels. His general conclusion was that 'if one conceives of "emotionality" as a characteristic of behaviour related to the activity of the adrenal cortex then the open-field test does not measure "emotionality"'. If the concept that "emotionality" is measured by the open-field test is retained, then one must reject the assumption that such a behavioural characteristic is related to adreno-cortical function. It is fair to state that adrenal response to the environmental situation reflects to a degree an "alarm reaction". Such a reaction might be only one of the facets of "emotionality" being evoked in the open-field test.

Within the rather limited investigations carried out in this study it seems clear that our attempt to relate behaviour from the open-field test to plasma cortisol levels has not been successful.

Open-field scores : Pigs.

Although the only extant literature dealing with large domestic animals in the open-field concerns the pig it is very difficult to select and record suitable behavioural indices for this species. Vocalisations are almost impossible to record and assess without sophisticated equipment and then probably only the intensity and duration of squealing would be suitable. The defecation response is as difficult to record for the pig as for the sheep. This leaves the ambulation score and, perhaps, time spent rooting or gnawing. With our outside arena we found that even the ambulation score for pigs was not satisfactory as 25% of the subjects tested lay down after varying periods in the open-field and could not be easily aroused. Some pigs lay down after 1 minute.

This experience of performance in the outside arena, together with the difficulty of obtaining temperament assessments for the pigs tested, means that apart from the species-specific behaviour which was shown by some of the subjects during open-field orientation of the pigs to the closed-field test, the data gathered has little meaning for this part of the study.

Squares broken by pigs, excluding those animals which refused to ambulate, ranged from 37 to 104 on day 1 and dropped to 34 to 70 on day 2. The daily average follows the pattern of the cow

rather than the sheep with a steady decline over the 3 day period. (Day 3 results are rather few in number but the trend is clear.)

As an observer assessing the behaviour of the pigs in the open-field it seems that these animals appear least upset of the 3 species studied. Although 10% of the pigs ran squealing between the entrance gate and the corners of the field, 30% moved very slowly, poking into the corners and making few vocalisations at all. A full discussion of pig behaviour will follow in a later section.

General Discussion

After a consideration of some of the procedures used in past studies to assess temperament in farm animals it was hoped that the open-field test might provide a number of objective behaviour scores which could be used and standardised, as indices of temperament. A number of problems have become apparent as the practical trials have proceeded with sheep, cattle and pigs.

Although 3 scores can be reliably recorded for cattle; i.e., ambulation, elimination and vocalisation, only 2 of these are possible for sheep and without considerable refinement of the recording equipment only an ambulation score is of practical use for pigs. Even in this case the use of an outside arena during warmer weather meant that pigs were fairly inactive and preferred to rest rather than ambulate in the open-field even on the first day of the trials. The shavings on the floor provided a suitable bedding material for resting pigs. The elimination score, which seems in rats to be the most reliable day to day index of "emotionality", is difficult to score in both sheep and pigs.

The correlation between the daily scores for any one of the parameters measured are in general related at the 1% level of confidence for both sheep and cattle, but the inter-relationships between ambulation or vocalisation with the elimination scores are not significant. For cattle, ambulation and vocalisation

scores on day 1 were correlated. Attempts at independent assessment of temperament either by experimenter ratings or the use of a physiological index of stress did not correlate significantly with any of the behaviour scores from the open-field test. It is of interest to note here that the factorial study of Whimbey and Denenberg, (1967) indicated 2 distinct factors of "exploration" and "emotional reactivity" involved in ambulation which were not inversely related functions of some single continuum such as "response to novelty" or "response to isolation". In the rat, as well as the cow and sheep, it seems that in a novel environment the subject is motivated by its exploratory tendencies, its "emotionality" or emotional reactivity, or by both. Both ambulation and elimination had to be considered over several days of testing to provide conceptual meaning for open-field performance in the rat. The position of day 1 points of entry and exit influence the subsequent days' performance, particularly in cattle.

The scoring of the eliminative response, even for cows, provided us with certain problems as the disturbance of settled animals prior to testing in many cases led to the first dunging and this might occur several times before the animals entered the arena. With sheep and pigs the possibility of accurate recording at distances of up to 60 feet from the subject, even

with 2 independent observers, proved unreliable. Certainly sheep under stress, such as those which are cast, provide copious amounts of faeces under these conditions.

Two problems must concern us at this point; the responses most appropriate for the species concerned and the design of open-field apparatus which will provide the most accurate behavioural scores without prejudicing the results with the experience from the previous days. Sheep, cattle and pigs, from their ambulation scores over the test period, provide evidence of the influence of the points of entry and exit from the open-field arena on the ambulation pattern of the subject on the second and third day. If it was decided however only to score the animal on the first day, then confounding factors could occur as with rats (Whimbey and Denenberg, 1967). Any arena with corners, or with set entrance and exit points, must have this influence on domestic animals which are familiar with gates and yards. It is not possible with such large subjects to place them by hand in certain positions in the open-field or to lift them out to avoid predisposing the spatial orientation of the animal concerned.

The first of these problems has been considered for a number of other species by Candland and Nagy (1969). They ask whether "species probably differ in the display of their characteristic

syndromes of emotionality". They studied 10 male squirrel monkeys, 12 adult cats and 4 kittens and 140 white Leghorn hens as well as rats and mice. The monkeys did not defecate and showed a wide variety of ambulation from subject to subject. Cats do not defecate and the ambulation pattern appears to be exploratory in that it covers the entire field. They also vocalise. The hen shows an increase in elimination with age and a characteristic freezing response on being placed in the open-field. This is followed by increased activity during the trial. In hens, vocalisation is most frequent in younger animals. They concluded that the types of behaviour most sensitive to a change in "emotionality" in each species must be determined. They also found that heart rate and defecation scores in rats did not correlate significantly during the open-field trials. When discussing the results from cats they suggested that the arena should be designed in a circular form with top-loading for entrance rather than the square or rectangular field with set entrance and exit points. Such a field for the farm animals would be both costly and of little use for other experimental work.

Although the defecation response of the cow appears to follow any disturbing influence it was noted that 35% of all the cows which defecated in the arena did not do so haphazardly at all. In these cases the animals sniffed old dung pads and moved to the new

ones and began pawing the shavings. During this period they also defecated and continued pawing. Of the 3 suggested functions of the defecatory response of animals in the open-field; i.e., (a) defecation in a novel situation because the situation is fear-provoking; (b) defecation in a strange arena to establish territorial rights or (c) defecation in order to give the strange area an odour which is familiar to that subject, this type of defecation pattern might fit patterns (b) or (c) rather than being an autonomic response.

The suggestions made to link ambulation to "emotionality" also vary. Animals may be active and explore until fear decreases, or fearful animals may explore little until fear decreases. Thus less fearful animals explore more than animals which experience greater fear. One case of freezing behaviour has been described during this study when a cow confined itself to one, 12 foot square, during the total trial period and had to be pulled by force from the arena. However, in general the cows moved about very freely and gave every appearance of exploring the environment. Sheep seem to be affected by isolation more and show an increase in both ambulation and vocalisation scores during the 3 day test period. It seems clear from the longer trial with 15 animals that modification of the test procedure to include a five or six day sample of the be-

haviour of sheep would be appropriate for this species. The rapid decrease in score averages with cows and pigs indicates that the 3 day test procedures are adequate. These suggestions are in agreement with Candland and Nagy (1969) who consider that procedures must be changed to sample the types of behaviour patterns most sensitive to a change in the "emotionality" of the species. Table 28 shows a summary of some of the tested characteristics of open-field behaviour of different species tested, including those of this study.

The domestic stock, in contrast to the laboratory animals, derive directly from herd or flock animals and there is a strong social component under normal farm management practices. The essential social nature of the sheep and its reactions to isolation in both the open and closed-fields cannot be discounted when discussing the procedures to be adopted for testing large animals. The performance of the first and last animals of any groups can be seriously biased because of this social factor. The vocalisation score may directly reflect the reaction to isolation. Unless the subjects are to be tested indoors or to have their hearing limited by some means then this social vocalisation cannot be eliminated from the test situation, nor should it be when the temperament of farm or flock animals is under study. It is however an exceptionally difficult variable

Table 28 : A summary of the characteristic open-field behaviour of different species tested (adapted from Candland & Nagy, 1969)

Species	Defecation	Ambulation	Other measures
Monkey Squirrel	none	highly variable with individuals	
Cat	none	higher in the young than adults	Vocalisations, high in kittens; decrease in a- dults with repeated testing.
Hens White leghorn	increases with age	freezing; greater with older hens Increases with repeated tests	Distress calls decrease after age 15 days
Rat Wistar albino	increases with age; decreases with repeated tests	increases with age	No vocalisations
Mouse (C3H)	increases with age; greater in females. With repeated tests increases	increases with age, decreases with repeated testing.	No vocalisations
Hamsters* golden	None or little shown	greater in fe- males than adult males. Greater in weanlings than adults.	Grooming, sniff- ing and rearing
Sheep, Romney	difficult to determine	increases with repeated test- ing till day 6-8	Vocalisation. Increases with re- peated testing till day 6-8
Cow Jersey	variable among subjects and from day to day.	decreases with repeated tests	Vocalisation. Decreases with repeated tests.
Pig Large white	difficult to determine	highly variable among subjects. Varies with seasonal changes	Vocalisation. Highly variable among subjects

*Based on studies by Swanson (1966) and Jowaisas (1969).

to control and even large amounts of "white noise" would not provide a satisfactory solution. The vocalisation of cows can travel over long distances. It seems clear from this study that 2 types of calls must be distinguished; (a) those emitted as a response to a call from an area external to the arena and (b) those given in response to the experimental test. This matter must receive more attention in further refinements of the apparatus and procedures.

When considering the background of cattle, familiar with yards and enclosures as well as more open spaces, the open-field test is not to be thought of as more than a novel environment. Before the test is abandoned as unsuitable for testing the "emotionality" of both cows and sheep, ways should be found of increasing the strangeness of the arena. A number of possibilities suggest themselves from the casual observations of cattle under a variety of circumstances. The introduction of a jumping mechanical object or a slowly rotating wheel will need to be investigated. A slow-moving, dog-like, object could be considered. This should greatly increase the sensitivity of the test and provide better discrimination among dairy cows which have been culled for a number of generations on the grounds of "temperament", and which are handled twice a day for most days of the year.

Our experience casts some doubt on the practice of taking apparatus developed for the rat and scaling up such equipment for the testing of large animals. The recent use of the open-field in a number of pig studies (McCann, 1966) as a test for Denenberg's hypothesis, (1964) of the monotonic relationship between the effects of early experience and subsequent emotionality in adulthood, without more preliminary study of the open-field test in use with pigs, seems to be unjustified. Many more wide ranging studies should be encouraged which explore the species-specific reactions of larger social animals in well designed apparatus. As yet Broadhurst's statement (1969) cannot be fully substantiated. He wrote, "the open-field test has played a long and honourable part in the relatively short history of comparative Psychology. It has been in use for 35 years and has now reached a status of a relatively standardised instrument in animal psychology along with the Skinner box, escape-avoidance conditioning and some of the standard maze patterns. All of these can give results which may be replicated in different laboratories." p.806. For the rat, and perhaps the mouse, this may be true, but for other species of importance to man very little work has been done with a view to standardising procedures and results from the open-field test. In fact, as Table 7 indicates, one must seriously question whether size, procedures, age at testing and other variables involved in open-field testing for rats have been adequately standardised.

The importance of an objective assessment of the temperamental characteristics of cattle in particular, remains very high on the list for behaviour studies in the field of practical agriculture. Further refinement of the open-field test should be attempted before this method is abandoned. The availability of monozygotic cattle twins both to aid in the validation of the open-field test and to be used for early experience studies once the test for "emotionality" has been standardised and made objective, provides great scope for future work. The calculation of twin indices for behaviour shown in the open-field in this study however, is of a low order. It is rather similar to the index for urination as calculated previously by Hancock (1954). At present, for open-field work, one pair of twins would only replace 3 cows drawn from a non-twin group of animals. The open-field does provide a better assessment of the capacities and behaviour of monozygotic twins than field observations as it eliminates the component of "imitation" in activities such as urination, defecation or grazing.

The Closed-Field Test.

After each subject had been tested in the open-field for 3 days it was given further orientation to the apparatus for the closed-field test. The groups of animals to be tested were run through the field four times on the fourth days. They were driven in a mob through the arena and round back through the return raceways. Food was left in the food box and many of the animals found it during this period. Gate E was alternated after each run so that they had experience in both the food boxes. As the food boxes were against the middle panel it was on the left of the animal in one run and the right in the other. After 4 complete cycles the subjects were left for a short time in the finish pen and then they were all returned to their holding area where the remainder of the daily rations were fed. After 2 more days without food, on Monday, each individual animal was given 5 runs in the open arena with food provided and the next day the A to F training series was begun with 9 runs per day per animal.

Sheep, cattle and pigs all reached the standard criterion of 8 correct runs out of the 9 on day E and F of the training period; i.e., within the first 6 days, but dogs required an extra day. The one cat tested so far reached criterion within the 6 days.

Initially the start gate A was always lowered but it was found that this provided a serious interruption to the smooth return flow of the animal. After this the start gate was always

left up unless the animal turned to retrace its steps after entering of the arena. This was a modification made to accommodate the larger animals and meant that no latency of entry score was feasible in this study. Radloff (1964) had already designed a similar type return raceway for rat work which incorporated non-return gates.

Group I (sheep) and Group II (cows) were only run on problems 1 to 6 but all other groups were run on the full 12 problems. In general, the weather was reasonably clement during the 3 year testing period. As Pollard had only utilised problems 1-6 for all the species he studied, the analysis and discussion of the closed-field data will be undertaken in 2 groups; i.e., the results of problems 1 to 6 and problems 7 to 12.

During the early training runs, up to one hour was required for each pair of animals to complete 9 runs and it was these slow times which were critical in determining the size of the experimental group which could be tested. In contrast to this the running of some of the simple visual test problems required as little time as 10 minutes for 3 animals. Several minutes were required for raking the shavings after each group of animals had completed their daily trial, before the next group could be run. The fastest time for the completion of a run was 5 seconds by a pig though the dogs ran consistently rapid trials.

Cattle in the closed-field test

Table 8 shows the time of year when the trials with cattle were conducted. Every attempt was made to test the dairy cows well before the expected calving date. In no case did a cow calve during the trials. The cows were kept in groups of 6 or 7 in small, wood shaving covered, enclosures between trials. The groups were kept small to prevent subdominant animals being continually harassed by more dominant animals in the holding areas. Only a few of the animals tested were rated as 5 on the temperament scale (see page 134) but these animals broke a number of gates and railings during the early training trials. These excitable animals were returned to the dairies, after 3 weeks of testing in the closed-field, as much more amenable animals. Consequently, after the first experimental group of cattle there was willingness to allow stock to be tested during the non-lactation season, to improve their reactions to handling.

During the tests 2 cows were fed in the goal boxes side by side for a short period but each animal was isolated during its time in the closed-field. Cows tolerate this treatment much better than sheep and in general they settled into the experimental routine with the minimum of difficulty. Many were hesitant to move out of the arena into the goal boxes in the early training period but the smell of hay and the presence of the other animals in the adjacent stall helped to overcome this

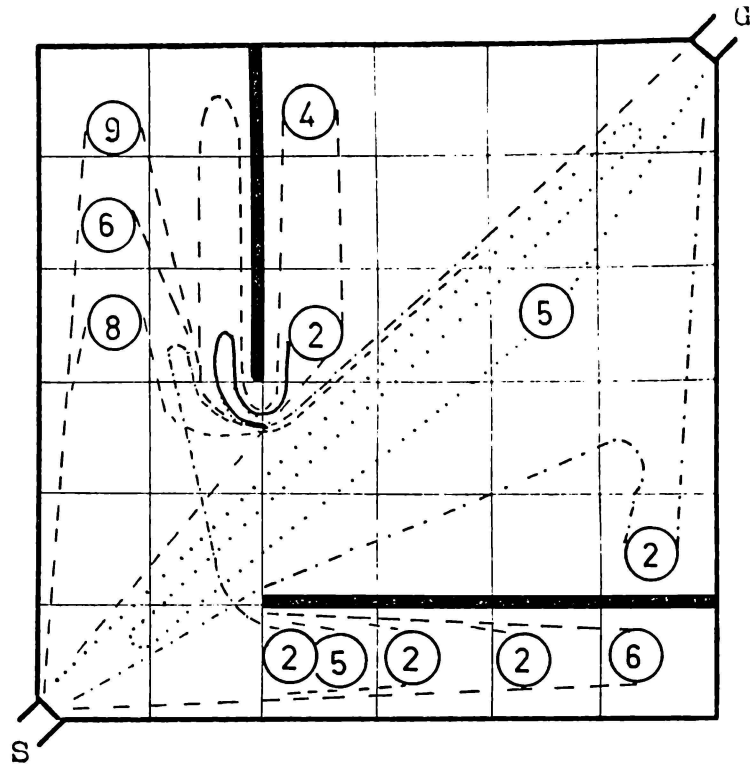
difficulty. There were 7% of the cows who ran the last portion of each run after the final baffle had been passed. Although 1 or 2 cows did not flow well in the return raceway, the majority moved back to the starting gate without coercion after the training trials were complete. Several times a cow was delayed at the start gate as she bellowed to cattle in the herds approximately half a mile away.

Dominant cows harassed other subjects in the small-sized holding yards during the trials, but these animals were given their trials early and moved into large pens as quickly as possible. In general, from the experimenter's point of view, the dairy cow can be recommended as a very amenable experimental subject which, within a few days, settles well into the experimental routine.

Following the daily trials, error and time scores were entered into the raw data sheets and the pathway data were filed for further analysis. As the cows showed the lowest average total error score for the 3 species tested, full examination of the typical pathways taken by cows for each training and test problem was made. The pathways and number of cows in error for each path (shown in circles) for the training problems A to F are shown in Figures 22, 23 and 24. Several comments are pertinent from a study of these figures. On the first day, 5 cows were reluctant to move into the goal box and fully retraced their steps to the point of entrance to find the gate was closed.

training
problem

A



training
problem

B

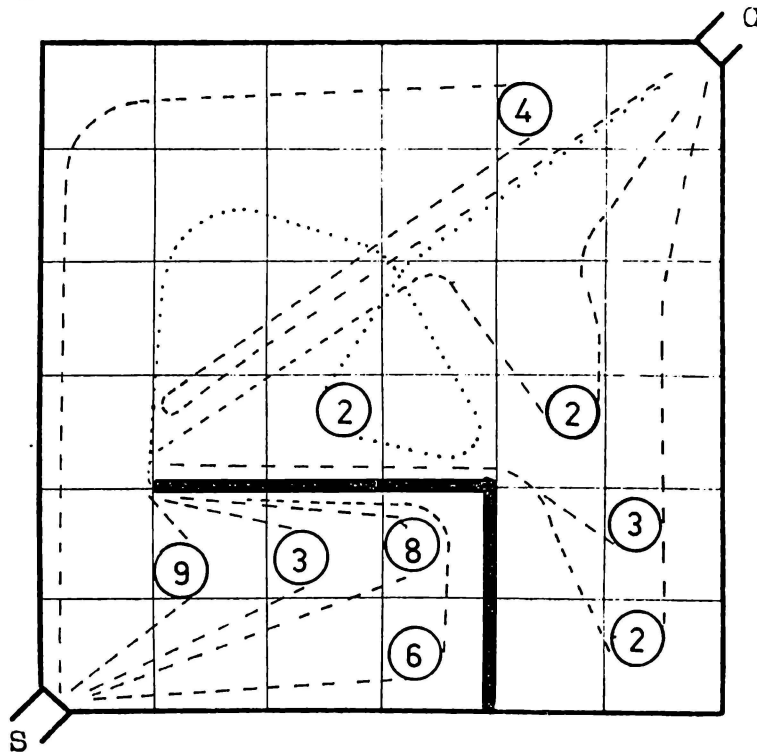
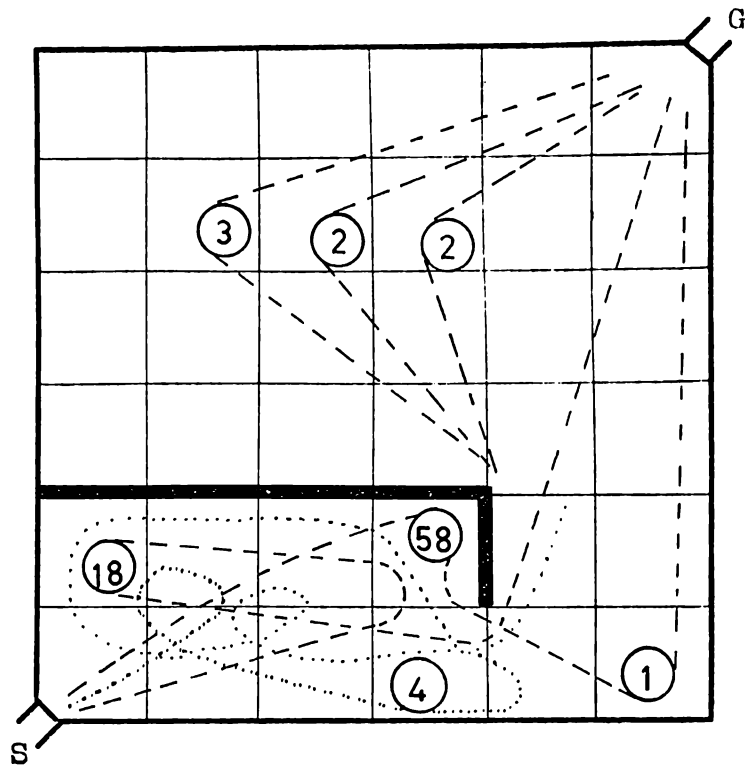


Figure 22.

Pathways taken by cows in training problems A and B in the Closed-field Test. The numerals in circles indicate the total number of cows which took that error pathway.

training
problem

C



training
problem

D

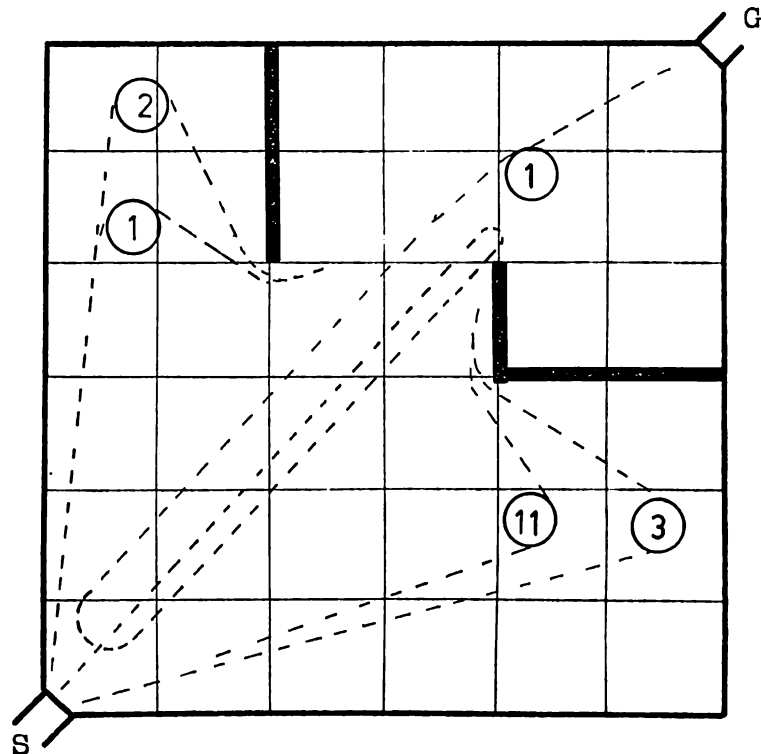


Figure 23.

Error pathways taken by cows in training problems C and D of the Closed-field Test. The numerals in circles indicate the total number of cows which took that pathway.

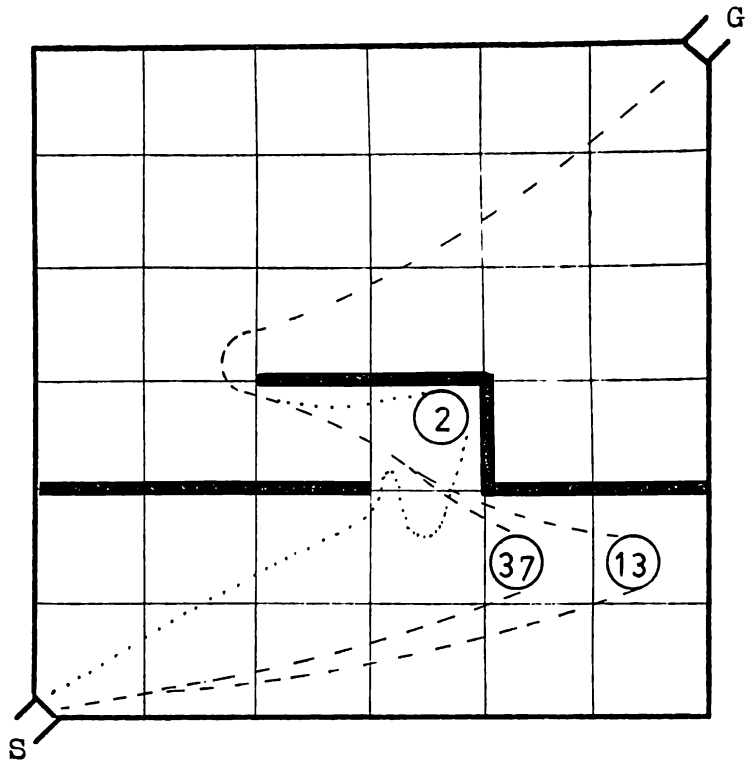
One cow still did this by training Problem D. Six animals exemplified this back-tracking of pathways on Problem B. The number of cows entering the cul-de-sacs behind the barriers dropped from 40 on day 1 to 31 on day 2; 17 on day 4 and 17 on day 6. The most difficult days for the subjects were days 2 and 3. On day 2 the test required a veer to the left. Marked reluctance to move into the goal box was apparent. On day 3 the cows were required to go right. Repeated attempts were made by all the species tested to find the gap for the day before and 80 animals found this transition rather difficult to make.

In general, it is considered after testing these numbers of large animals, that the Rabinovitch and Rosvold training problems are well designed and provide training in the basic skills and modes of orientation which will be required of the animals during the test series. The general popularity of these for the training trials by so many investigators (see Table 6) is additional evidence of their satisfactory nature.

By problems E and F all the cows tested could run 8 correct runs even if they moved off the shortest path for the first run. By this criterion they were ready for the test series after the first complete cycle of the training problems. All the pigs tested also met this requirement as did all but two of the sheep. The majority of the dogs required an additional day; i.e., Problem E was not easily mastered and took many of the

training
problem

E



training
problem

F

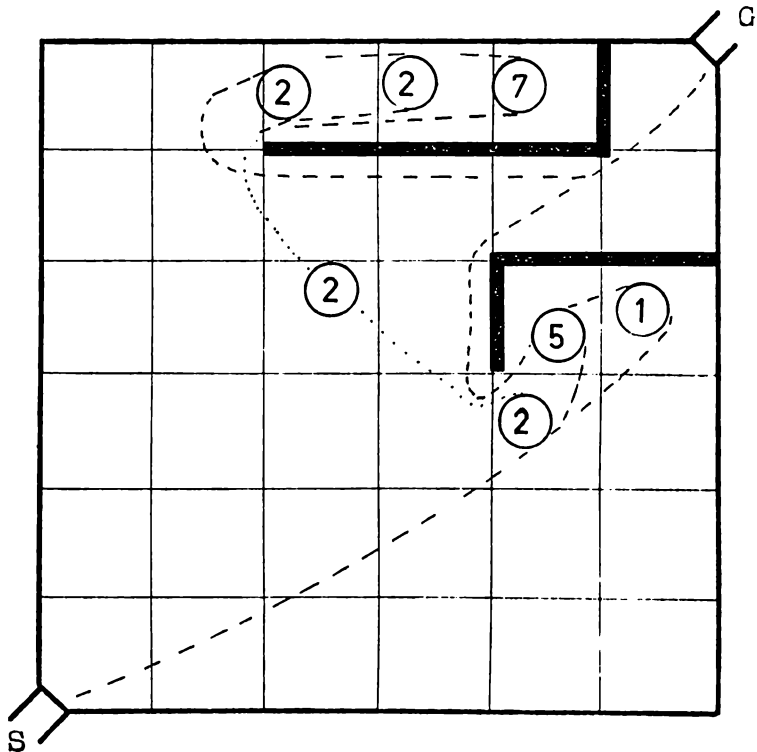


Figure 24.

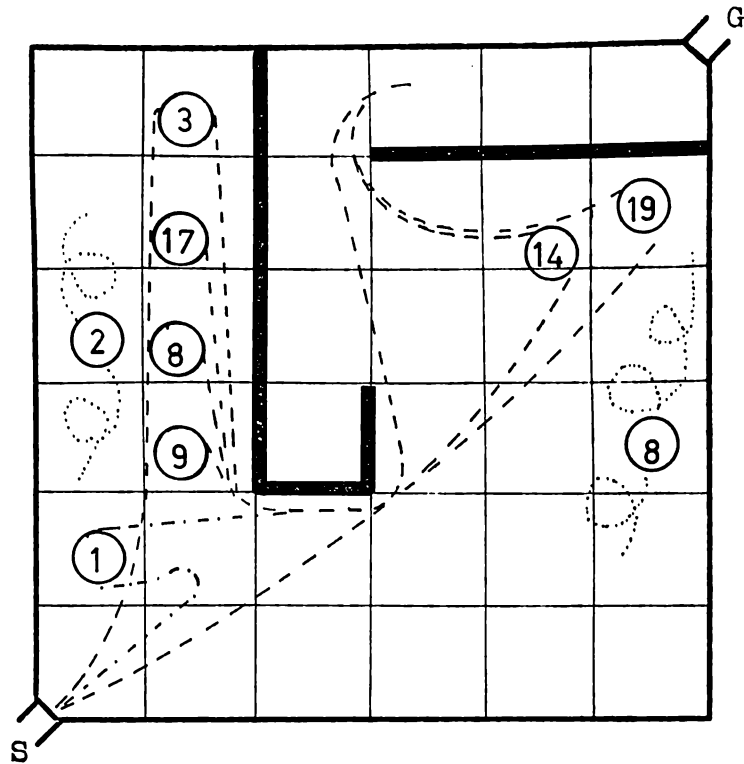
Error pathways taken by cows in training problems E and F of the Closed-field Test. The numerals in circles indicate the total number of cows which took that pathway.

dogs 2 runs before the shortest path was taken.

Fourty-four percent of the cows proceeded through the first trial of the test problem 1 without error. In no other first trial of the problems (1-6) was this performance equalled. Only 12% of the cows committed more than 10 errors on their first attempt at this problem. Ten cows performed as though they were misoriented when finding themselves in the 2 possible cul-de-sacs of this problem and they are shown in the diagrams by circling dotted lines. Only 1 cow of the 73 tested committed more than 50 errors. Another interesting trend became apparent during test problem 1, i.e. in "blinds" away from the area adjacent to the goal area, cows turned back and retreated when within approximately 20 to 24 ft. of the dead end. In test problem 2, twice as many cows avoided the blind near the goal box area at approximately 20 ft. as crossed the last 12 ft. square. Although the pathways do not show this aspect of behaviour as clearly as the observations at the time of the trials, cows on entering such blinds in most cases hesitated or stopped temporarily either before turning back or proceeding to investigate at a closer range. At this same point several days later, 12 cows avoided entering this blind at all. No more cows made more than 10 errors in the first run of the non-visual form of this problem than of its visual counterpart.

All cows tested corrected their path of the shortest route during the eight runs. This was not the case with every sheep

test
problem
1



test
problem
2

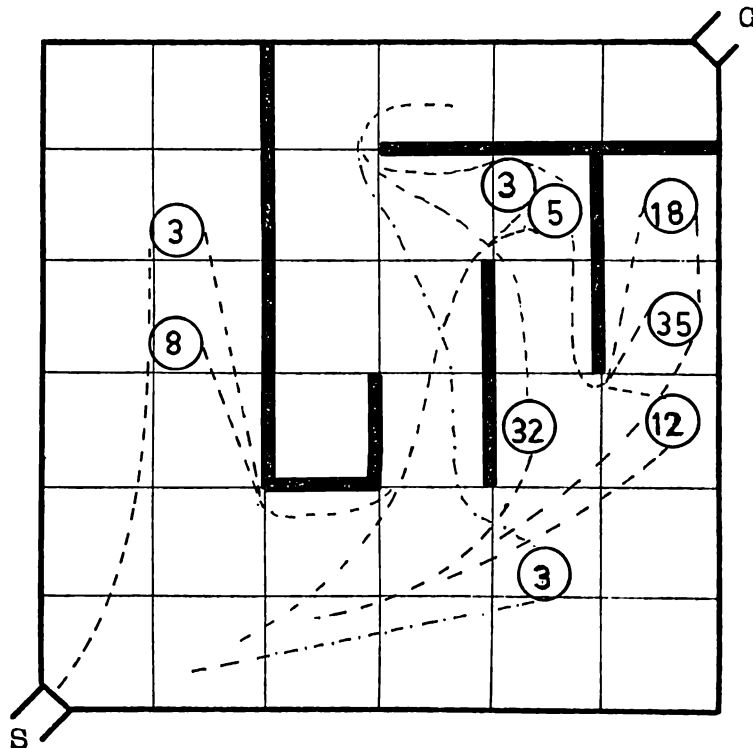


Figure 25.
Error pathways taken by cows in test problems 1 and 2 of the Closed-field Test. The numerals in circles indicate the total number of cows which took that pathway.

or pig. Two or 3 animals of these species continued to flow around the first baffle, following the essential path of the 32 cows, throughout the complete trial. Another comment to be made on the pathway diagram of test 2 is the difficulty subjects had in eliminating blinds in the direction of the goal box in comparison with those leading away from the goal. (see Fig. 25)

It is of some interest to note that only 7% of the cows could run without error through the visual problem 3 on the first run. This problem takes the animals away from the "expected" diagonal pathway. Some cows persisted in moving along the diagonal and going almost to the corner right through to the 7th run. However most cows avoided the corner from a visual distance of over 30 ft. In contrast to the sheep, which found it very difficult to travel in straight lines, the majority of cows could travel directly from the entrance gate around the end of the barrier without committing an error.

Problem 4, the non-visual counterpart of problem 3, took 50% of the cows into the 6 error category on the first run but this dropped to 2 errors on subsequent runs. Only 1 cow remained seriously confused after the first run on this problem, making 28 errors on run 2. 22% of the cows took a 2 error pathway up until the fourth run on this problem. (see Fig. 26)

Problem 5 is solved by a central route, yet 71% of the cows tested moved behind the barrier shielding the goal box and

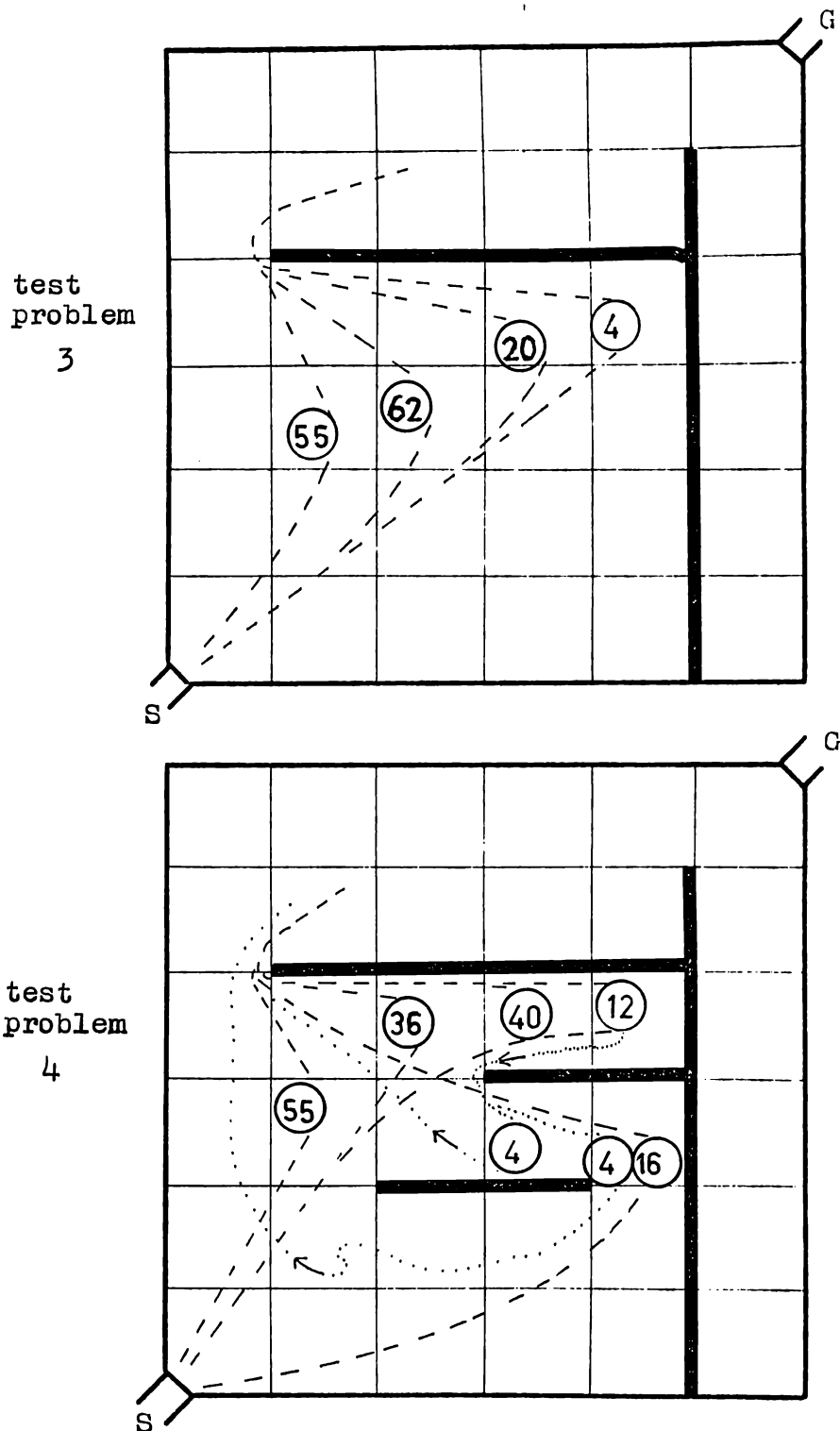


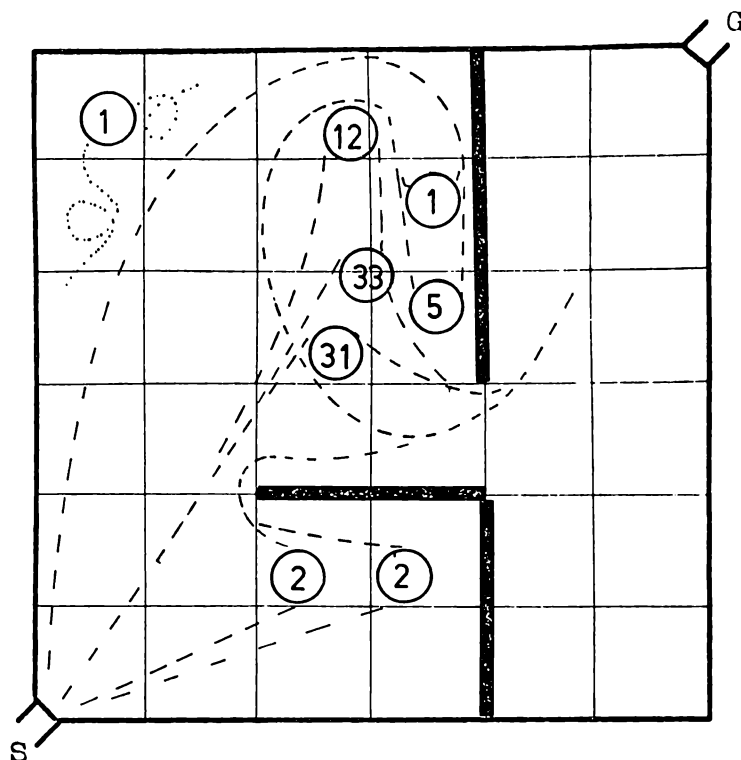
Figure 26.
Error pathways taken by cows in test problems 3 and 4
of the Closed-field Test. The numerals in circles
indicate the total number of cows which took that
pathway.

committed at least 4 errors. Only 6 cows of the 73 made a perfect run. Virtually all serious errors were eliminated in this problem after the first run. Overall, this problem was the easiest for most species tested. (see Fig.27)

Problem 6, its non-visual counterpart, proved to be a rather complicated problem in the first run but was quite quickly learnt. Eight to 12 errors were most commonly committed on the first run though 14% of the cows made a perfect run on the first trial. In many cases these animals made serious errors during the second run after missing the correct pathway. This problem also has the distinction of being completed perfectly by every subject on run 5. In every other run in problems 1-6 at least 1 animal made an error. The pathways taken by animals on this problem tended to be very complicated and a number of animals became quite distressed, vocalising and pushing against the barriers during the first or second runs.

Despite the apparent simplicity of problem 7 for the human observer, this problem caused the most difficulties for the majority of animals of all species tested. More cows made errors in this problem than any other and the 91 cows making the 2 errors shows how difficult it was for the subjects to make a straight path from the entrance to the corner of the major barrier of five protruding baffles. At least 9 cows made errors on this problem in every one of the 8 runs during the test indicating that it was also the most difficult problem to master. Eight animals became completely disoriented as shown by the dotted circling tracks.

test
problem
5



test
problem
6

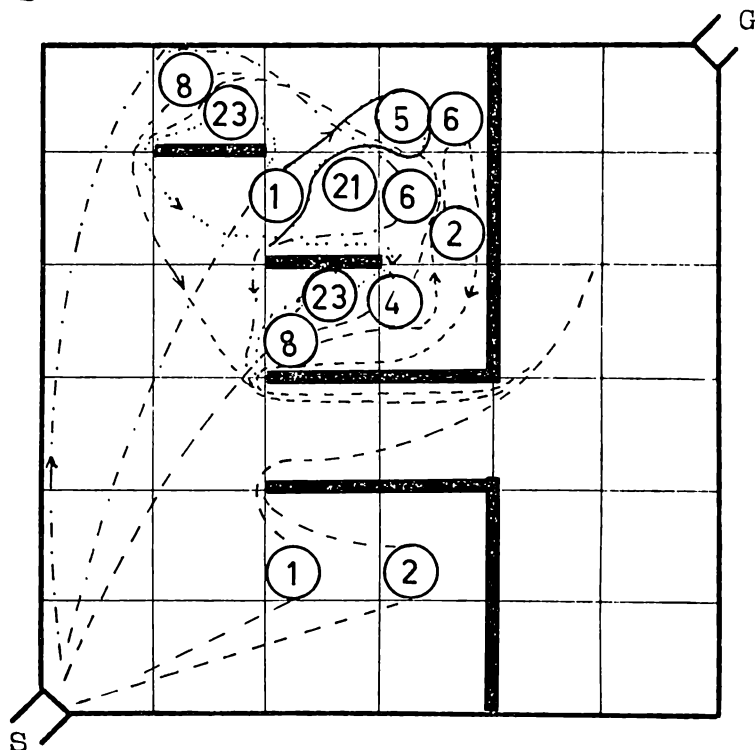


Figure 27.

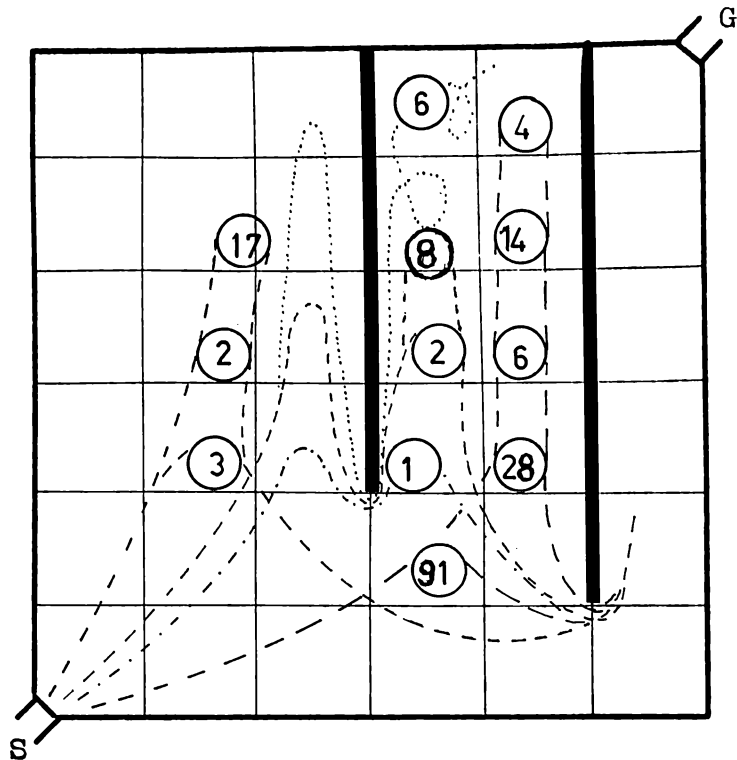
Error pathways taken by cows in test problems 5 and 6 of the Closed-field Test. The numerals in circles indicate the total number of cows which took that pathway.

In general, the first movements of the animals towards the goal box being frustrated meant that they retraced their steps behind the central baffle and moved back and forward in a very stereotyped manner between either side of the central baffle until finding the solution. (see Fig. 28)

Problem 8 is the most complicated but proved easier to solve. After moving into the central blind most animals explored the other area but on the return many were able to try the alternative gate and thus solve the problem. Twenty-one cows made error scores greater than 30 over the first 2 runs. However, very few cows continued to err after the third run. The red lines between the 2 blind areas on the diagram indicates the number of cows which traversed between these 2 points, e.g., 7 cows entered one square into the goal direction blind before turning and moving back to the other blind and going 2 squares in before retracing their steps again. Another 7 animals made maximum penetrations into both cul-de-sacs during solution of this problem.

In problem 9 although a relatively simple visual problem, many cows began in the wrong direction, probably following the path of the previous day. Most of these animals turned back at distances between 22 and 30 ft. from the wall. In the non-visual problem 10, 1 cow committed 74 errors and 6 became disoriented in the blind near the start gate while 2 did so in the cul-de-sac near the goal box. All cows had mastered these 2 problems, 9 and 10, by the last run. (see Fig. 29)

test
problem
7



test
problem
8

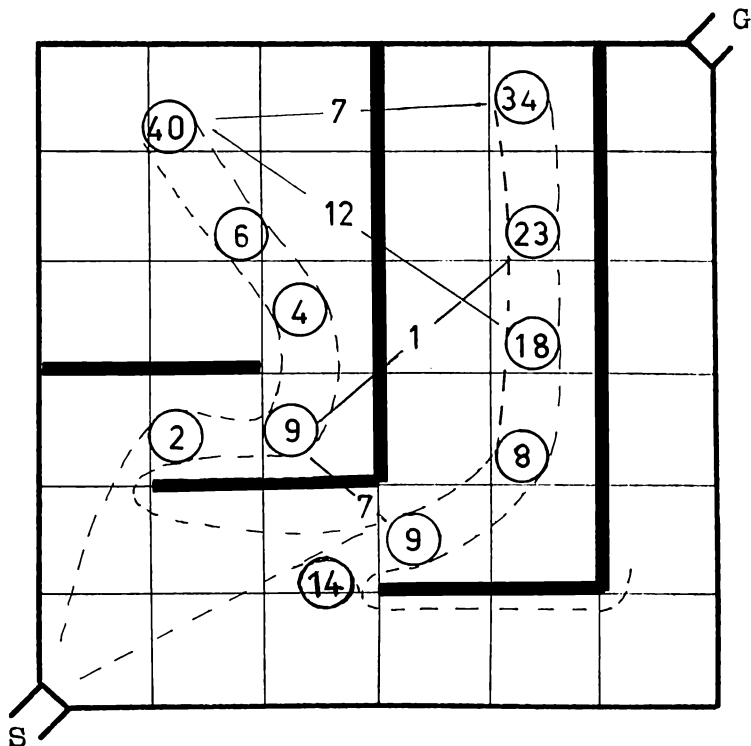
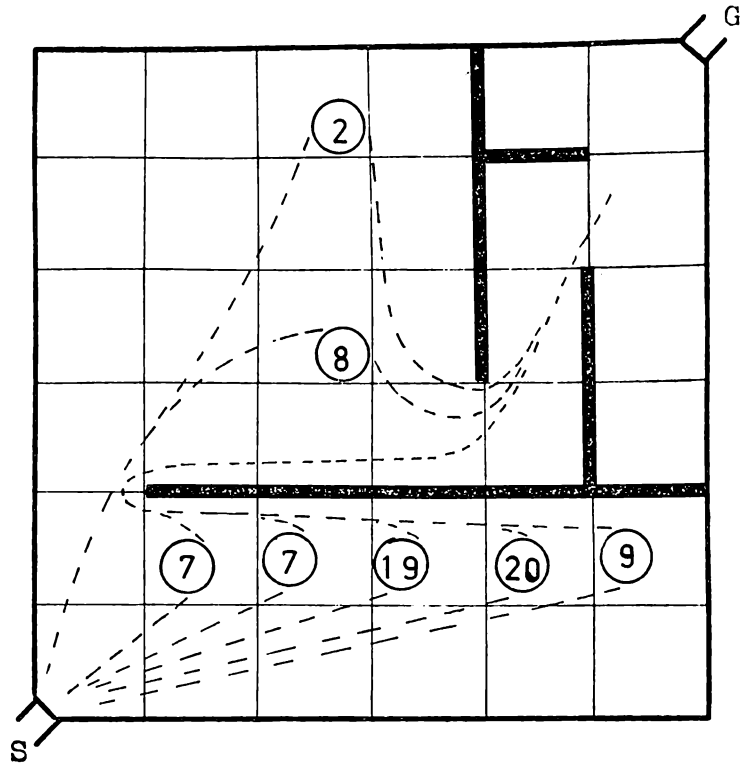


Figure 28.
Error pathways taken by cows in test problems 7 and 8 of the Closed-field Test. The numerals in circles indicate the total number of cows which took that pathway.

test
problem
9



test
problem
10

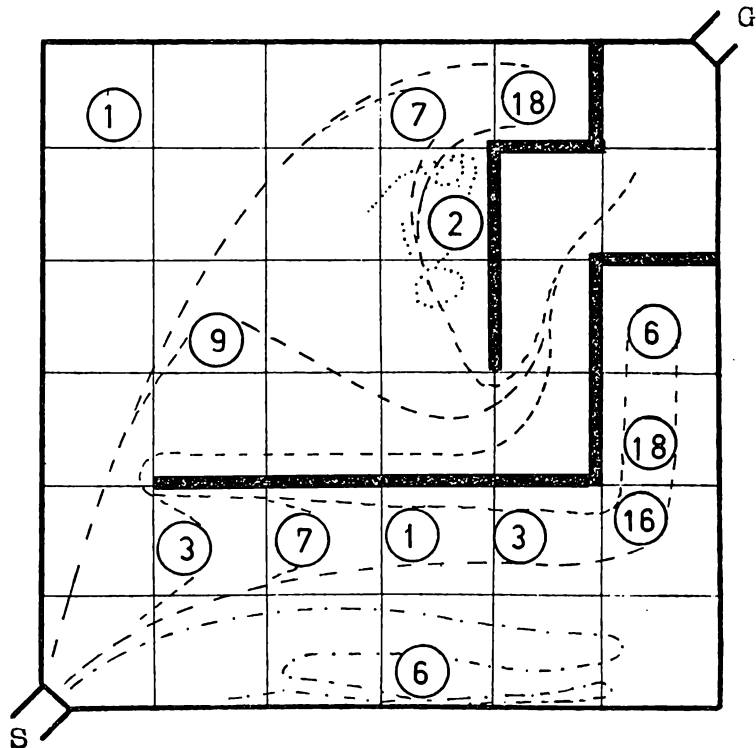


Figure 29.

Error pathways taken by cows in test problems 9 and 10 of the Closed-field Test. The numerals in circles indicate the total number of cows which took that pathway.

Problem 11 was solved perfectly by 30% of the cows on the first run, yet 7% made over 50 errors on the same run. Eleven of the 59 animals tested were seriously disoriented in the corner near the goal box and spent considerable time attempting to "find" a way through in that corner and returning to it repeatedly. (see Fig. 30)

In problem 12, though the majority of animals made directly for this corner they tended to flow on and in a few cases cows were tracked moving round and round the central three-baffle barrier. Many of the cows found themselves missing the correct path on the second run and getting in behind the detached barrier for some distance before retracing their paths.

From a visual examination of the pathways for each problem it is clear that a visual problem presupposes a rather uncomplicated problem and these present few difficulties to the large domestic cattle unless they take the animal to one of the corners well away from the central diagonal pathway. If the animal is to be tested in a way that will sample its full detour performance, the pathway of each succeeding day must fall in a different position to that of the day before. This supports the logic of our original problem selection. It also necessitates a fixed order of problem presentation, though each animal group could well begin the series at a different stage of the sequence. The

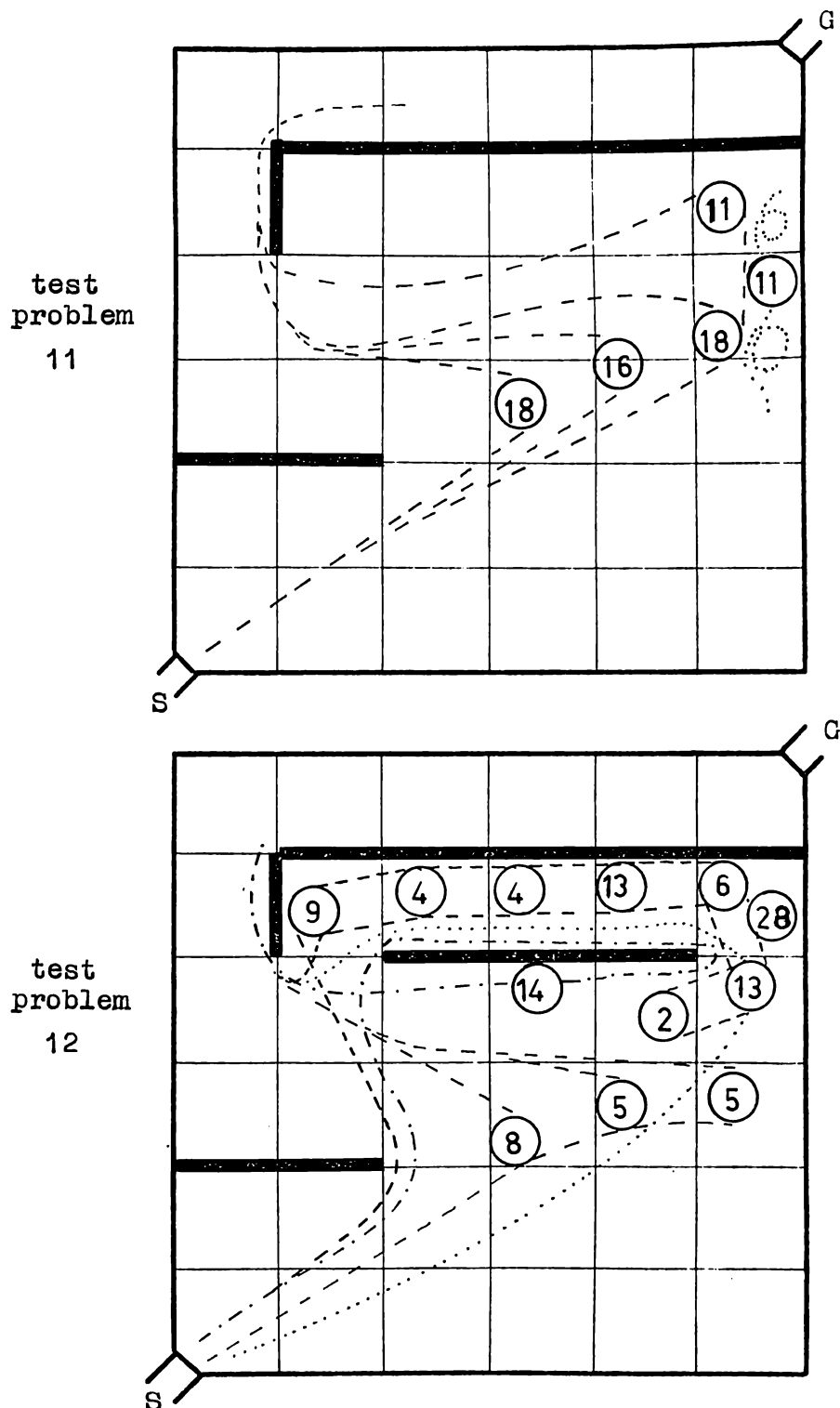


Figure 30.

Error pathways taken by cows in test problems 11 and 12 of the Closed-field Test. The numerals in circles indicate the total number of cows which took that pathway.

non-visual problems, on the other hand, can be made either more or less complicated as long as the correct pathway is kept. Extra baffles could be added to alter or test the animals ability to learn the right path among many. Problem 4 and problem 10 could be made more difficult for the early run performances by the use of additional baffles. In general, though the problems vary quite widely in difficulty for cows they appear to be satisfactory in design. The difficulty level of the problems for the species tested will be dealt with in a later section.

Considering the distances to be travelled to solve each particular problem (see table 12) it soon became apparent that after the first few runs the speed of the run for each particular cow was remarkably similar. In fact, when the actual paces taken by the animals were counted as the animals walked the distance they seldom varied by more than one step. The times seldom varied by more than a second or two. Such uniform performance allowed a high degree of predictability of the performance of cattle in the closed field test. The speed of learning and the trial speeds will be considered under the species comparisons.

Table 29 contains a summary of the total errors made by cows on each of the problems 1 to 6 for each of the 8 runs. On the first run fewer cows made mistakes on problem 1 than in any other. This either indicates that the training series provided

Table 29: Summary of total errors made by 73 cows tested on problems one to six of the closed-field test.

run no.		Problem no.						total	% of total
		1	2	3	4	5	6		
1	Ss in error	41	55	68	72	67	63	366	84%
	total error	354	482	258	546	306	934	2880	
	cow av.	8.6	8.7	3.8	7.6	4.6	14.8	7.9	
	range	0-56	0-32	0-8	0-52	0-16	0-54		
	S.D.	10.18	10.61	3.70	8.17	3.10	42.27		
2	Ss in error	9	16	26	37	9	8	105	24%
	total error	56	26	78	136	38	56	390	
	cow av.	6.2	1.6	3.0	3.7	4.2	7.0	3.7	
	range	0-18	0-8	0-6	0-28	0-18	0-14		
	S.D.	2.74	1.75	1.93	1.95	2.26	0.33		
3	Ss in error	4	10	14	19	1	2	50	11%
	total error	16	34	38	52	2	28	170	
	cow av.	4.0	3.4	2.7	2.7	2.0	14.0	3.4	
	range	0-6	0-4	0-6	0-8	0-2	0-26		
	S.D.	1.02	1.16	1.33	1.55	0.22	0.22		
4	Ss in error	5	7	8	7	1	3	31	7%
	total error	20	16	32	28	2	46	144	
	cow av.	4.0	2.3	4.0	4.0	2.0	15.3	4.6	
	range	0-6	0-4	0-6	0-8	0-2	0-16		
	S.D.	1.16	0.76	1.36	1.36	0.22	2.15		
5	Ss in error	3	7	4	6	1	-	21	5%
	total error	12	28	12	24	6	-	82	
	cow av.	4.0	4.0	3.0	4.0	6.0	-	3.9	
	S.D.	0.86	1.39	0.83	1.30	0.70			
6	Ss in error	4	7	7	5	1	2	26	6%
	total error	14	30	28	28	2	10	112	
	cow av.	3.5	4.3	4.0	5.6	2.0	5.0	4.3	
	S.D.	0.91	1.58	1.31	1.10	0.22	8.54		
7	Ss in error	3	7	8	4	1	3	26	6%
	total error	14	32	44	16	2	30	138	
	cow av.	4.7	4.6	5.5	4.0	2.0	10.0	5.3	
	S.D.	1.08	1.45	1.36	1.10	0.22	1.79		
8	Ss in error	2	6	6	5	1	1	21	5%
	total error	10	20	20	18	2	26	96	
	cow av.	5.0	3.3	3.3	3.6	2.0	26.0	4.6	
	S.D.	0.95	1.14	1.06	1.12	0.22	3.02		
Ss in error 1-4		59	88	116	135	78	76	552	
Total error 1-4		446	558	406	762	348	1064	3584	
cow av. 1-4		7.6	6.3	3.5	5.6	4.5	14.0	6.5	
Ss in error 5-8		12	27	25	20	4	6	94	
total error 5-8		50	110	104	86	12	66	428	
total error 1-8		496	668	510	848	360	1130	4012	
Ss in error 1-8		71	115	141	155	82	82	646	
cow av. 1-8		7.0	5.8	3.6	5.5	4.4	13.8	6.2	

an adequate background for the first day of the test series, even after only 6 days, or that the pathway to be followed most closely approximated that of the last day of the training series. The average error score on run I for the cows was lowest for problem 3, followed by problem 5. The average error score for the visual problems was lower than that for their non-visual counterpart, as was expected, but not greatly so in problem 1 and 2. Problems 5 and 6 showed the greatest differences in average error score for the first run. The range is rather similar for the most difficult problems.

On the whole series, problem 5 was the easiest to learn, with only 16 errors made after the second run. Six percent of the 73 cows tested, though not the same cows, continued to make errors right through to the last run of the day on the average over the 6 days' trials. An average of 23% made perfect runs on the first run of the problems for the 6 days. As would be expected the gross errors were soon eliminated though the range shows that 1 animal still made 26 errors on problem 6 on the third run, i.e., one of the 2 cows still making errors. This was a cow which took the correct path on the first trial and proceeded to make errors on this problem on the second and third runs. If a cow did move in the incorrect direction in problem 6 it was likely to make quite a few errors before it was able to retrieve itself because of the problem's design, i.e., the cow which made errors on the last run made 26 errors in problem 6.

Table 30 : Summary of total errors made by 59 cows tested on problems 7 to 12 of the closed-field test.

run no.	Problem no.						(a) total	(b) total	(a) % of total	(b) % of total
	7	8	9	10	11	12	7-12	1-12		
1 Ss in error	59	56	39	41	41	51	287	653	81%	82%
total error	994	1822	300	738	624	1070	5548	8428		
cow av.	16.8	32.5	7.7	18.0	15.2	21.0	19.3	12.9		
range	2-90	0-118	0-14	0-74	0-82	0-98				
S.D.	31.54	46.92	5.17	16.95	16.22	34.93				
2 Ss in error	40	19	17	19	7	24	126	231	36%	29%
total error	140	248	108	236	62	184	978	1368		
cow av.	3.5	13.1	6.4	12.4	8.9	7.7	7.8	5.9		
range	0-26	0-50	0-10	0-24	0-18	0-24				
S.D.	3.42	7.09	1.61	2.73	2.95	4.67				
3 Ss in error	21	11	9	16	6	10	73	123	21%	16%
total error	62	78	40	130	30	104	444	614		
cow av.	3.0	7.1	4.4	8.1	5.0	10.4	6.1	5.0		
range	0-8	0-16	0-10	0-16	0-12	0-30				
S.D.	1.64	2.37	1.76	0.47	1.70	4.52				
4 Ss in error	15	6	2	3	5	7	38	69	11%	9%
total error	40	52	10	56	30	64	252	396		
cow av.	2.7	8.7	5.0	18.7	6.0	9.1	6.6	5.7		
range	0-10	0-28	0-6	0-12	0-24	0-24				
S.D.	1.80	3.47	0.79	2.26	2.26	3.02				
5 Ss in error	15	6	2	3	5	7	38	59	11%	7%
total error	44	42	8	40	28	64	226	308		
cow av.	2.9	7.0	4.0	13.3	5.6	9.1	6.0	5.2		
S.D.	1.51	2.35	0.72	2.73	2.37	2.74				
6 Ss in error	10	2	1	1	7	3	24	50	7%	6%
total error	22	4	6	10	30	24	96	208		
cow av.	2.2	2.0	6.0	10.0	4.3	8.0	4.0	4.2		
S.D.	0.86	0.22	0.70	1.16	1.16	1.59				
7 Ss in error	10	3	2	1	1	1	18	44	5%	6%
total error	36	20	8	2	2	6	74	212		
cow av.	3.6	6.7	4.0	2.0	2.0	6.0	4.1	4.8		
S.D.	1.86	1.32	0.45	0.22	0.22	0.70				
8 Ss in error	10	3	-	-	-	1	14	35	4%	4%
total error	30	14	-	-	-	8	52	148		
cow av.	3.0	4.7	-	-	-	8.0	3.7	4.2		
S.D.	1.27	1.05	-	-	-	0.92				
Ss in error1-4	135	92	67	79	59	92	524	1076		
total error1-4	1236	2200	458	1160	746	1422	7222	10836		
cow av. 1-4	9.2	23.9	6.8	14.7	12.6	15.5	13.8	10.1		
Ss in error5-8	45	14	5	5	13	12	94	188		
total error5-8	132	80	22	52	60	102	448	876		
total error1-8	1368	2280	480	1212	806	1524	7670	11712		
Ss in error1-8	180	106	72	84	72	104	618	1264		
cow av. 1-8	7.6	21.5	6.7	14.4	11.2	14.7	12.4	9.3		

An index of the rapidity of learning is given in the total % of cows making errors in each of the 8 runs over the 6 problems. This shows a rapid drop during the first 4 runs to reach a plateau of 6% of cows in error. (see right hand column of table 29). In table 30, which shows the error scores for the series 7 to 12, the problems are harder for the cows and the percentage of cows correct on the first run is 18%. Problems 7, 8 and 12 could not be solved easily on the first run. In fact, in problem 7, only 19 animals ran it perfectly on the second run of the day.

The cows were able to eliminate errors completely by the last trial for problems 9, 10 and 11, and only one animal of the 59 tested made an error on the last run of problem 12.

A clearer picture of the error patterns emerges when these scores are broken into categories, as in table 31 for problems 1 to 6, and table 32 for problems 7 to 12. Five error categories have been used in these tables: the group which was without error; those cows which made between 2 and 10 errors; those cows which made between 12 and 20 errors; those between 20 and 50 errors and those over 50. Only three animals were involved in the over 50 category on problems 1 to 6 and one of these was from the first day of testing in problem 1. Very few cows made more than 10 errors after the first run; i.e., a deviation across 5 squares from the shortest path. The greatest number of errors were made by cows on problems 3 and 4. The pattern for

Table 31: Summary of individual error scores of 73 cows in problems one to six of the closed-field test.

[illegible]

the series 7 to 12 is rather similar in that no cows committed more than 50 errors after run 1, but 24 animals fell into this class on the first run in contrast to 3 for the earlier series. Of the 472 cows which were run through the complete 8 runs, 180 made errors on problem 7 and 106 on its non-visual counterpart. It can be seen that problem 12 was also difficult for cows. The error grouping scores are the basis for the comparative analysis of a later section.

When the animals shown, as making errors on the pathway diagrams (figs. 22-30) are compared with Tables (31) and (32), at first sight some discrepancy might seem evident. However, the actual pathway errors count the number of cows on a particular pathway and cows which have already made errors on one axis may be counted again on another. They will thus be counted twice. 71 cows made errors in problem 1 and 81 are shown in error on the pathway diagram (figure 25). The five cows which deviated both to the top left and top right corners are counted twice in the pathway analysis. In the cows making errors over the whole series, problems 9, 10 and 11 appear very comparable with problems 1, 5 and 6. The error scores, being based on the number of squares broken minus the number of squares traversed in the shortest path, means that they are always even numbers. If the animal entered the square it had also to move out of it again back to the correct path. The deviation of one square results in an error score of 2 and so on. The minimum number of squares to a solution however is

Table 32 : Summary of individual error scores of 59 cows in problems 7 to 12 of the closed field test.

[illegible]

an odd number, the shortest path being 11 squares broken. In this way the animal which moves along the wall of the arena breaks no more squares than one which moves across the diagonal. For species comparisons this does not penalise the animal which avoids open spaces to the same degree as other scoring systems might. Following the procedures of Pollard (1961) all the raw error scores were transformed by taking their square root and multiplying by 100. The data for further analysis was computed from these transformed scores. The first calculation made was for % P (P standing for problems). This is a comparison of the performances of each individual animal on the pairs of problems with the same common correct pathway, the problems with the visual and non-visual counterparts. It is possible for animals using visual cues to make correct runs on the visual form of the problem whereas this is unlikely on the non-visual form. This score then is an index of the reliance of the species on vision. A total of 81 cows did get the first run correct on the six visual forms of the 1-12 series compared with 58 animals which got the non-visual forms correct. The score is so arranged that the lower it is the better the visual performance of the species. Scores over 50% indicate that a better performance was made in the non-visual form of each problem. Although a higher percentage of cows performed the first run free of error in the visual rather than the non-visual tests except in problems 5 and 6 and 7 and 8; in problem 9 and 10 the differences are not very great. This is reflected in the % P scores for cattle. Table 33 shows these scores for the three domestic species

tested and the cattle scores are shown in column 2. The range of scores is from 12.9 to 87.3 with an average score of 39.4. Eighteen percent of the animals scored over 50 for % P showing that they did better on the non-visual form of the problem. This score must be viewed in the context of the total error score which is on average lowest for cattle of all species tested. An examination of the original score sheets of representative animals, illustrates the performances of individuals with a high % P.

Cow 7156 scored a % P score of 72.8 and cow 7155, her twin, scored 87.3. 7155 made 30 errors on the first run in problem 1; none in problem 2; 12 in problem 3; and 6 in problem 4; 6 in problem 5 and none in problem 6. Her total error score was 241.9 which was almost on the mean score for cattle. Her errors were eight times greater in the visual problems. In a similar way, her twin, by making 20 errors in problem 1 increased her error balance for the visual problems and led to a % P score of 72.8. With the very rapid learning which occurs in cows and with the low Total Error Scores (TES), in this case 272.5, the balance of this index can be easily changed by the scores from one problem alone, of the six which are combined for the calculation.

Knowing how critical this is, it is of interest to examine the % P scores for the 7-12 problems, problems designed for greater difficulty. (see Table 75). The correlation between the ranked % P scores for problems 1-6 and 7-12 is 0.06 (NS) for

<u>Sheep</u>	<u>cattle</u>	<u>pigs</u>	<u>Sheep</u>	<u>cattle</u>	<u>pigs</u>	<u>Sheep</u>	<u>cattle</u>	<u>pigs</u>
0.0			34.3	37.5				56.4
0.0			36.5	38.5				57.1
10.5	12.9		36.5	38.6				57.2
10.9=	14.3		37.3	39.0				57.5
11.0	15.1		37.6	39.2				58.5
11.8	16.7		37.7	<u>39.4</u> _x				58.7
12.2	17.8		38.0					59.4
13.2	19.3		38.1			63.4	67.1	60.0
13.2			38.3			64.1		60.4
14.7			38.7					61.1
15.5			38.8					61.5
15.5			39.9					61.8
16.9			41.1	40.9	40.3			62.6
18.5			41.5	41.9	40.4			63.3
19.3			42.3	41.9	41.1			65.0
20.8	20.6	22.4	43.3	42.0	42.4			67.4
22.7	21.0	28.0	43.3	42.8	42.8			68.6
23.1	21.2	29.2	43.7	42.9	42.8		72.8	
24.9	21.6		43.7	43.5	43.0		74.1	
25.2	24.4		44.0	43.5	43.2			
25.4	25.4		44.9	43.7	43.6		87.3	
26.1	26.3		45.2	43.8	43.6	N=79	N=73	N=62
27.3	26.5		45.6	43.8	44.1			
27.4	27.0		45.9	44.3	44.1			
27.5	28.2		45.9	45.3	44.7			
27.6			48.0	46.2	45.6			
28.9				46.9	46.0			
29.4				47.1	46.0			
29.9				47.4	46.7			
30.3	30.2	31.0		48.0	46.8			
30.4	30.7	37.9		48.3	46.9			
30.9	30.9	38.2		48.3	47.2			
30.9	30.9	38.4			47.3			
<u>31.2</u> _x	30.9	38.6			47.4			
31.5 _x	31.3	39.0			48.6			
31.6	31.4	39.3			48.8			
31.7	31.7				<u>48.9</u> _x			
31.7	32.5				49.2 _x			
31.8	32.5		50.9	52.0	51.0			
31.9	32.9		52.5	52.1	51.2			
32.2	35.3		53.9	52.4	52.3			
32.4	35.3		54.2	55.8	52.5			
32.5	35.9			57.6	52.6			
32.7	36.1			58.2	53.5			
33.1	36.8			58.3	54.1			
33.7	37.3			59.4	55.6			
34.0	37.4			59.8	55.9			

Table 33 showing %P
for sheep, cattle and
pigs in problems 1 to
6 of the closed-field
test.

the sum total of experimental animals.

The second score used by Pollard is the % R score (R stands for runs). This score is derived from a comparison of the errors made by each subject in the first 4 of the 8 runs daily with the second four runs, i.e. runs 1-4 v runs 5-8. It was reasoned that the animals should be able to make some progress in eliminating errors during runs 1 to 4 and the best of them would have few errors during the 5 to 8 runs. The subjects without errors at all in runs 5 to 8 would score 100%. Those scoring 50% would be making as many errors in the first four runs as the last four. This score gives some indication of the speed of elimination of errors or the rate of learning. The % R scores for cows are shown in the second column of table 34. 53% of all the cows tested scored 100% and the mean score for cattle was 90.4. They ranged, however, from 100% to 52.8%. The high percentage of cows with 100% R score reflects the consistent performance of cattle which, after errors have been eliminated, deviate very little from the set pathway. An examination of the performance of one of the low scoring animals is of considerable interest. Cow 060 showed a perfect performance on problem 1 and 5; 6 errors on the first run of problem 2 and 2 errors each on runs 6 and 8; balanced errors of 4 on runs 1 and 5, and 6 errors on runs 4 and 7 in problem 3; 8 errors on run 1 in problem 4 and 2 errors in runs 7 and 8; and finally 2 errors on run 6 in problem 6. 060 has a TES of 230.1 which is

Table 34 showing %R for sheep, cattle and pigs in problems 1 to 6 of the closed-field test.

Sheep 100% for 30 animals (38% of sample).	Cattle 100% for 39 animals (53% of sample).	Pigs 100% for 24 animals (39% of sample).	Sheep	Cattle	Pigs
96.3	92.2	96.5	79.1	79.7	79.6
93.8	91.8	96.5	77.4	79.6	78.2
93.5	91.7	96.3	77.3	79.3	78.1
93.0	91.1	96.0	76.7	77.5	76.5
92.1	<u>90.4</u>	96.0	75.4	77.2	73.0
90.2	x	95.4	75.3	75.2	70.2
		95.0	75.0	74.8	
		95.0	74.6	74.6	
		94.6	74.4	71.2	
		94.5	73.8	71.0	
		94.5	72.8	70.4	
		94.4	71.9		
		94.4	71.4		
		93.5	69.3	68.0	66.1
		92.9	68.7	66.8	
		<u>92.8</u>	68.6	65.4	
		92.3	67.1	61.0	
		91.7	61.8		
		91.6	58.8	59.0	58.0
		90.0	58.0	52.8	
			55.7		
			55.0		
			50.0		
			49.6		
89.6	88.8	89.2			
89.5	87.7	88.5			
89.3	86.5	88.3			
89.0	86.4	87.2			
88.7	86.0	87.1			
88.2	85.7	86.5			
87.7	83.4	85.4			
<u>87.6</u>	83.2	84.0			
83.9 ^x	82.4	83.0			
83.6	80.3				
83.3	80.3				
83.1					
82.7					
82.7					
82.7					
81.7					
81.3					
80.0					

better than average. A serious error in this type of scoring, after 6 perfect runs in a problem, can sway the ratio seriously against the subject concerned. It becomes evident that a ratio score such as % P and % R presupposes a certain minimum total error score and if the animals fall below this then a few errors in either of the groupings used for comparison can have a large influence on the score. All the extreme animals examined both for % P and % R fall into this category in series 1-6.

The final score calculated was the total error score (TES) which was a summation of all errors committed on the six problems. The TES is shown in Table 35 (in column 2 for cows). The cows range from 83.6 to 521.4 with a mean of 251.2 which puts them slightly ahead of sheep and significantly ahead of pigs. Only four of the cattle scores are greater than the mean score for pigs. Both the visual animals, cattle and sheep, are able to keep their error scores as a whole lower than the pigs. Animals with the best Total Error Score (TES) commit fewer than 24 errors in the complete six days of testing, the best cow making only 16 square crossings. Problems 1, 4 and 6 were without errors at all. The high scorers for TES were of two kinds; firstly those animals which made mistakes regularly throughout the problems. Cow 7127 fell into this category. She made 4 errors in Problem 1; 12 in problem 2; at least 2 or 4 errors on every run in problem 3; and only had 2 correct runs

<u>Sheep</u>	<u>Cattle</u>	<u>Sheep</u>	<u>Cattle</u>	<u>Pigs</u>	<u>Sheep</u>	<u>Cattle</u>	<u>Pigs</u>
55.6	83.6	269.5	284.0				479.5
91.5		274.1	284.4				485.5
112.2	114.0	278.0	289.7				486.0
122.5	114.4	279.9	298.8	261.6			494.4
147.7	115.9	282.3	299.1	273.9	505.0	502.0	500.4
149.6	123.6	283.0		274.1	510.3	521.4	506.2
158.5	127.4	286.0		275.9	517.3		511.1
161.0	136.6	285.0		290.2	562.0		529.7
162.0	137.8						543.6
162.1	151.2	303.2	300.7	304.4			553.6
166.6	161.6	312.1	300.8	305.0			576.5
166.6	170.5	312.4	304.2	307.5			577.3
168.0	171.1	312.6	305.7	314.1			598.6
168.8	179.4	322.9	306.9	315.5	609.7		607.5
170.5	180.3	334.5	312.7	316.7	645.2		608.4
180.2	181.9	349.3	314.1	318.9			611.2
180.4	183.4	361.3	319.7	323.6			721.4
189.1	188.4	366.6	333.6	324.4	N= 79	N= 63	N= 62
189.8	195.0	376.8	343.1	333.4			
194.1	195.5	378.8	343.8	346.6			
197.4	198.0		374.1	350.0			
199.3	198.6		376.8	353.5			
	199.5		398.9	359.7			
			399.2	361.2			
202.5	200.4			368.6			
204.7	200.5			371.1			
207.0	207.3			374.7			
208.8	209.0			379.0			
211.0	210.0			386.1			
212.8	211.1			386.5			
217.4	213.5			387.8			
218.6	220.0			393.8			
219.0	221.4			395.1			
222.6	224.2	410.4	411.0	406.6			
224.1	224.7	422.9	417.7	406.6			
225.9	225.1	456.6	422.0	411.0			
226.4	230.1	458.5		425.6			
234.4	237.5	469.6		436.7			
247.0	241.9	482.5		437.4			
247.4	249.4			437.5			
248.8	249.9			441.9			
250.9	251.2			443.1			
251.6	253.9			445.7			
259.4	259.9			445.8			
260.7	261.0			452.5			
265.0	262.1			453.8			
265.9	264.5			454.7			
267.3	272.5			457.5			
267.4	273.4			474.3			
267.8	280.4						

Table 35 showing the total error score for sheep, cattle and pigs in problems 1 to 6 in the closed-field test.

in problem 4. Five runs, 3, 4, 6, 7 and 8 were perfect in problem 5, and 10 errors were made on the first run only on problem 6. (TES = 521.4). The other type of cow is one which makes an ordinary score in all but one or two of the problems. Cow 635 falls into this class. Only 30 errors were made in problems 1 to 5 but then on problem 6 she made 110 errors very evenly spread over the 8 runs. She was still making 26 errors on the last run. Looking for some factor which would cause this strange behaviour is difficult. The fact of doing poorly and becoming upset on the first run seems to transfer in such animals to the performance for the whole day. There is no evidence that she was coming in to oestrus or that other peculiar circumstances may have influenced her performance, though such factors may unsuspectingly have a role to play in the performance of animals in this class. However, as the TES's of the cows as a group are rather evenly spread from the lowest to the highest one need not be too concerned for the animals at either extreme. In general it is clear that cows make some use of visual cues; they show a greater percentage of animals which can eliminate errors and keep to the fixed shortest pathways and they show the least number of errors in the total problems.

Finally it is possible to examine the results from % P, % R and TES Tables for the pairs of monozygotic twins which have been run separately, in the same way as the analysis for the scores in the open-field (see page 140). Fourteen pairs of twins had been tested during the trials and their scores are shown in Table 36.

Table 36 : Closed-field scores for the monozygotic twins tested.

Cow no.	Problems 1 - 6			Problems 7 - 12		
	%P	%R	TES	%P	%R	TES
6150	37.5	100.0	300.8	34.3	93.5	269.1
6151	25.4	86.0	376.8	39.8	95.2	520.4
7165	72.8	100.0	272.5	60.3	77.6	473.0
7166	87.3	79.3	241.9	48.2	75.9	750.3
059	31.3	100.0	280.5	47.1	70.9	571.7
060	48.3	52.8	230.1	45.2	91.2	349.5
664	48.3	90.5	264.5	43.1	88.3	564.0
665	39.2	100.0	224.7	37.3	100.0	293.5
351	38.5	74.6	347.1	53.3	78.4	542.1
352	47.1	100.0	273.4	40.4	81.9	429.6
705	40.9	77.2	399.2	49.4	85.0	470.9
706	58.3	74.8	417.7	42.6	94.2	608.0
407	38.6	100.0	312.7	40.8	94.3	442.1
408	35.9	100.0	237.5	38.0	100.0	377.5
7183	45.3	80.2	179.4	27.8	68.1	358.7
7184	47.4	100.0	207.3	29.9	100.0	234.6
683	67.1	100.0	200.3	46.1	100.0	414.6
684	31.4	100.0	289.7	40.3	100.0	503.1
725	36.8	100.0	115.9	68.8	100.0	98.2
726	30.7	80.3	220.0	51.9	78.1	160.9
7170	52.1	83.4	422.0			
7169	55.8	100.0	298.9			
7172	43.8	68.0	299.1			
7171	31.7	100.0	213.5			
713	46.2	59.0	200.4			
714	30.9	100.0	137.8			
709	27.0	90.4	319.7			
710	32.5	92.2	225.1			

A visual examination of the scores within each pair of twins does not seem to indicate closer scores than between any set of twins and the result of the analysis for the "similarity index" of twins gives the following:-

- a. % P scores - similarity index = 2.1
- b. % R scores - similarity index = 0.6
- c. TES scores - similarity index = 1.2

These indices are very similar to those obtained for the open-field scores in table 22 and indicate that a pair of monozygotic cattle twins would only replace 3 cows from a random drawn sample for behaviour studies when each animal is tested individually. It is possible that the twin efficiency values of Hancock (1954) include an effect from imitation of one of the other of the twins, in such activities as grazing. The open and closed-field procedures precluded this factor.

Further discussion of the closed-field test results for cattle is reserved for the section headed, species comparisons, (page 296).

Sheep in the closed-field test. Ewes have been tested throughout the year (see table 8).

Twenty-four rams including groups from Southdown and Romney Marsh breeds and several groups of lambs, half of which had been reared by hand, have been tested. Two methods were used: (a) one group was fed as separate individuals with maximum human handling and the other (b) was made up of lambs which had remained on the mother for 3 days and was then fed from racks of bottles with minimum human handling. A small group of 3 rams from Massey University, selected from nearly 100,000 rams for the peculiarities of their chromosomal structure; i.e., Chromatin positive Klinefelters Syndrome rams showing an XXY pattern of sex chromosomes were tested. The closed-field test trials indicated that no significant differences could be shown between these rams and normal rams in any of the scores, (Kilgour and Bruere, 1970).

Sheep were used in the early pilot trials for the closed-field test. At first it appeared impossible to get sheep to run 9 times through the apparatus, one run after another. The first alternative was to keep the whole group together and pick the next sheep to be run out of the mob each time, running them in a random order. This was time-consuming and caused a periodic disturbance to the whole group. As the food was placed in an open pen during the trial the experimenter had to enter the pen. This was upsetting for the subject and made it reluctant to move from the arena into the goal box area to eat, when a few minutes

later it would be disturbed again. Two of the 12 subjects gave overt signs of being upset and despite precautions taken, they both lost weight and died. No cause for death was discovered at the post mortem diagnosis. It was realised that the ewes which died were at the lowest end of the dominance hierarchy. At this stage the goal box was redesigned so that the free flow of the animals was not continually disrupted. A holding pen was built adjacent to the food box so that a subject which had completed a run could be as close as possible to the flock, and a double goal box was designed so that each sheep would move into the goal box next to a sheep that was already feeding. The final holding pen was visible from the food box.

The second difficulty which had to be overcome was the type of preferred food for the reward. After the first pilot trial a wide range of food (sheep nuts, newly mown grass and good quality hay) was offered to all sheep in three slightly spaced parts of the food box. Strong individual preferences were displayed during the first week but it was found that over the 3-weekly trial period, a number of animals moved from one type of foodstuff to another with a general trend towards a preference for sheep nuts. On very hot summer days drinking water was provided in the goal box for lambs.

Provided food was being eaten and the disturbances at the goal box were minimal during the early trials, it was possible to have sheep run 9 consecutive runs per problem. The minimising of

the disturbance in the goal box area appeared to be critical. Every attempt was made to keep the subject isolated from the flock for the shortest possible time. Other difficulties occurred in the early training trials. Frequent stopping for defecation and urination, vigorous shaking of the body even in dry weather and "displacement grazing" were all components of behaviour in the arena. The marked reluctance of the sheep to leave the open arena and enter the goal box was demonstrated time after time. Even very small events were disturbing to sheep. The flapping of a sack, the barking of a distant dog, leaves falling from trees in autumn, the swirling of shavings on the floor with eddies of wind, the flight of a bird across the pathway, could upset an animal for several runs or perhaps the whole day. Sheep would remain at a point in the return runway where they had been frightened on an earlier run in the daily trials or even from the runs of the day before. The presence of a dog, even up to $\frac{1}{4}$ of a mile away, influenced the sheep during their running in the return raceway and every attempt was made to minimise this type of disturbance. By the time the test series was underway however, the animals were more placid and 40% of all the ewes and rams tested would approach the experimenter and eat sheep nuts directly from the hand by the time the trials were complete. The sheep tested reached the criterion of eight out of nine trials correct on days E and F of the training series in all but 2 cases which again indicated that they had settled well into the experimental routine. The

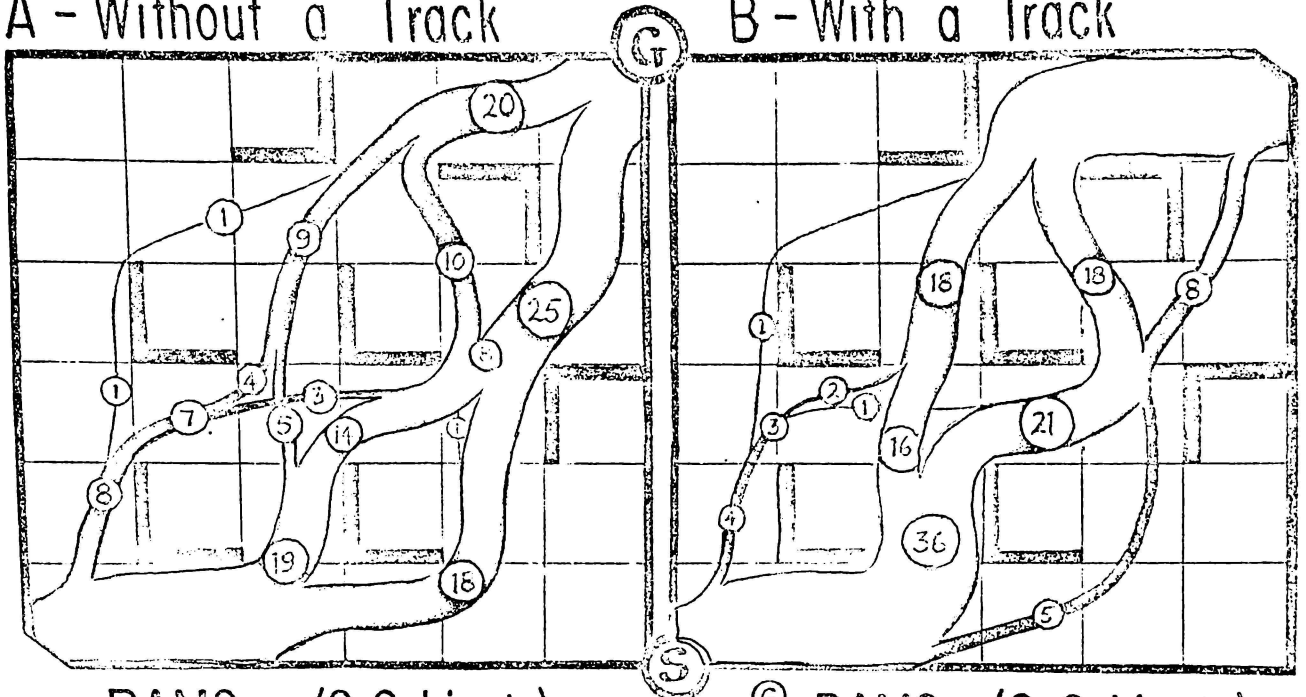
hand-reared lambs were the easiest to handle of all the experimental groups to be tested.

During the tests the sheep ran freely, except for stopping to defecate or urinate, but they did not travel in straight lines. The paths left behind were always of a wavy nature both in the return raceway and when the sheep had moved into the last straight run of the problem after going around the last barrier. Though the tracks inside the arena were raked out regularly they still developed a strikingly similar pattern. Concern was felt that despite efforts to eliminate tracks, sheep, and even cattle, might be taking up visual cues from the shavings. A small trial of 5 runs per animal was conducted to see if sheep would follow pathways laid down by other sheep when there was a variety of routeways which could be taken. The barriers were set up as in figure 18 and the results are shown in figure 31. These flow charts show that sheep were free to leave the path at any place and many sheep were not influenced at all by a very well defined distinctive track. This was similar to the findings of Liddell (1925) who found that when tracks were laid in the snow in his maze, sheep still frequently turned into blind alleys. Closer visual observation of sheep and cows in the arena showed that generally the head is held high and is moved from side to side, especially at choice points. This is reminiscent of the swaying of rats on the Lashley jumping stand termed "vicarious trial and error" behaviour, (Munn, 1950).

A discussion of the routes taken by sheep can be made with

A - Without a Track

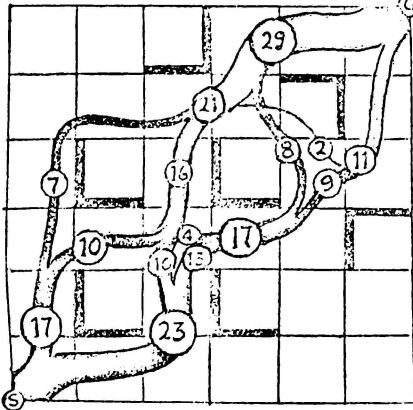
B - With a Track



RAMS (9 Subjects)

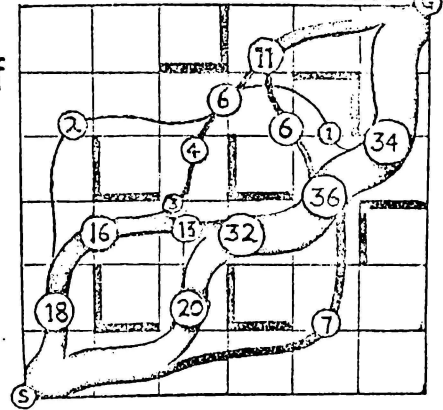
RAMS (9 Subjects)

B - With a Track



EWES - (10 Subjects)

B - With a Track



COWS (9 Subjects)

Figure 31. Flow diagrams showing the number of animals (in circles) choosing each of the possible pathways through the closed-field. The barrier pattern and the track, which had been formed by animals prior to the test is shown in the central key.

reference to the pathways used by cattle (see figures 22 to 30). In general, whereas cattle move in straight lines, sheep seldom do. In problems 3 and 4, and 7 and 8 in particular, the sheep invariably "wobble" and break a square on every run. If sheep settle into a final pathway which includes a swing sufficient to break one square, thus scoring 2 errors it could be considered that these sheep are in error. However if it is an error it is a species-specific one. When a sheep had fixed its pathway into its final form for each problem so that it moved in the correct general direction, the next run and those thereafter were scored as perfect runs in this study. If a further deviation was made during a later run into the incorrect areas of the maze, this was scored as an error.

In problems A to F sheep showed considerable approach and withdrawal activity near the goal box gate. Small circling motions and detours of irregular shape on a relatively straight directional pathway were also frequent but the complete backtracking shown by cows from goal box to start gate was not shown by sheep. They would often move back over their past track for distances up to 36 feet but did not trace the full length of the diagonal course. The training problems showed the sheep as having rather similar problems of adjustment to those of cows.

In problem A (figure 22) five sheep went to the right behind the barrier while 38 went behind the left hand barrier, and only one sheep went behind both. Problem B caused sheep little

difficulty but there was reluctance to enter the goal box on day 2. The majority of sheep in problem C went straight to the gap of the previous day and only had some difficulty extricating themselves on the first run. Once the sheep had passed around the barrier however, they veered considerable distances away from the direct path to the goal box. Twenty sheep made deep incursions of 6 or more errors in loops and unpredictable pathways in this area to the left of the goal box. Similar percentages of sheep and cows made errors in D but sheep showed the characteristic wavy pathways. Seventeen sheep broke the square to the right of the central gap in problem E and in problem F 32 sheep were trapped behind the top left cul-de-sac and 15 others behind the blind to the right.

On the test problems, 5 sheep were lost or confused on problem 1; 4 on problem 4; 1 on problem 5; 2 on problem 6; 2 on problem 7; 13 on problem 8; and 3 on problem 10.

In the first test problem (figure 25) one sheep moved into the bottom right corner and several made small reversals of pathway. In problem 2, 25 sheep penetrated into the right hand top corner. One hundred and ninety-two of the sheep "wobbled" across the first square on problem 3 but only 8 penetrated more than 3 squares into the corner. One sheep moved back into the blind alley right next to the finish gate. On problem 4 there were 135 sheep "wobbling" and very few sheep took a straight path to the edge of the protruding line of baffles. As many sheep entered the last 12 foot square in the central blind alley as turned back at the second square. Sheep

penetrate a blind alley to about 10-12 feet from the end before retracing their steps. In problem 6 many of the sheep moved round and round the two isolated barriers before retracing their pathway and finding the gap. Only one sheep made a slight error on the start gate side of the opening to the correct path.

In problem 7 (figure 28) the "U"-shaped movement around the central projecting barrier was pronounced and in problem 8, sheep were more confused than cows. Thirteen sheep became lost for extended periods and times up to 45 minutes were recorded on run 1 in this problem. In problem 9 all but 2 of the errors were made on the start gate side of the main barrier, and in problem 10, 18 sheep took two complete penetrations of the right side cul-de-sac before they turned back to the correct path. Once past the main barrier a number of the sheep which were moving towards the top blind corner, turned away and found the correct gap. Tortuous pathways were shown by the sheep in problem 11. Extensive circling and retracing of pathways were shown and several subjects moved through the correct gap but then turned back into the main arena area for a further period of movement. On problem 12 the sheep showed a lot of movement in the squares away from the central part of the arena. Several subjects moved right into the bottom right corner for a time. Others missed the correct gap after several perfect runs and entered the blind behind the row of three unattached baffles.

Table 37 contains the summary of the total errors made by

Table 37 : Summary of total errors made by 103 sheep tested on problems 1 to 6 of the closed-field test.

Run no.	Problem no.						total 1-6	% of total
	1	2	3	4	5	6		
1 Ss in error	59	83	79	103	88	77	489	79%
total error	726	636	308	1172	394	1290	4526	
sheep av.	12.3	7.7	3.9	11.4	4.5	16.8	9.3	
range	0-150	0-24	0-70	0-48	0-62	0-102		
S.D.	20.28	5.60	3.52	5.04	3.77	36.93		
2 Ss in error	11	27	26	60	12	19	155	25%
total error	44	126	52	214	40	186	662	
sheep av.	4.0	4.7	2.0	3.6	3.3	9.8	4.3	
range	0-8	0-16	0-2	0-10	0-8	0-28		
S.D.	1.40	1.74	1.07	2.37	1.54	1.25		
3 Ss in error	4	23	18	35	4	7	91	15%
total error	24	92	46	132	14	66	374	
sheep av.	6.0	4.0	2.6	3.8	3.5	9.4	4.1	
range	0-8	0-8	0-8	0-22	0-6	0-16		
S.D.	1.12	1.91	1.15	1.34	0.87	2.06		
4 Ss in error	3	18	20	20	2	7	70	11%
total error	6	74	52	96	8	66	302	
sheep av.	2.0	4.1	2.6	4.8	4.0	9.4	4.3	
range	0-2	0-14	0-6	0-14	0-6	0-12		
S.D.	0.22	1.42	2.23	2.30	0.70	1.62		
5 Ss in error	5	13	15	17	5	3	58	9%
total errors	20	56	30	46	10	42	204	
sheep av.	4.0	4.3	2.0	2.7	2.0	14.0	3.5	
S.D.	0.97	1.42	0.74	0.86	0.50	2.84		
6 Ss in error	5	12	11	24	5	3	60	
total error	20	40	22	78	12	30	202	
sheep av.	4.0	3.3	2.0	3.3	2.4	10.0	3.4	
S.D.	1.07	0.97	0.63	1.54	0.84	0.22		
7 Ss in error	5	9	14	18	3	5	54	9%
total error	20	24	34	42	6	26	152	
sheep av.	4.0	2.7	2.4	2.3	2.0	5.2	2.8	
S.D.	0.76	0.91	0.94	0.89	0.50	1.05		
8 Ss in error	2	11	13	21	5	6	58	
total error	6	64	32	62	14	80	258	
sheep av.	3.0	5.8	2.5	3.0	2.8	13.3	4.4	
range	0-4	0-38	0-6	0-10	0-4	0-22		
S.D.	0.44	4.29	0.88	1.57	0.84	0.80		
Ss in error 1-4	77	151	143	218	106	110	805	
total error 1-4	800	928	458	1614	456	1608	5864	
sheep av. 1-4	10.4	6.2	3.2	7.4	4.3	14.7	7.3	
total error 5-8	66	184	118	228	42	178	816	
Ss in error 1-8	94	196	196	298	124	127	1035	
total error 1-8	866	1112	576	1842	498	1786	6680	
sheep av.	9.2	5.7	2.9	6.2	4.0	14.1	6.5	

sheep; i.e., both ewes and rams on problems 1 to 6. The best first run performance was in problem 1 where only 59 of the 103 animals made errors. The average error score on run 1 was lowest in problem 3 followed by problem 5. The non-visual problem no. 6 was highest for this score, followed by problem 4. In overall difficulty problems 1 and 5 were the easiest and problem 4 was the most difficult for sheep.

The increased difficulty of series 7-12 is seen from an examination of table 38. No sheep mastered problem 7 on the first run and 26% of the sheep were still making errors on their last run. Only 3 animals ran problem 8 correctly on the first run. Problem 12 too, was only slowly mastered by sheep, while problems 9, 10 and 11 presented few difficulties after the second run. On the harder problems the range for sheep in the early runs is greater than for cattle in both series 1-6 and 7-12. The percentage of sheep making correct pathways in each run over the whole 12 problems declines from 75% in run 1 to a plateau of 13% after run 4.

The error classes are shown for sheep in tables 39 and 40. Only in problem 6 were there more than 12 errors in runs after the first. The large error scores were rapidly eliminated and after run 1 sheep seldom made more than four errors. Some subjects continued to make errors on all runs of all problems. In problems 8 and 12 some sheep made between 12 and 20 errors on all runs, or all but one, respectively.

Table 38 : Summary of total errors made by 93 sheep tested on problems 7 to 12 of the closed-field test.

run no.	Problem no.						total total 7-12		
	7	8	9	10	11	12	7-12	1-12	%
1 Ss in error	93	90	51	56	41	66	397	886	71
total error	1462	2374	414	1052	314	1006	6622	11148	
sheep av.	15.7	26.4	8.1	18.8	7.7	15.2	16.7	12.6	
range	0-174	0-146	0-18	0-44	0-22	0-154			
S.D.	24.85	52.09	5.72	46.45	13.38	43.72			
2 Ss in error	62	41	25	25	10	64	227	382	40
total error	410	372	146	276	50	446	1700	2362	
sheep av.	6.6	9.1	5.8	11.0	5.0	7.0	7.5	6.2	
range	0-28	0-24	0-20	0-18	0-10	0-40			
S.D.	3.93	20.12	2.65	15.24	1.47	9.75			
3 Ss in error	42	22	10	10	6	28	118	209	21
total error	124	194	70	88	18	186	680	1054	
sheep av.	3.0	8.8	7.0	8.8	3.0	6.6	5.8	5.0	
range	0-8	0-26	0-10	0-14	0-6	0-28			
S.D.	2.06	5.31	0.38	2.46	0.47	2.42			
4 Ss in error	37	13	4	9	5	21	89	159	16
total errors	108	118	22	62	20	248	578	880	
sheep av.	2.9	9.1	5.5	6.9	4.0	11.8	6.5	5.5	
range	0-8	0-10	0-8	0-14	0-6	0-18			
S.D.	1.90	1.13	1.20	2.06	1.05	5.88			
5 Ss in error	20	16	4	9	4	22	75	133	14
total error	80	36	18	98	16	136	384	588	
sheep av.	4.0	2.3	4.5	10.9	4.0	6.2	5.1	4.4	
S.D.	1.74	3.51	1.34	2.42	0.41	3.00			
6 Ss in error	28	17	3	3	4	18	73	133	13
total error	102	134	14	18	16	108	392	594	
sheep av.	3.6	7.9	4.7	6.0	4.0	6.0	5.4	4.5	
S.D.	1.69	0.22	1.25	1.27	1.27	2.58			
7 Ss in error	24	24	7	9	2	12	78	132	14
total error	70	112	40	84	8	122	436	588	
sheep av.	2.9	4.7	5.7	9.3	4.0	10.2	5.6	4.5	
S.D.	1.91	0.83	1.70	2.10	0.74	4.73			
8 Ss in error	24	13	4	7	9	7	64	122	11
total error	66	92	24	40	40	42	304	562	
sheep av.	2.8	7.1	6.0	5.7	4.4	6.0	4.8	4.6	
S.D.	1.61	3.11	1.20	0.98	1.23	1.44			
Ss in error1-4	234	166	90	110	62	179	831	1636	
total error1-4	2104	3058	652	1478	402	1886	9580	15444	
sheep av. 1-4	9.0	18.4	7.3	14.8	6.5	10.5	11.5	9.4	
total error5-8	318	374	96	240	80	408	1516	2332	
Ss in error1-8	330	236	108	128	81	238	1121	2156	
total error1-8	2422	3432	748	1718	482	2294	11096	17776	
sheep av. 1-8	7.3	14.5	6.9	13.4	6.0	9.6	9.8	8.2	

Table 39 : Summary of individual error scores of 103 sheep in problems 1 to 6 of the closed-field test.

Run no.	Problem no.						Total
	1	2	3	4	5	6	
1. errorless	44	20	24	-	15	26	129
2-10 errors	49	68	78	80	82	27	384
12-20 errors	5	14	1	11	4	33	68
22-50 errors	2	1	-	10	2	15	30
50+ errors	3	-	-	2	-	2	7
	<u>103</u>	<u>103</u>	<u>103</u>	<u>103</u>	<u>103</u>	<u>103</u>	<u>618</u>
2. errorless	93	76	77	43	91	84	464
2-10 errors	10	25	26	60	12	12	145
12-20 errors	-	2	-	-	-	6	8
20+ errors	-	-	-	-	-	1	1
							<u>618</u>
3. errorless	99	80	85	68	99	96	527
2-10 errors	4	23	18	34	4	5	88
12-20 errors	-	-	-	-	-	2	2
20+ errors	-	-	-	1	-	-	1
							<u>618</u>
4. errorless	100	85	83	83	101	96	548
2-10 errors	3	17	20	19	2	5	66
12-20 errors	-	1	-	1	-	2	4
							<u>618</u>
5. errorless	98	90	88	86	98	100	560
2-10 errors	5	13	15	17	5	1	56
10+ errors	-	-	-	-	-	2	2
							<u>618</u>
6. errorless	98	91	92	79	98	98	556
2-10 errors	5	12	11	24	5	4	61
10+ errors	-	-	-	-	-	1	1
							<u>618</u>
7. errorless	98	94	89	85	100	99	565
2-10 errors	5	9	14	18	3	3	52
10+ errors	-	-	-	-	-	1	1
							<u>618</u>
8. errorless	101	92	90	82	98	97	560
2-10 errors	2	10	13	21	5	2	53
12-20 errors	-	-	-	-	-	3	3
20+ errors	-	1	-	-	-	1	2
							<u>618</u>
Errorless 1-8	731	628	628	526	700	696	3909
2-10 errors	83	177	195	273	118	59	905
12-20 errors	5	17	1	12	4	50	89
22-50 errors	2	2	-	11	2	17	34
50+ errors	3	-	-	2	-	2	7
						<u>824</u>	<u>4944</u>

Table 40 : Summary of individual error scores of 93 sheep in problems 7 to 12 of the closed-field test.

Run no.	Problem no.						7-12 Total	Overall Total
	7	8	9	10	11	12		
1 errorless	-	3	41	27	52	27	150	279
2-10 errors	57	22	51	15	32	31	208	592
12-20 errors	18	27	1	33	9	24	112	180
22-50 errors	14	32	-	18	-	10	74	104
50+ errors	4	9	-	-	-	1	14	21
							<u>558</u>	<u>1176</u>
2 errorless	31	52	73	68	83	54	361	825
2-10 errors	53	25	19	9	10	27	143	288
12-20 errors	6	14	1	16	-	8	45	53
20+ errors	3	2	-	-	-	4	9	10
							<u>558</u>	<u>1176</u>
3 errorless	51	71	83	83	87	65	440	967
2-10 errors	42	14	10	7	6	24	103	191
12-20 errors	-	6	-	3	-	3	12	14
20+ errors	-	2	-	-	-	1	3	4
							<u>558</u>	<u>1176</u>
4 errorless	56	78	89	84	88	68	463	1011
2-10 errors	37	13	4	8	5	20	87	153
12-20 errors	-	-	-	1	-	2	3	7
20+ errors	-	2	-	-	-	3	5	5
							<u>558</u>	<u>1176</u>
5 errorless	63	76	89	84	89	71	472	1032
2-10 errors	30	14	4	4	4	20	76	132
12-20 errors	-	3	-	5	-	2	10	12
							<u>558</u>	<u>1176</u>
6 errorless	65	75	90	90	89	75	484	1040
2-10 errors	27	14	3	3	4	17	68	129
12-20 errors	1	4	-	-	-	1	6	7
							<u>558</u>	<u>1176</u>
7 errorless	68	69	86	84	91	81	479	1044
2-10 errors	25	21	7	5	2	8	68	120
12-20 errors	-	3	-	4	-	2	9	10
20+ errors	-	-	-	-	-	2	2	2
							<u>558</u>	<u>1176</u>
8 errorless	69	80	89	86	84	85	493	1053
2-10 errors	24	11	4	7	9	8	63	116
12-20 errors	-	2	-	-	-	-	2	5
20 + errors	-	-	-	-	-	-	-	2
							<u>558</u>	<u>1176</u>
Errorless 1-8	403	504	640	606	663	526	3342	7251
2-10 errors	295	134	102	58	72	155	816	1721
12-20 errors	25	59	2	62	9	42	199	288
22-50 errors	17	38	-	18	-	20	93	127
50+ errors	4	9	-	-	-	1	14	21
						<u>744</u>	<u>4464</u>	<u>9408</u>

Sheep run slowly. They get a little slower each run after the third as they become less hungry. A few sheep did not take food after the 6th run though they still gave a satisfactory performance and had eaten well on the earlier runs for the day.

The transformed error scores for sheep are shown in the first column of tables 33, 34 and 35. In the 12 problems run, 176 sheep made perfect tracks on run 1 in the visual problems compared with 113 animals on the non-visual problems. (Tables 39 and 40). This ratio is almost identical for sheep and cattle; i.e., for cattle 58% perfect pathways in run 1 on visual problems compared with 63% in sheep. Two of the 103 ewes tested did not make an error at all in the three visual problems of the 1-6 series and therefore had %P scores of 0.0%. The ewe range of %P is from 0.0 to 64.1 and the mean score is similar to that for cattle. The TES score covers a similar range for sheep and cattle so the %P score does not reflect a species difference. An examination of the very high and very low %P scores bears this out as it did for cows. Both ewes which ran perfectly in the visual problems also had low TES, viz., 122.5 and 112.2 respectively. They had poor %R scores of 55.0 and 50.0%; i.e., the errors which they made were on runs 5 to 8 in the non-visual problem no.2.

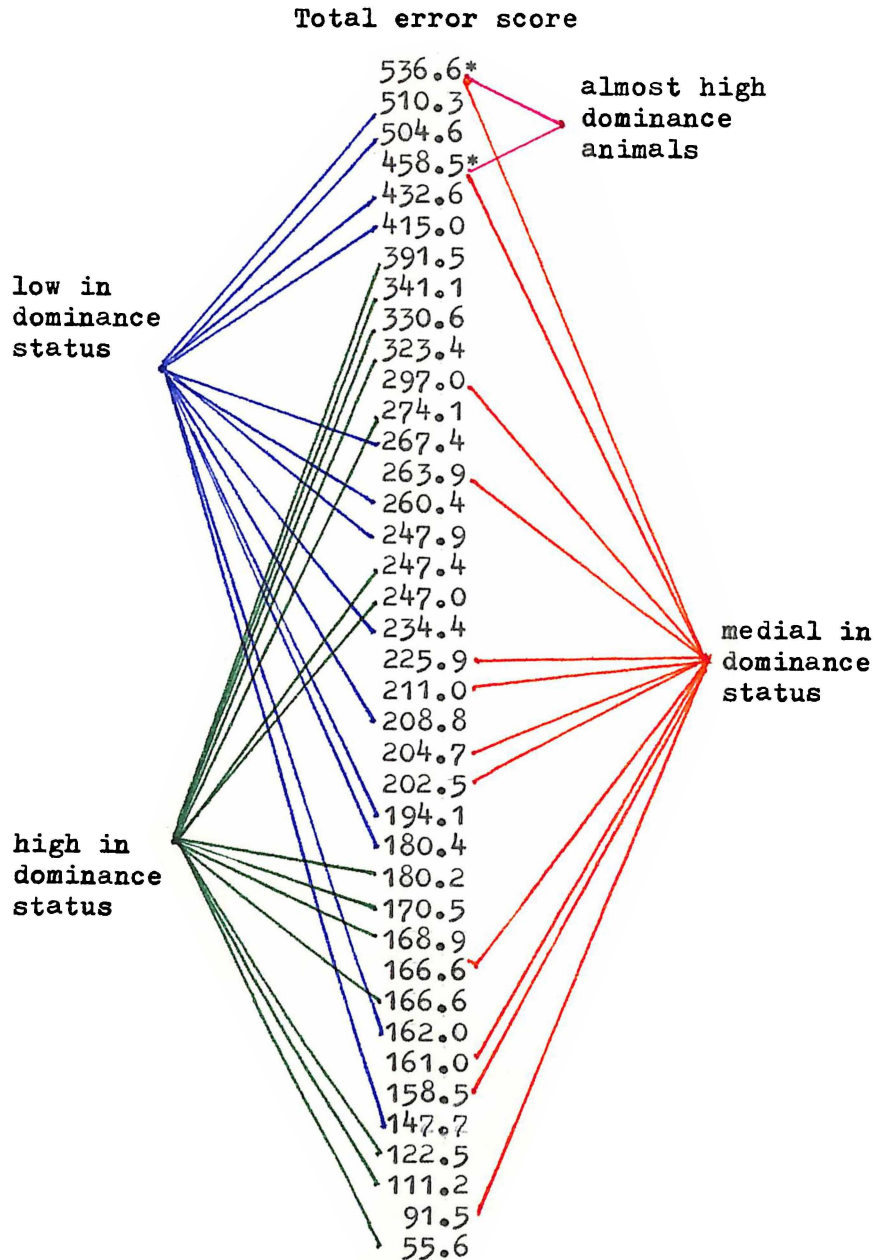
Turning to %R scores it is found that only 38% of the ewes had eliminated error scores completely by run 5. The percentage for cattle is higher. Some sheep, after running perfectly in runs 4 and 5, became erratic and committed errors on runs 6 or 7. The

higher error plateau, as shown in table 38 on the last five runs, reflects this trait in sheep. The sheep scoring low %R scores fall into this group where the early runs were perfect and the later runs show deterioration. This means that for sheep the %R scores were lowest of the three major species tested; i.e., sheep, cattle and pigs. It was considered that the low scorers on %R and the high scorers on TES were the subordinate animals in the dominance order for each experimental group and this is examined later in table 41.

In the Total Error Scores (TES) of series 1-6, the best sheep performed as well as cattle and the poorest the same as the better pigs. The mean for cattle and ewes was not greatly different. From an examination of the actual pathways of the sheep which made low TES scores it was found that the mistakes were made only on one or 2 runs. Up to 4 runs of the complete 48 were in error for the 1-6 series. The ewes with high TES eliminate errors within the first 2 or 3 runs but on the 5th, 6th, 7th and perhaps even the 8th run they begin to stop often and to move widely and unpredictably away from the shortest path.

An impression gained during the runs of sheep was that the most subordinant ewe in each experimental group was also the sheep with the poorest overall performance. The dominance order was plotted from the results of encounters between ewes in the experimental groups during the course of testing. The dominance status taken from a pen score of each of the sheep was then plotted against the TES for animals in three of the experimental groups, as in table 41.

Table 41. Total error scores (TES) in series 1-6 of 39 ewes ranked from highest errors to lowest errors linked with the corresponding dominance ranking of the subject concerned. Three dominance groupings are used; high, medial and low in dominance.

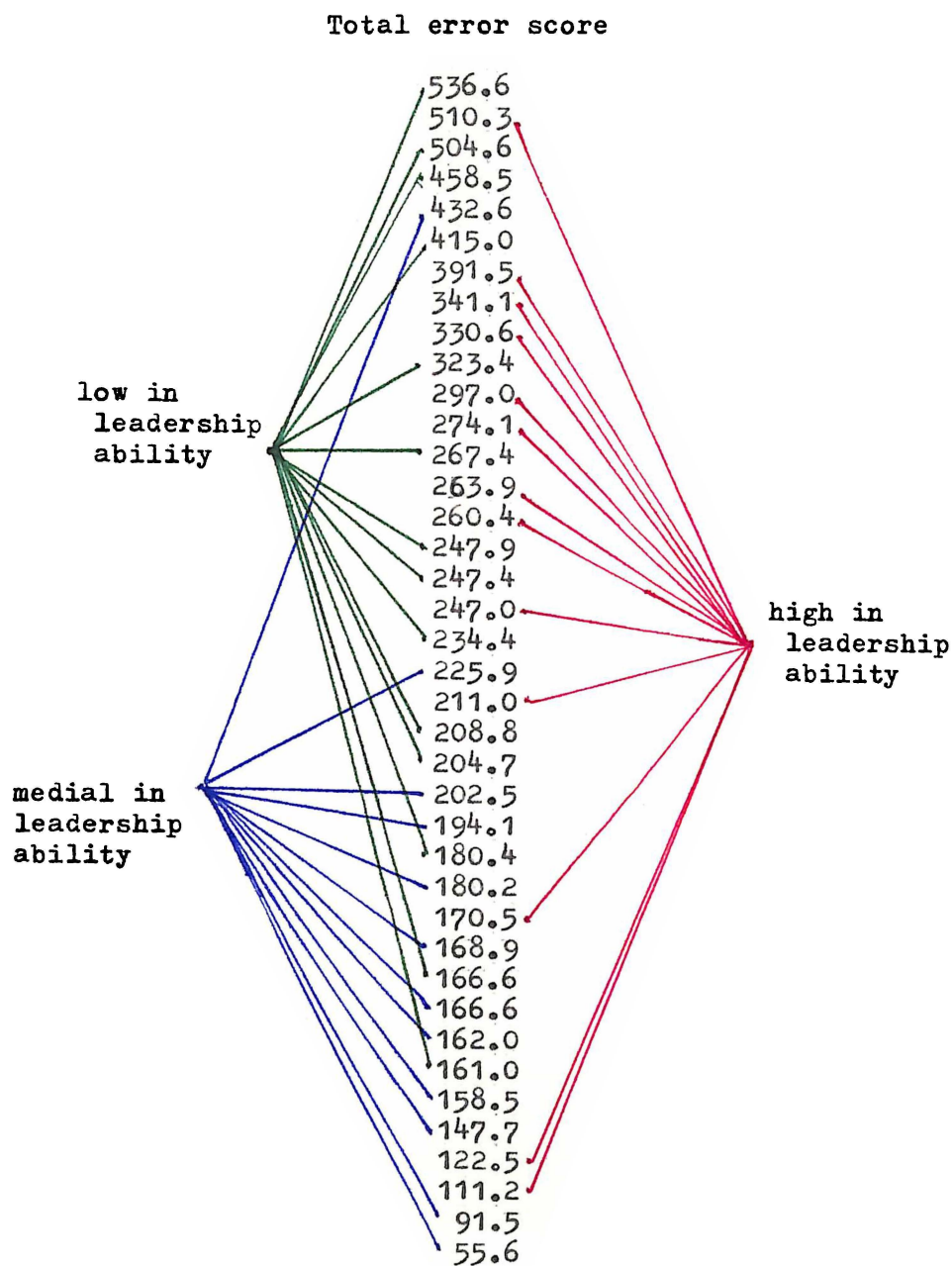


Similarly, a leadership ranking, scored during the movement of sheep in groups in raceways, was plotted against TES and this is shown in table 42. The total error scores in the 1-6 series are placed in rank order beginning with the animal with the greatest number of errors. To the left and right of this TES column each animal, ranked as high, medial and low in dominance status or leadership is shown linked with its appropriate TES. The three experimental groups of 10, 11 and 18 animals have been combined for this analysis.

Animals ranked medial or low in social dominance are spread over the full range of TES while animals high in dominance exclude the six highest TES; i.e., scores greater than 400.0. However, two animals (shown with an asterisk) border between medial and high dominance status and it seems most likely that animals from each of these groupings are in fact scattered throughout the full range of TES. Correlations (using Spearman's rho) of dominance rankings and TES in each of the 3 experimental groups were 0.05, 0.18 and 0.25; all non-significant relationships.

In the leadership grouping table, table 42, a slightly clearer pattern emerges. The animals in the middle of the flock during free movement fall with one exception, into the animals making the lowest scores of TES. The "follower" animals, at the rear of movements, are mostly animals with a TES higher than 200.0 while the "leader" animals are scattered throughout the range of scores. Correlations (Spearman's rho) between ranked leadership scores and ranked TES for the three groups were -0.01; 0.45 and 0.10; all

Table 42. Total error scores (TES) in series 1-6 of 39 ewes ranked from highest errors to lowest errors, linked with corresponding leadership rankings of the subject concerned. Three leadership groupings are used; high, medial and low in leadership ability.



non-significant. Animals medial in flock leadership scored well in the closed-field detour tests. The followers do poorly while the leaders' scores range widely. In some cases an animal with leadership tendencies ran so freely and rapidly in the arena that more errors were made than with a slower moving animal.

Leadership was scored during free movements of these groups. Dominance was scored from witnessed encounters during testing. The size of the experimental group and the number of aggressive animals in the group could have an influence on the degree of pressure to which sheep were subjected in each experimental group. The yards and pen sizes were fixed whatever the number of subjects run in one group. Perhaps a false impression is given by summing each experimental group into the collective data. If the model of McBride's (1968) has any validity then the poorer performances of the animals of the subordinate social status positions will be reflected in the general scatter of the group scores and the tendency for a negative skew in the graphed results. (see fig.32). The means for each of the 6 experimental groups were therefore adjusted to the overall mean for the entire sample and the other scores were calculated accordingly to provide the adjusted TES for this analysis. These adjusted scores were graphed in histogram form and this is shown in figure 33.

Of the 11 subjects with high adjusted TES scores, 8 were ranked as lowest or second to lowest in the experimental groupings. One animal in each of categories 350-375; 375-400 and 425-450 however was not subdominant (marked * on the graph). The subjective

A = high, B = medium and C = low densities.

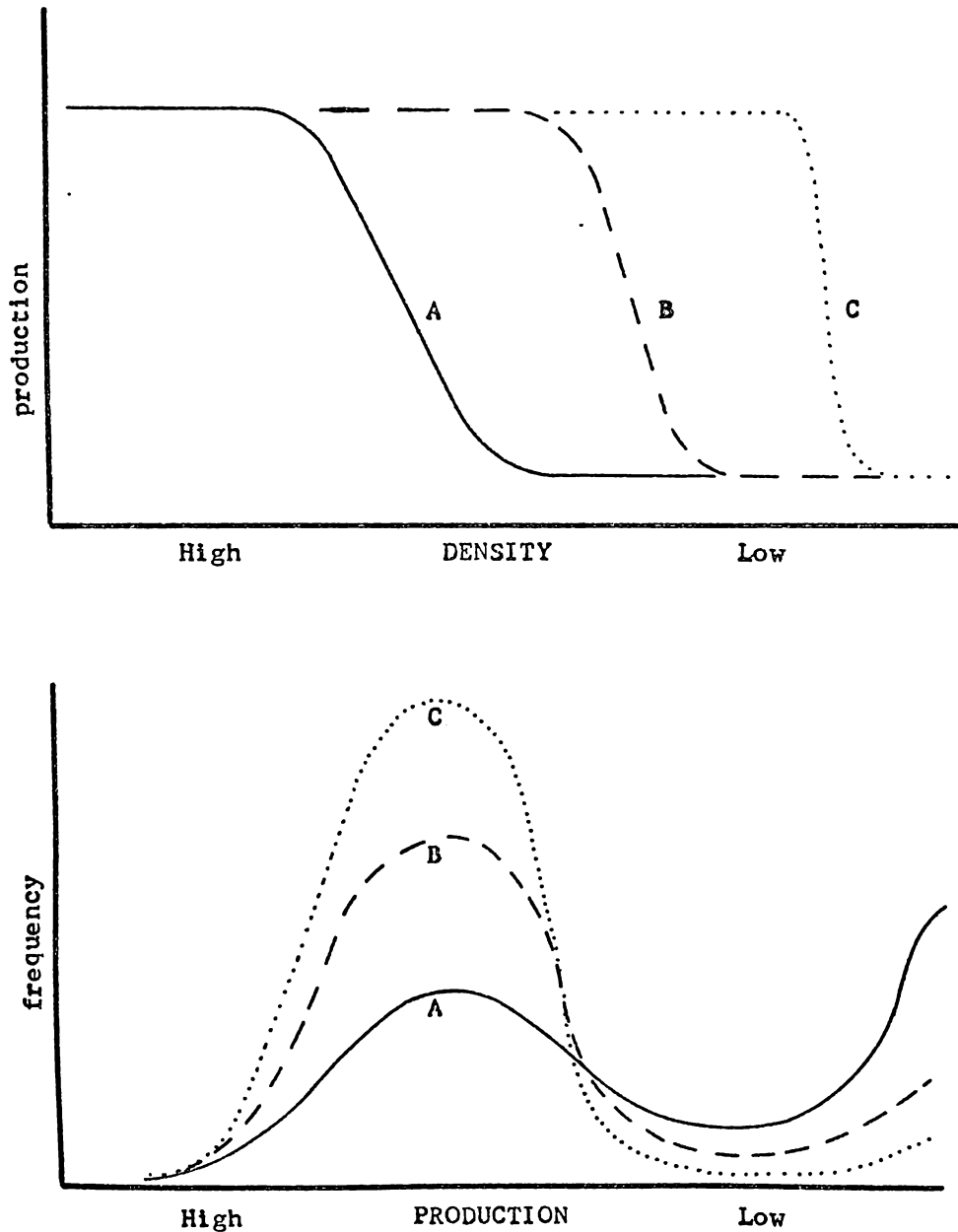


Figure 32. Above. Relationship of productivity and growth to social rank under three different densities (in hens).

Below. Frequency histograms of productivity under the three different conditions above.
(after McBride, 1964, 1968.).

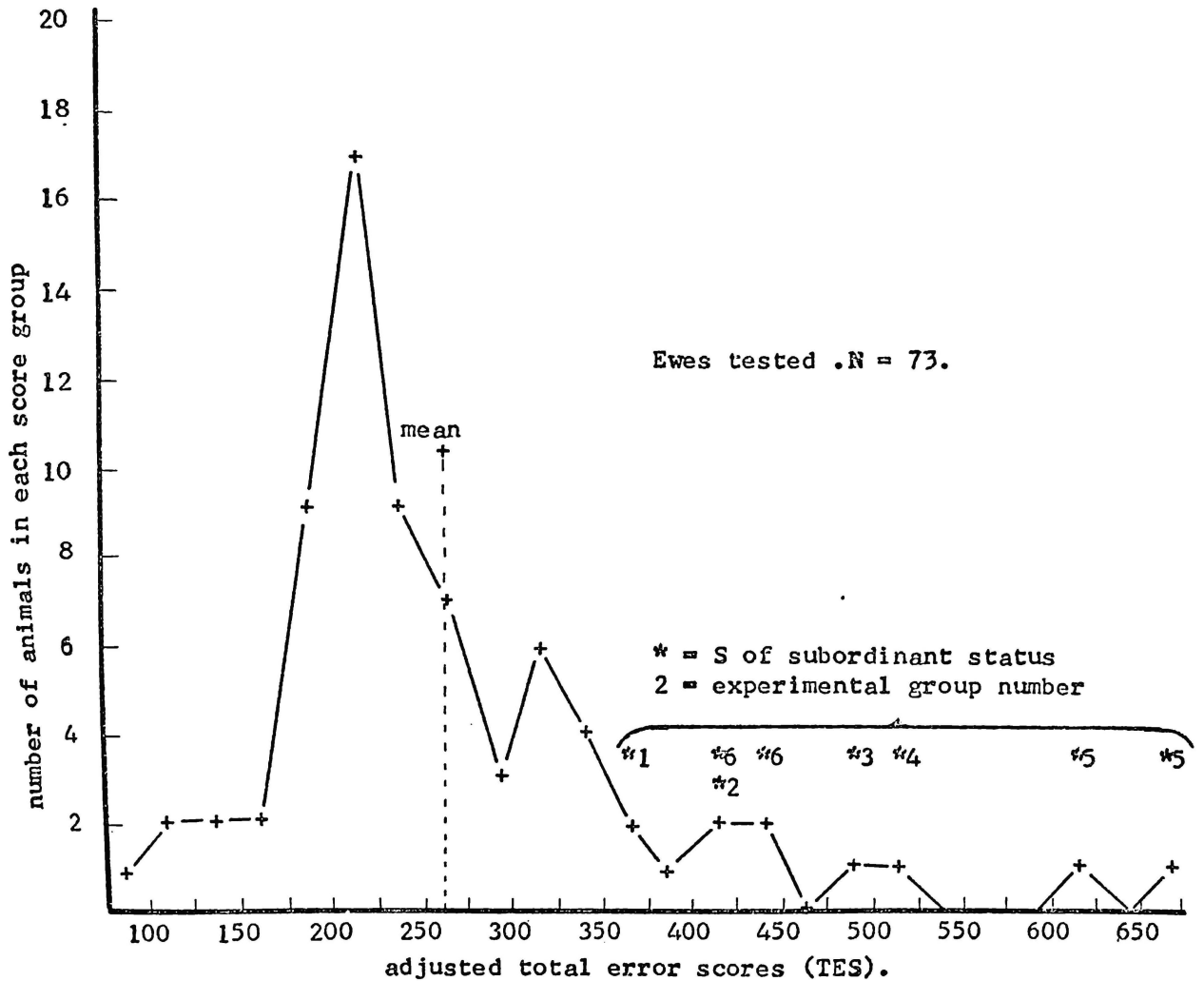


Figure 33. A graph plotting adjusted TES from animals of 6 experimental groups against frequency in each score group and the position of ewes of subordinate social status in each group.

impressions recorded several times during closed-field testing in sheep gain some support from this analysis after group means have been equated. Similar analyses for cows and pigs were not supportive.

That the low dominance status and social ranking of a ewe has a carry over into the productive performance might be expected, (McBride, 1964). That this same status should, during times of social stress such as closed-field testing, have an influence on the individual's "mental abilities" is an interesting observation that deserves more careful experimental verification in this species.

A total of 24 rams including 5 animals of two breeds, Romney Marsh and Southdowns were tested. Four rams with chromosomal abnormalities have been tested. The ram results are shown in tables 43 and 44. An examination of the results from rams and ewes allowed comparisons to be made for sex differences (Table 45). The percentage of ewes and rams making errors in each of the eight runs in both series 1-6 and 7-12 show that rams make more errors in all but 1 or 2 of the eight runs in both series. The average TES for ewes and rams also differs significantly when tested by the Kruskal-Wallis analysis of variance (Kruskal and Wallis, 1952). ($H = 19.26$; $df = 1$; $p = \text{significant greater than } 0.001$). The %P and %R scores are not significantly different. The range of the scores indicate few differences. Sex differences in sheep can be differentiated in the closed-field test by the Total Error Score only. Any differences between rams of the two breeds could not be measured.

Ewes and rams are handled rather dissimilarly on New Zealand

Table 43. Summary of individual scores of 24 rams
in problems 1 to 6 of the closed-field test.

run no.	problem no.						total
	1	2	3	4	5	6	
1. errorless	6	3	5	-	9	12	35
2-10 errors	13	18	19	17	14	2	83
12-20 errors	3	3	-	2	-	3	11
20-50 errors	2	-	-	5	1	6	14
50+ errors						1	1
						<u>24</u>	<u>144</u>
2. errorless	22	16	20	7	20	17	102
2-10 errors	2	6	4	17	4	4	37
12-20 errors		2				2	4
20+ errors						1	1
						<u>24</u>	<u>144</u>
3. errorless	23	19	17	13	24	23	119
2-10 errors	1	5	7	10		1	24
20-50 errors				1			1
							<u>144</u>
4. errorless	22	17	15	18	24	21	117
2-10 errors	2	6	9	6		1	24
12-14 errors		1				2	3
							<u>144</u>
5. errorless	22	19	18	19	24	24	126
2-10 errors	2	5	6	5			18
							<u>144</u>
6. errorless	23	19	19	17	23	21	122
2-10 errors	1	5	5	7	1	2	21
12 errors						1	1
							<u>144</u>
7. errorless	22	22	19	18	24	24	129
2-10 errors	2	2	5	6			15
							<u>144</u>
8. errorless	22	20	18	18	24	21	123
2-10 errors	2	4	6	6			18
12-18 errors						.3	3
							<u>144</u>

run	Total errors for 24 rams in series 1-6.						
1.	202	148	88	320	62	306	1126
2.	8	52	8	74	6	66	214
3.	8	8	18	56	0	0	90
4.	4	38	26	28	0	32	128
5.	6	22	10	22	0	0	60
6.	4	18	10	26	0	22	80
7.	10	4	12	16	0	0	42
8.	6	12	14	18	0	48	98
	<u>248</u>	<u>302</u>	<u>186</u>	<u>560</u>	<u>68</u>	<u>474</u>	<u>1838</u>

Table 44. Summary of individual scores of 24 rams in problems 7 to 12 of the closed-field test.

run no.		7	8	9	10	11	12	7-12 total	1-12 total
1.	errorless	0	1	10	12	13	5	41	76
	2-10 errors	12	4	14	5	9	9	53	136
	12-20 errors	5	6	0	4	2	7	24	35
	22-50 errors	4	11	0	3	0	2	20	34
	50+ errors	3	2				1	6	7
							<u>24</u>	<u>144</u>	<u>288</u>
2.	errorless	1	11	20	18	18	12	80	182
	2-10 errors	18	8	3	2	6	9	46	83
	12-20 errors	3	5	1	4		3	16	20
	22-28 errors	2						2	3
								<u>2</u>	<u>3</u>
								<u>144</u>	<u>288</u>
3.	errorless	8	21	19	22	22	20	112	231
	2-10 errors	16	2	5	1	2	4	30	54
	12-14 errors		1		1			2	2
									1
								<u>144</u>	<u>288</u>
4.	errorless	12	24	23	22	23	20	124	241
	2-10 errors	12		1	2	1	4	20	47
								<u>20</u>	<u>47</u>
								<u>144</u>	<u>288</u>
5.	errorless	15	21	23	21	22	18	120	246
	2-10 errors	9	3	1	1	2	6	22	40
	12 errors				2			2	2
								<u>2</u>	<u>2</u>
								<u>144</u>	<u>288</u>
6.	errorless	16	21	24	24	24	19	128	250
	2-10 errors	7	2				4	13	34
	12-20 errors	1	1				1	3	4
								<u>3</u>	<u>4</u>
								<u>144</u>	<u>288</u>
7.	errorless	16	18	23	21	24	23	125	154
	2-10 errors	8	5	1	2		1	17	32
	12-14 errors		1		1			2	2
								<u>2</u>	<u>2</u>
								<u>144</u>	<u>288</u>
8.	errorless	15	22	23	20	22	24	126	149
	2-10 errors	9	1	1	4	2		17	35
	16 errors		1					1	4
								<u>1</u>	<u>4</u>
								<u>144</u>	<u>288</u>
run	Total errors for 24 rams in series 7-12.								
1.	628	658	92	136	72	362	1948	3074	
2.	174	112	38	64	28	112	528	742	
3.	42	20	34	14	12	24	146	236	
4.	34		6	10	4	26	80	208	
5.	22	12	6	26	12	32	110	170	
6.	44	14			2	30	90	170	
7.	16	30	6	26	6	2	86	128	
8.	24	18	8	16	14		80	178	
	<u>984</u>	<u>864</u>	<u>190</u>	<u>292</u>	<u>150</u>	<u>588</u>	<u>3068</u>	<u>4906</u>	

Table 45. Comparative scores for sheep summarised from the raw and adjusted scores of the closed-field test tables viz. 33,34,35,37,38,39,40, (ewes)43,44,78,79,80, (rams) 46,47,48,78,79,80, for lambs, and appendix 2.

a. Percentage of animals making error in each run in problems series 1-6 and series 7-12.

run no.		1	2	3	4	5	6	7	8
series 1-6	ewes	80%	24	14	8	8	8	8	8
	rams	76%	39	17	19	13	14	10	15
	lambs	80%	35	29	25	19	16	16	15
series 7-12	ewes	73%	32	21	18	15	15	14	12
	rams	71%	44	22	14	16	11	13	13
	lambs	81%	38	23	16	11	9	8	11

b. Average total error score per problem.

problem	1	2	3	4	5	6	7	8	9	10	11	12
ewes	10.4	5.7	2.8	6.0	4.2	13.2	6.1	14.1	7.4	13.4	6.1	10.4
rams	8.3	5.3	3.0	6.8	3.4	16.3	9.0	16.3	7.0	9.1	6.3	11.5
lambs	6.2	10.0	2.8	5.2	6.6	18.4	6.5	25.4	10.2	13.7	8.4	15.0

c. Scores from adjusted errors for series 1-6 and series 7-12

		%P	%R	% Ss on 100.0%R	T.E.S.
mean	79 ewes	31.4	85.0	38	266.8
	24 rams	33.7	81.3	25	332.4
	37 lambs	31.4	81.6	19	411.6
range	ewes	0.0-64.1	49.6-100%		55.6-645.2
	rams	14.7-56.7	55.3-100%		123.8-484.0
	lambs	12.0-46.6	58.3-100%		215.0-846.1

Series problems 1 to 6

mean	ewes	37.5	78.7	8	412.7
	rams	45.1	79.7	7	412.5
	lambs	33.3	86.8	16	474.5
range	69 ewes	10.9-63.9	39.5-100%		161.0-1057.1
	14 rams	17.5-60.3	61.0-100%		210.8-635.9
	32 lambs	14.4-62.4	58.1-100%		293.6-853.4

Series problems 7-12

farms. In the same way, the few bulls which have been tested in the arena have also indicated rather different scores from the milking cows. Whether in fact these reflect true sex differences or merely the differences in current farm handling practices cannot be firmly stated, though in every case the bulls and the rams reached the criteria during the training problems at the same time as the members of the female groups.

It can be generally concluded from these samples, small though they are in terms of total numbers of animals tested, that although the closed-field test is sensitive enough to indicate some sex differences it cannot differentiate between breeds of sheep.

A considerable amount of research in the field of early experience has supported the contention that rearing animals from birth in a stimulating environment, rearing them without a mother, or even handling them for a few minutes each day, has an effect on later adult maze learning ability. (Forgays and Forgays, 1952; Denenberg, 1966; Newton and Levine 1968). It was to help test hypotheses like these that the original Hebb-Williams closed-field test was designed (Hebb, 1949).

Two groups of lambs have been reared by hand, as single lambs and as lambs reared together from racks of bottles, to ascertain whether performance in the closed-field test would discriminate rearing effects in sheep as it has for other species: viz., rats and dogs. In the first group 10 lambs were successfully raised by hand feeding and these lambs were fully imprinted onto human beings.

They would come when called and eat directly from the hand after weaning. Four weeks after weaning these lambs were matched by weight with another group of lambs reared by their mothers at a hill country farm until the time of weaning.

In the second group, lambs were separated from their mothers after one week and were reared as a group. They were fed from bottles in racks. These lambs tended to avoid human beings. They were matched with mother-reared control animals for the test. The results for all lambs are shown in tables 46, 47 and appendix 2. The relevant totals have been included with those of ewes and rams in table 45 to enable the comparisons between young and mature animals to be made.

In terms of the total percentage making errors, lambs were slower than ewes to reach the correct solution and on runs 5,6,7 and 8 show similar scores to the rams in series 1-6. In series 7-12 they gave a better performance in runs 5-8 compared with adult animals. In the more complex non-visual problems 2,6,8 and 12 they made more errors than adult animals, but in the simpler problems the scores were almost the same. The lambs appear to profit most from experience in the closed-field test. From the low score of 19% achieving the perfect score on %R (100%), in series 1-6, they did better than both ewes and rams in series 7-12. In this, 16% of the lambs scored perfectly compared with 8% and 7% respectively for ewes and rams. The TES for lambs in average and lower range scores is poorer than for adult ewes but not rams. It appears that the closed-field test can distinguish between the performance of young

Table 46 : Summary of individual scores of 38 lambs in problems 1 to 6 of the closed-field test.

Run no.	Problem no.						Total
	1	2	3	4	5	6	
1. errorless	25	5	1	-	-	15	46
2-10 errors	10	23	37	25	33	5	133
12-20 errors	2	7	-	4	2	12	27
22-50 errors	-	1	-	5	2	5	13
50+ errors	1	2	-	4	1	1	9
						<u>38</u>	<u>228</u>
2. errorless	35	19	26	1	34	33	148
2-10 errors	3	17	12	35	4	2	73
12-20 errors	-	2	-	2	-	3	7
							<u>228</u>
3. errorless	33	25	27	5	36	35	161
2-10 errors	5	12	11	33	2	1	64
12-20 errors	-	1	-	-	-	2	3
							<u>228</u>
4. errorless	33	26	27	8	38	38	170
2-10 errors	5	11	11	30	-	-	57
10+ errors	-	1	-	-	-	-	1
							<u>228</u>
5. errorless	37	31	26	16	37	37	184
2-10 errors	1	6	12	22	1	1	43
10+ errors	-	1	-	-	-	-	1
							<u>228</u>
6. errorless	33	36	27	21	38	37	192
2-10 errors	5	2	11	17	-	-	35
20+ errors	-	-	-	-	-	1	1
							<u>228</u>
7. errorless	36	36	26	17	37	38	190
2-10 errors	2	2	12	21	1	-	38
							<u>228</u>
8. errorless	37	37	26	17	38	38	193
2-10 errors	1	1	12	21	-	-	35
							<u>228</u>
Errorless 1-8	269	215	186	85	258	271	1284
2-10 errors	32	74	118	204	41	9	478
12-20 errors	2	12	-	6	2	17	39
22-50 errors	-	1	-	5	2	6	14
50+	1	2	-	4	1	1	9
	<u>304</u>					<u>304</u>	<u>1824</u>

Table 47 : Summary of individual scores of 32 lambs in problems 7 to 12 of the closed-field test.

Run no.	Problem no.						7-12 Total	Overall total
	7	8	9	10	11	12		
1. errorless	-	-	8	11	14	2	35	81
2-10 errors	27	6	20	1	14	6	74	207
12-20 errors	1	4	1	15	2	14	37	64
22-50 errors	4	12	1	5	-	7	29	42
50+ errors	-	10	2	-	2	3	17	26
							<u>192</u>	<u>420</u>
2. errorless	11	16	29	26	28	10	120	268
2-10 errors	20	6	3	2	4	8	43	116
12-20 errors	-	7	-	4	-	10	21	28
22-50 errors	1	3	-	-	-	3	7	7
50+ errors	-	-	-	-	-	1	1	1
							<u>192</u>	<u>420</u>
3. errorless	22	27	31	27	28	12	147	308
2-10 errors	9	4	-	3	4	14	34	98
12-20 errors	1	0	1	2	0	5	9	12
20+ errors	-	1	-	-	-	1	2	2
							<u>192</u>	<u>420</u>
4. errorless	26	29	32	30	26	19	162	332
2-10 errors	6	2	-	1	6	12	27	84
12-20 errors	-	1	-	1	-	1	3	4
							<u>192</u>	<u>420</u>
5. errorless	29	29	31	32	29	21	171	355
2-10 errors	3	1	1	-	3	10	18	61
10+ errors	-	2	-	-	-	1	3	4
							<u>192</u>	<u>420</u>
6. errorless	28	31	32	29	28	27	175	367
2-10 errors	4	1	-	1	3	5	14	49
10+ errors	-	-	-	2	1	-	3	3
20+ errors								1
							<u>192</u>	<u>420</u>
7. errorless	29	29	30	31	31	26	176	366
2-10 errors	3	3	2	1	1	5	15	53
10+ errors	-	-	-	-	-	1	1	1
							<u>192</u>	<u>420</u>
8. errorless	28	29	31	29	32	22	171	364
2-10 errors	4	2	1	2	-	10	19	54
10+ errors	-	1	-	1	-	-	2	2
							<u>192</u>	<u>420</u>
Errorless 1-8	173	190	224	25	216	139	1157	2441
2-10 errors	76	25	27	11	35	70	244	722
12-20 errors	2	15	2	25	3	32	79	118
22-50 errors	5	16	1	5	-	11	38	52
50+ errors	-	10	2	-	2	4	18	27
						<u>256</u>	<u>1536</u>	<u>3360</u>

immature animals and mature adult sheep.

When the %P, %R and TES scores for lambs reared in various groups are considered, as shown in tables 80, 78 and 79, it is only in the %P scores that the bottle-fed separately reared group tend to show a cluster in the mid-twenties. The Kruskal-Wallis one way analysis of variance indicates differences in this rating score (%P) at the 2% level of confidence ($H = 5.43$, $df = 1$; $p = 0.02$); and for the TES score for the two groups of lambs ($H = 2.56$; $df = 1$; $p = 0.2$). As the %P is the least reliable of the three adjusted scores it is safe to conclude that results to date do not show very clear cut influences of the effects of various rearing methods on ability characteristics as measured in the closed-field test. A much larger sample of animals is required.

Having raised a group of lambs with a known background it was possible to obtain results from a retest of these animals one year after the original test and again six months after this retest. This latter test was given with each problem reversed according to the mirror image of the original problem. Unfortunately the original experimental group was savaged by marauding dogs soon after the first retest and this decreased the numbers to seven animals for comparisons for test-retest reliability of the closed-field test.

The results from the three trials are set out in table 48. No consistent trends are shown for %P, %R and TES scores. In the group of 7 subjects for which three scores are available, the TES

Table 48. The results of the original test of lambs one month after weaning on the closed field test, together with scores for their retest after one year, and a further test six months later using the mirror image of the standard problems.

lamb no.	Original scores			1 year retest			18 months retest (mirror image)		
	%P	%R	TES	%P	%R	TES	%P	%R	TES
0622	12.0	90.0	354.3	36.5	56.7	413.9	14.2	71.4	123.7
0540	22.8	60.8	288.8	36.7	37.3	164.1	46.2	100%	131.5
0538	27.4	79.5	267.5	11.4	70.0	155.3	19.4	100%	128.9
0865	39.2	68.2	577.6	29.5	74.1	204.1	30.0	100%	117.4
0535	32.4	72.5	512.5	0.0	100%	30.6	32.7	100%	161.5
0863	16.5	84.7	443.0	47.3	100%	105.6	19.0	90.5	195.0
0615	27.5	84.8	347.4	25.4	54.1	208.1	0.0	67.5	108.5

Actual scores for each of the problems 1 to 6 made by each of 7 lambs subject to test retest procedures after 12 and 18 months from the original test series.

lamb no.	Problem no.																	
	1	a	b	2	a	b	3	a	b	4	a	b	5	a	b	6	a	b
0622	2	10	0	32	18	8	0	12	0	68	26	8	4	0	2	0	0	8
0540	0	2	0	12	10	8	8	6	2	34	8	0	2	0	6	0	0	8
0538	0	0	0	14	6	10	6	0	0	18	8	0	2	2	4	0	14	16
0865	4	8	0	38	2	10	20	0	2	34	14	4	4	0	2	24	8	2
0535	0	0	0	26	0	8	18	0	4	28	6	4	2	0	2	22	0	8
0863	4	4	0	22	0	20	6	4	2	44	10	4	2	0	2	40	0	10
0615	2	6	0	20	6	10	8	0	0	18	10	2	2	0	0	14	14	4
	<u>12</u>	<u>30</u>	<u>0</u>	<u>164</u>	<u>42</u>	<u>74</u>	<u>66</u>	<u>22</u>	<u>10.24</u>	<u>4.82</u>	<u>22</u>	<u>18</u>	<u>0</u>	<u>18</u>	<u>100</u>	<u>36</u>	<u>56</u>	

Total scores 1-6

	original test	retest (12 months)	mirror image retest (18 months)
0622	106	66	26
0540	56	26	24
0538	40	30	30
0865	124	32	20
0535	96	6	26
0863	118	18	38
0615	64	36	16
	<u>604</u>	<u>214</u>	<u>180</u>
	89	31	26

show a considerable drop over the period of a year between testing although one animal is still high. At the 18 months mirror image retest the TES scores drop again and show consistency for the group, something not seen for any other experimental group run in this test. As the animals got older or were tested again more of them were able to eliminate making errors after run 4; i.e., they could score 100% on %R.

On further analysis the actual error scores for each problem were tabulated; i.e., original test scores (labelled 1 to 6); retest scores 12 months later (labelled a) and mirror image retest scores after 18 months (labelled b). These are shown in table 48. Improved performance on most problems is shown on the 12 months retest and a further improvement is shown on the visual problems with the mirror image retest 18 months after the original test. With the non-visual, average-difficulty problems like 2 and 6, the subjects gave a poorer performance on the mirror image retest. In the series 1-6, scores showed the greatest drop between the original test and the 12 months retest.

Very close scores for all subjects were made on the retest at 18 months. Because of the possible effects of increasing maturity, it is difficult to draw valid conclusions from this work. The animals can be considered mature only at the time of the first retest. The very close scores on the second retest seem to indicate that if adult subjects are tested again, individual variation in scores is considerably decreased and the rank order

of any subject could easily be changed.

Further discussion on the results from sheep is reserved till the section on species comparisons.

Pigs in the closed-field test. Pigs were tested as they became

available from the piggery and this could not be planned in a great deal of detail beforehand. Rings were placed in the noses of all subjects to prevent them rooting in the shavings on the floor of the maze. The trials run in summer with pigs had to be carried out early in the morning as the Large Whites were susceptible to sun-burn. In the autumn trials, difficulty was experienced with leaves from poplar trees some 100 metres distant being blown into the arena by easterly winds. Despite the systematic removal of these by hand, the pigs managed to find a few that had been missed and they would spend time during the training trials searching for leaves. At other seasons when leaves were not present, the pigs would pick up the larger chips among the shavings and hold these in their mouths during the trials, rejecting them into the food box. In one winter trial, road metal used to prevent pugging in a raceway, provided small round pebbles which the pigs rooted out of the soft mud and carried in the mouth.

In the first trial with pigs a dry pellet food was used as reward. This proved satisfactory during the training trials but during the test runs it was found that the pigs were not eating the nuts but holding them in the mouth until they had entered the arena for the next run. They then scattered these nuts around in

the shavings and spent time nosing and rooting around until they were gathered up again and eaten. Up to 5 minutes was spent in this activity before the run was continued. This same group of pigs continued to gain weight during the experimental period and it was found that they were consuming large quantities of bedding straw. The data from these four pigs has not been included in this analysis.

Beginning with the second group, the feeding meal was mixed with water to a porridge-like consistency and these problems were overcome. Breland and Breland (1961) when describing pigs being trained for show performances stated that the behaviour after a period of time begins to regress and the subjects begin to exhibit primitive rooting patterns. They considered it to be a species-specific "instinctual" behaviour pattern.

Considerable difficulty was experienced with pigs in the return raceway during training and a small stick was carried to hit the snout of the pig each time it reversed. This was not always successful and at times pigs would have to be brought back along the raceway several times before they could be forced into the start gate entrance for the next run. Pigs rushed headlong into barriers of all kinds during these early training trials, pushing through any available hole or crevice. They provided the most severe test for the apparatus. A number of pigs became so interwoven with timber and wire netting that they had to be cut free with saw and wire-cutters. Only pigs over 120 lbs were large

enough for testing in the apparatus. Even the most stubborn and excitable pig did not go without food for longer than two days and they settled down into the experimental routine with little trouble after day 3 of the training trials. All pigs reached the criterion of 8 runs out of 9 correct on days E and F of the training problems.

While being taken across to the experimental area on the fourth day, the first experimental group bolted down the raceway and was found searching for food in the food box area. By the beginning of the test problems the pigs were running freely in the return raceway without aid and the pushing and shoving of the group to get through the gate from the holding pen to begin the trials made it difficult to let through one pig at a time.

The smaller pigs of the litter groups which were tested in the early training runs displayed a grunt-listen sequence. They would stop in the arena and grunt, then listen for a few moments, then move several yards and repeat this behaviour. After the first few days of trials however, the pigs ran very freely and on the simple visual problems such as problem 9, groups of 3 pigs could be run in slightly under 10 minutes for the completed trial. In general the pigs were the most amenable and easy to handle, and worked well for a food reward when compared with the ruminant subjects used. One group of pigs was maintained for six months at constant body weight using the feeding schedule adopted.

In an attempt to assess the relative importance of vision and olfaction in the solution of detour problems by pigs, a small trial

was run with blindfolded pigs and pigs with their nostril areas coated with Vicks common cold preparation which contains methanol, camphor and oil of eucalyptus. Blindfolded pigs were not able to solve the detour problems even though 4 normal subjects had run their eight runs perfectly before the trials. Blind animals ran into walls and barriers repeatedly and even though one animal by chance almost moved out the exit gate it reversed its movements and after one hour had not reached a solution. Some difficulty was experienced in keeping the blindfold on a pig and as an alternative trial a test during darkness was attempted. On a night without a moon the six pigs tested ran almost without error through a new detour problem including 3 pigs which had had the treatment to disrupt the olfactory cues which might be present. Sufficient light was available to allow the experimenters, after their eyes had become dark-adapted, to follow the pigs from four vantage points around the arena. It was considered that visual cues are essential to pigs in their mastery of detour problems in the closed-field test.

A study of the pathways taken by pigs in each problem provides some contrasts with the routes taken by cattle and sheep (figures 22 to 30). Pigs have to penetrate to within 4 to 6 feet of a blind end before they turn and retrace their steps. This means that greater numbers of subjects went further into blinds than for both sheep and cattle. As they travel at a faster overall speed they tend to range quite widely from the straightest pathway in the first

few runs. Because of their poor use of vision they sometimes turn back even after moving in the correct path, such as in problem E of the training series or D where one pig turned back after passing the last baffle and being within 30 feet of the exit gate. Four of the training problems and the routeways used by pigs are shown in figure 34, to illustrate these basic differences in performance.

In problem A, 29 pigs penetrated the top left blind to the last square and only 16 pigs entered the bottom right blind, nine turning back before the corner. Only 3 of the 63 pigs showed any marked retracing of pathway or major deviation from the diagonal path after getting clear of the blind alleys. In problem B, 35 pigs went into the corner and 29 other pigs were trapped for a time in this area. Seven pigs ran along the wall and 3 pigs followed the barrier wall before moving to the exit gate.

Twenty-nine pigs made a devious pathway behind the barrier in problem C trying to find the gap from the day before. The overall impression was that pigs have a short-range spatial orientation and search for place positions in the maze. Like sheep, 13 pigs moved well off the direct route after the main barrier had been rounded with one pig going right to the far corner to search for the exit gate without success. One pig displayed a very erratic pathway on both sides of the barrier. A greater number of pigs were trapped behind the barriers of problem D than cattle or sheep. The pig pathways reflect their inability to use longer distance visual cues for direct solution. In problem E, 22 pigs, after

Fig. 34 Pathways taken by pigs in selected training problems in the Closed-field Test. The numbers in circles indicate the number of pigs which took that error pathway.

moving varying distances through the gap in the wall turned back before getting clear of the last baffle and spent further time exploring the area on the entrance gate side of the main barrier before solution. No mistakes were made on the second run. Finally in problem F of the training series most pigs were trapped behind the right side blind and only 7 pigs went behind the top left cul-de-sac. In all cases the shortest pathway was followed on run 2 and all pigs reached criteria on problems E and F.

In problem 1 (figure 35) 22 pigs moved into the last square in the top left hand blind; 24 to within one square; 14 to within two squares and 16 broke one square into this blind. Thirty-six went right into the corner in the goal box direction and 21 turned away one square from the corner. Ten pigs became lost in this general area. Altogether 3 pigs doubled back into the hook of the "J" barrier. This was not expected. On problem 2 only a few pigs went into either of these corners, 15 to the top left and 16 to the top right cul-de-sac. In problem 3, 47 pigs broke one square; 34 moved across two squares; 36 across 3 squares and 27 went right into the blind corner on the diagonal path. No pig was confused in this problem however. More pigs than sheep or cows, viz. 56, went right into the corner on the diagonal pathway in problem 4. Forty-one went to within one square; 34 within 2 squares and 38 veered off the main pathway to make two errors. As well as this another 17 pigs got involved in pathways behind or around the two baffle barrier that stands apart from the main baffle pattern.

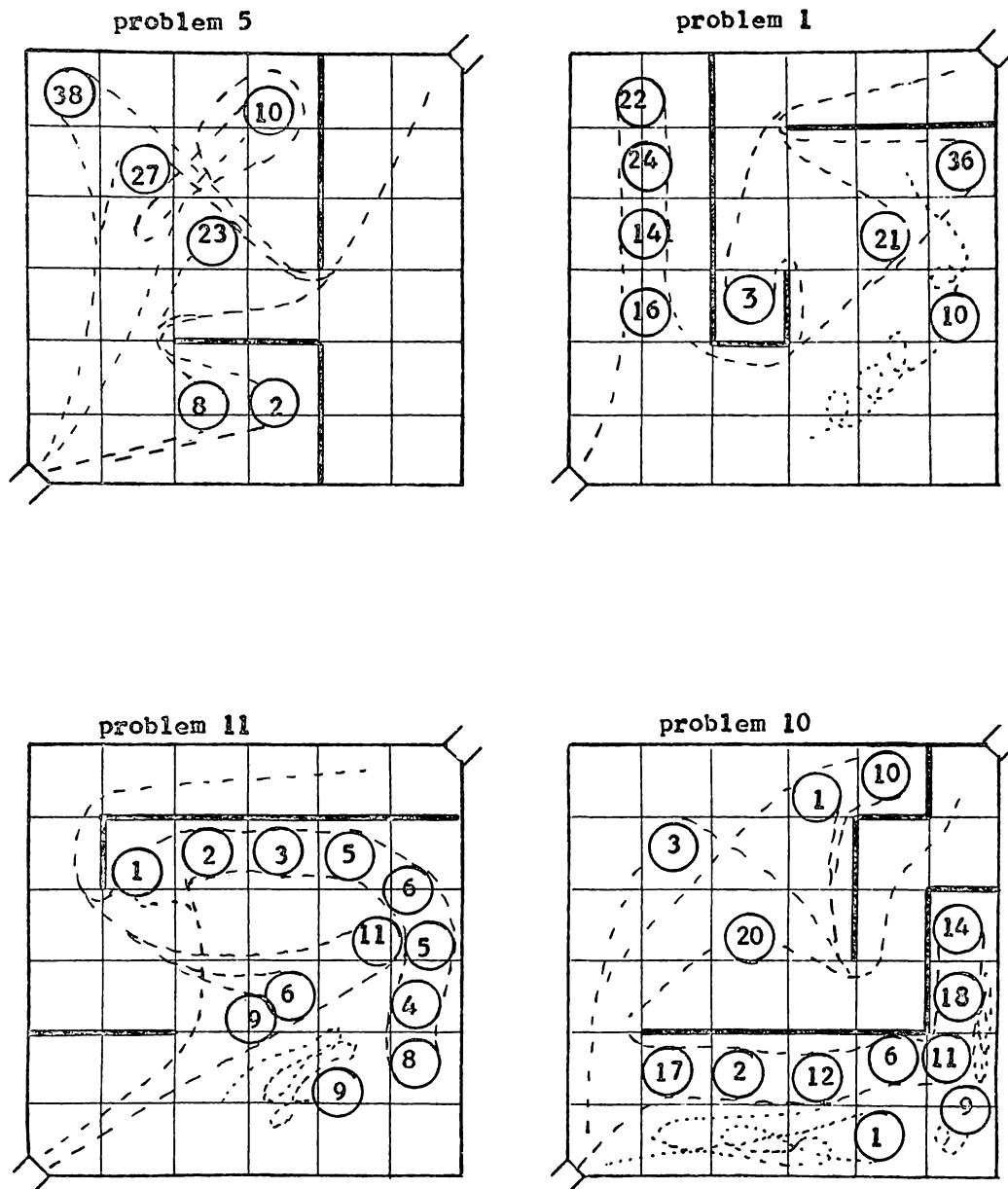


Fig. 35 Pathways taken by pigs in selected test problems in the Closed-field Test. The numbers in circles indicate the number of pigs which took that error pathway.

Figure 35 shows the pig pathways for problems 1, 5, 10 and 11. The pathways in number 5 problem show an unpredictable trend towards the top right hand corner before turning and finding the gap, as though the pigs were following the pathway of problem 4 on the previous day. Only 10 animals made any signs of entering the first cul-de-sac near the entrance gate. The patterns of pathway on problem 6 are exceptionally complicated and pigs found this a difficult problem although only 35 pigs erred on the first run. They made a higher average error score on this problem than on any other. Some pigs, after fully exploring the area to the top left side, turned back and went behind the barrier near the start gate. Thirty-two of the pigs showed complicated pathways in the top left segment, most breaking more than 24 squares. In a similar way, problems 7 and 8 were difficult for all pigs and the most complicated pathways were common on the first run. The central barrier generally acted as a pivot point and the animals ran up one side and then up the other side and this pattern was repeated. In problem 9 all but five of the errors were in the blind on the bottom right, the direction of the pathway of the problem of the day before. Twenty-two pigs penetrated into the last square, 18 to the one before, then 7, 5 and 5 respectively as pigs eliminated this blind completely. The patterns of problem 10 are illustrated in figure 35. They follow very much the picture of problem 9 in that the majority of errors are in the bottom right cul-de-sac and only 14 seriously err once past the main barrier.

Nine pigs had considerable difficulty in retracing their pathway from the right hand blind and spent time running back and forwards in this area and one pig showed similar behaviour in the area nearer the start gate. The patterns of problem 11 very clearly illustrate the pathways of pigs. The original movements across the diagonal and the correction of the pigs to the proper pathway is shown. The second trend is when pigs missed the opening and followed the barrier wall almost completing the arc before retracing their steps and eventually coming through the gap to the final alleyway. Nine pigs became confused in the central area and one closer to the main barrier. In problem 12, the complication of the 3 baffles to form the non-visual problem affected the pigs in a different way from sheep or cows. Only four pigs of the 59 tested moved directly across the diagonal as one would expect for sheep or cows. Another 21 moved 2 squares across the diagonal, seemingly following the path of the problem of the day before, before correcting themselves to the shortest pathway. Almost all the errors were made after pigs missed the correct gap, got in behind the barrier then swept through a similar arc to that shown on problem 11. Some circled the barrier several times and 12 pigs after doing this twice, made for the bottom right hand corner as the exit gate.

Turning to the error scores it can be seen that all pigs in table 49 or all but one in table 50 made errors in problems 1, 3, 4, 5, 7 and 8 in the first run and this happened again in run 2 for problems 4 and 7. Only six pigs had mastered problem 7 by the third run and only 9 had mastered problem 4 by the third run. One pig made 220 errors in problem 11 and a score of over 100 was made by

Table 49 : Summary of total errors made by 63 pigs tested on problems 1 to 6 of the closed-field test.

run no.	Problem no.						Total % of	
	1	2	3	4	5	6	1-6	total
1 Ss in error	62	28	63	63	62	35	313	83%
total error	1238	258	482	792	514	1302	4586	
pig av.	20.0	9.2	7.7	12.6	8.3	37.2	14.7	
range	0-128	0-54	0-22	0-46	0-30	0-116		
S.D.	43.36	2.40	12.75	14.97	13.19	46.24		
2 Ss in error	43	13	53	63	28	18	218	60%
total error	214	76	178	410	136	500	1514	
pig av.	5.0	5.8	3.4	6.5	4.9	27.8	6.9	
range	0-22	0-16	0-8	0-24	0-8	0-156		
S.D.	6.31	3.01	3.32	3.26	2.44	8.81		
3 Ss in error	20	11	18	54	10	9	122	33%
total error	70	72	62	224	34	130	592	
pig av.	3.5	6.5	3.4	4.1	3.4	14.4	4.9	
range	0-10	0-14	0-8	0-8	0-6	0-54		
S.D.	2.26	2.59	1.95	3.92	1.35	7.47		
4 Ss in error	5	3	6	30	1	5	50	13%
total error	20	4	22	114	2	62	224	
pig av.	4.0	1.3	3.7	3.8	2.0	12.4	4.5	
range	0-6	0-2	0-4	0-8	0-2	0-30		
S.D.	1.21	0.50	1.14	2.34	0.24	1.34		
5 Ss in error	3	3	9	12	3	4	34	9%
total error	20	16	30	52	20	44	182	
pig av.	6.7	5.3	3.3	4.3	6.7	11.0	5.4	
range	0-10	0-12	0-6	0-8	0-16	0-28		
S.D.	1.52	1.59	1.30	1.19	2.03	1.90		
6 Ss in error	3	4	6	11	1	1	26	7%
total error	8	16	24	42	24	66	180	
pig av.	2.7	4.0	4.0	3.8	24.0	66.0	6.9	
S.D.	0-64	1.09	1.23	1.63	3.00	8.24		
7 Ss in error	-	5	8	10	1	1	25	7%
total error	-	32	26	36	2	4	100	
pig av.	-	6.4	3.3	3.6	2.0	4.0	4.0	
S.D.	0	2.11	1.28	1.58	0.24	0.50		
8 Ss in error	-	4	7	9	-	1	21	6%
total error	-	22	26	32	-	16	96	
pig av.	-	5.5	3.7	3.6	-	16.0	4.6	
S.D.	0	1.43	1.41	1.37	0	2.0		
Ss in error 1-4	130	55	140	210	101	67	703	
total error 1-4	1542	410	744	1540	686	1994	6916	
pig av. 1-4	11.9	7.5	5.3	7.3	6.8	29.8	9.8	
total error 5-8	28	86	106	162	46	130	558	
SS in error 1-8	136	71	170	252	106	74	809	
total error 1-8	1570	496	850	1702	732	2124	7474	
pig av. 1-8	11.5	7.0	5.0	6.7	6.9	28.7	9.2	

Table 50. Summary of total errors made by 59 pigs tested on problems 7 to 12 of the closed-field test.

run no.	Problem no.						total 7-12	total 1-12	% of 7-12
	7	8	9	10	11	12			
1 Ss in error	59	59	46	53	39	34	290	603	82%
total error	2016	2010	408	910	1106	534	6984	11570	
pig ave.	34.2	34.1	8.9	17.2	28.4	15.7	24.1	19.2	
range	0-194	0-118	0-50	0-16	0-220	0-63			
S.D.	48.92	170.31	4.55	63.04	56.73	11.61			
2 Ss in error	58	25	10	37	19	26	175	393	50%
total error	564	388	46	442	336	268	2044	3558	
pig ave.	9.7	15.5	4.6	11.9	17.6	10.3	11.7	9.1	
range	0-42	0-40	0-8	0-26	0-94	0-40			
S.D.	10.13	7.34	1.56	24.66	9.62	7.49			
3 Ss in error	53	10	2	12	9	17	103	225	29%
total error	382	90	6	94	64	148	784	1376	
pig ave.	7.2	9.0	3.0	7.8	7.1	8.7	7.6	6.1	
range	0-56	0-16	0-4	0-12	0-22	0-22			
S.D.	8.62	2.68	0.56	2.82	3.76	8.44			
4 Ss in error	32	4	-	8	4	11	59	109	17%
total error	138	32	-	76	14	96	356	580	
pig ave.	4.3	8.0	-	9.5	3.5	8.7	6.0	5.3	
range	0-12	0-24	-	0-16	0-42	0-26			
S.D.	2.30	3.14	0	3.27	5.47	2.64			
5 Ss in error	19	1	1	7	1	4	32	66	7%
total error	70	2	6	48	-	68	194	376	
pig ave.	3.7	2.0	6.0	6.9	-	17.0	5.9	5.6	
S.D.	2.71	0.24	0.77	2.77	0	2.00			
6 Ss in error	4	2	-	2	-	5	13	39	4%
total error	10	14	-	20	-	28	72	252	
pig ave.	4.0	7.0	-	10.0	-	5.6	5.5	6.5	
S.D.	0.72	1.56	0	1.84	0	1.59			
7 Ss in error	1	1	1	4	2	4	13	38	4%
total error	2	2	2	30	6	74	116	216	
pig ave.	2.0	2.0	2.0	7.5	3.0	18.5	8.9	5.7	
S.D.	0.24	0.24	0.24	2.01	0.56	8.25			
8 Ss in error	-	2	-	-	1	6	9	30	3%
total error	-	6	-	-	8	26	40	136	
pig ave.	-	3.0	-	-	8.0	4.3	4.4	4.5	
S.D.	0	0.56	0	0	1.03	1.62			
Ss in error 1-4	202	98	58	110	71	88	627	1330	
total error 1-4	3100	2520	460	1522	1520	1046	10168	17084	
pig ave. 1-4	15.3	25.7	7.9	13.8	21.4	11.9	16.2	12.8	
total error 5-8	82	24	8	98	14	196	422	980	
Ss in error 1-8	226	104	60	123	74	107	694	1503	
total error 1-8	3182	2544	468	1620	1534	1242	10590	18064	
pig ave. 1-8	14.1	24.5	7.8	13.2	20.5	11.6	15.2	12.0	

a pig in each of problems 1, 6, 7 and 8. These all dropped below the 100 errors by run 2 except for one pig in problem 6. An average of 37 errors per pig was committed by those which went astray on the first run in problem 6. Rather similar total scores and average scores were made on problems 7 and 8 by pigs in the first run but the correct path was easily taken in problem 8 by all but 25 pigs on run two, while 58 pigs were having difficulty in problem 7. This similar trend is shown on runs 3 and 4 for these two problems. Problem 4 was the most difficult to master and 9 pigs were still making errors on run 8.

The error groupings for pigs are shown in tables 51 and 52. Whereas with cows and sheep more animals were getting the problem correct by run 2 than were making mistakes, this was not so with pigs except in problem 6. As a general rule it can be said that because of the limited use of visual cues in pigs, their performance was inferior to that of sheep or cows. Though problem 6 and problem 2 had a greater number of pigs making runs without errors in the whole 8 runs, only one pig made more than 20 errors on problem 2 while 14 pigs made more than 50 errors in problem 6. Pigs found problem 7 difficult and it took 4 runs to have more than 50% of the animals correct. The pigs making errors in problem 12 were slow to eliminate them, yet the number of runs on which all pigs were perfect was better than for either sheep or cows. Though they were a little slower in initial learning they scored fewer errors in later runs.

The transformed scores for pigs are found in the third column

Table 51 : Summary of individual error scores of 63 pigs in problems 1 to 6 of the closed-field test.

Run no.	Problem no.						Total
	1	2	3	4	5	6	
1. errorless	1	35	-	-	1	28	65
2-10 errors	21	17	54	33	46	1	172
12-20 errors	25	10	8	23	15	11	92
21-50 errors	13	-	1	7	1	16	38
50+ errors	3	1	-	-	-	7	11
	<u>63</u>	<u>63</u>	<u>63</u>	<u>63</u>	<u>63</u>	<u>63</u>	<u>378</u>
2. errorless	20	51	10	-	25	45	151
2-10 errors	39	10	53	60	38	5	205
12-20 errors	3	2	-	2	-	6	13
22-50 errors	1	-	-	1	-	5	7
50+ errors	-	-	-	-	-	2	2
							<u>378</u>
3. errorless	43	51	45	9	52	54	254
2-10 errors	20	10	18	54	11	6	119
12-20 errors	-	2	-	-	-	2	4
20+ errors	-	-	-	-	-	1	1
							<u>378</u>
4. errorless	58	60	57	33	62	58	328
2-10 errors	5	3	6	30	1	2	47
22-50 errors	-	-	-	-	-	3	3
							<u>378</u>
5. errorless	60	60	54	51	60	59	344
2-10 errors	3	2	9	12	2	2	30
12-20 errors	-	1	-	-	1	1	3
20+ errors	-	-	-	-	-	1	1
							<u>378</u>
6. errorless	60	59	57	52	62	62	352
2-10 errors	3	4	6	11	-	-	24
12-20 errors	-	-	-	-	-	-	-
22-50 errors	-	-	-	-	1	-	1
50+ errors	-	-	-	-	-	1	1
							<u>378</u>
7. errorless	63	58	55	53	62	62	353
2-10 errors	-	4	8	10	1	1	24
12-20 errors	-	1	-	-	-	-	1
							<u>378</u>
8. errorless	63	59	56	54	63	62	357
2-10 errors	-	4	7	9	-	-	20
12-20 errors	-	-	-	-	-	1	1
							<u>378</u>
Errorless 1-8	368	433	334	252	387	430	2204
2-10 errors	91	54	161	219	99	17	641
12-20 errors	28	16	8	25	16	21	114
22-50 errors	14	-	1	8	2	26	51
50+ errors	3	1	-	-	-	10	14

Table 52 : Summary of individual error scores of 59 pigs in problems 7 to 12 of the closed-field test.

Run no.	Problem no.						7-12 total	Overall total
	7	8	9	10	11	12		
1. errorless	-	-	13	6	20	25	64	129
2-10 errors	14	7	41	11	13	15	101	273
12-20 errors	18	6	5	30	8	12	79	171
22-50 errors	13	35	-	12	14	5	79	117
50+ errors	14	11	-	-	4	2	31	42
	<u>59</u>	<u>59</u>	<u>59</u>	<u>59</u>	<u>59</u>	<u>59</u>	<u>354</u>	<u>732</u>
2. errorless	1	34	49	22	39	33	178	329
2-10 errors	46	10	10	10	11	18	105	309
12-20 errors	9	7	-	25	5	6	52	66
22-50 errors	3	8	-	2	2	2	17	24
50+ errors	-	-	-	-	2	-	2	4
	<u>59</u>	<u>59</u>	<u>59</u>	<u>59</u>	<u>59</u>	<u>59</u>	<u>354</u>	<u>732</u>
3. errorless	6	49	57	47	50	42	251	505
2-10 errors	48	6	2	9	7	14	86	205
12-20 errors	2	4	-	3	2	2	13	17
20+ errors	3	-	-	-	-	1	4	5
							<u>354</u>	<u>732</u>
4. errorless	27	55	59	51	55	48	295	623
2-10 errors	31	3	-	5	3	9	51	98
12-20 errors	1	-	-	3	1	1	6	6
20+ errors	-	1	-	-	-	1	2	5
							<u>354</u>	<u>732</u>
5. errorless	40	58	58	52	59	55	322	666
2-10 errors	18	1	1	5	-	2	27	57
12-20 errors	1	-	-	2	-	1	4	7
20+ errors	-	-	-	-	-	1	1	2
							<u>354</u>	<u>732</u>
6. errorless	55	57	59	57	59	54	341	693
2-10 errors	4	1	-	1	-	5	11	35
12-20 errors	-	1	-	1	-	-	2	2
20+ errors	-	-	-	-	-	-	-	2
							<u>354</u>	<u>732</u>
7. errorless	58	58	58	55	57	55	341	694
2-10 errors	1	1	1	3	2	3	11	35
12-20 errors	-	-	-	1	-	-	-	-
					50+	1	2	3
							<u>354</u>	<u>732</u>
8. errorless	59	57	59	59	58	53	345	702
2-10 errors	-	2	-	-	1	6	9	29
							<u>354</u>	<u>732</u>
Errorless 1-8	246	368	412	349	397	365	2137	4341
2-10 errors	162	31	55	44	37	72	401	1041
12-20 errors	31	18	5	65	16	22	157	271
22-50 errors	19	44	-	14	16	10	103	155
50+ errors	14	11	-	-	6	3	34	48
	<u>472</u>	<u>472</u>	<u>472</u>	<u>472</u>	<u>472</u>	<u>472</u>	<u>2832</u>	<u>5856</u>

of tables 33, 34 and 35. The mean %P score is almost at 50% indicating that they did as well on the non-visual problems as on the visual problems. Noted comments taken during the closed-field trials also indicate this. In some cases it seemed to the observers that sheep and cows were led astray by their better vision in the non-visual problems whereas pigs, being at a disadvantage in both, did comparatively well on the more complicated non-visual problems. On the %R score their ability to avoid errors after run 4 is clearly shown in the higher mean for pigs. Although only 39% of the pigs scored 100% on this score, only 17 subjects scored lower than 90%. In overall errors (TES) the pigs made considerably more errors than either sheep or cows with a mean of 422.6. They follow approximately 200 units behind the cows in their range of scores.

As the pigs made a greater number of errors it can be expected that their ratio scores for %P and %R would be more reliable than for similar scores for sheep and cows. An examination of the high and low scorers revealed the following: the pig with the second lowest %P; i.e., 28.0% performed very well indeed on all problems except problem 6 where in the second run, $7\frac{1}{2}$ minutes were spent trying to find the gap between the barriers. This one run raised the score considerably to 28.0%. A pig with 65.0%P made perfect runs on problems 2 and 6 and made only 8 more errors in problem 4 than 3. Errors on problem 1 and an incorrect run 6 in problem 5 made up this high %P score.

Similar patterns are shown for the %R scores as discussed earlier for sheep and cows, in one case serious error on run 7 in

problem 2 led to a poor %R score. The pigs with the highest TES were those which showed consistent error from trial to trial and problem to problem rather than the pigs which became confused in one problem only. This would be expected in an animal less dependent on vision than sheep or cows. Further discussion of the pig results is reserved until the section on species comparisons.

Dogs in the closed-field test. Although some difficulty was experienced in obtaining large numbers of dogs for testing it has been possible to run 15 dogs through the series 1-6 and 12 dogs through the series of 7-12 problems. The first group to be tested were trained farm dogs which were in use at Ruakura. They were used for sheep work during the testing period only when no other dog was available, and under no circumstances were they allowed to roam or be fed while working. The full ration of daily food was given during the trial period. As the dogs were required to work, deprivation could not be too severe and some dogs ran poorly during training. The mince meat offered was largely rejected by some dogs for several days.

The large entrance and exit gates to the arena were left closed at all times and the dogs were let into the field through a small sliding trap door specially built into the larger door. This design enabled caged animals to be run as the cage could be butted directly against the start or finish gates making it impossible for the subject to escape. As well as the two observers for recording pathways, two additional persons were required for running the dogs; the farm dogs required one person at the start gate to call dogs for the next trial run, and one person at the finish gate to feed the subject as it rushed by. Several of the bitches ran each run in 6 to 7 seconds and would be back around the return raceway in another 10 seconds, so the trial time for the day amounted to a few minutes. The male dogs, in contrast, were much more unpredictable

in their times, pathways and overall performance. Many stopped to urinate and sniff certain corners and areas of the arena during the trial runs.

Another difficulty with dogs was their ability to perceive the recorder even in the best type of hide available, and to wait for some type of human direction from the experimenters. The farm dogs were particularly prone to this and would stop for some time during the training period near the observation points. As the animals became hungry however they ran freely through the arena.

The second experimental group was made up of dogs from city owners. In this case the two experimenters had to stand near the goal box; one to feed the animal and the other to send it off on its way round the return raceway. Once the dog had started to move it continued to run around and entered the arena. It was impossible to continue to run 3 of these dogs in the series 7 to 12 because of the strong desire of the owners to have them back in the household. It appears that two weeks of separation is as much as can be tolerated by most dog owners. Age, breed and background for each dog tested is shown in table 53.

Both groups of dogs only reached criterion with 7 days of training. It might be that with the slow introduction of the deprivation schedule adopted, poor motivation on the early days of training was responsible for this additional day in the experimental procedure. As dogs were not readily available for testing it has not been determined if this is so, or if dogs as a species require

Table 53. Breed and background history of 15 dogs tested in the closed-field test.

Name	Breed	Sex	Other details	Age at testing
Tyke	Sheep/collie	male	Trained farm dog -head and hunt	6 yrs
Dan	Sheep/beardie	male	Trained farm dog -head and hunt	4 yrs
Ben	Sheep/?	male	Farm pup in training - heading	5 mths
Shah	Samoyed	male	Town dog	2 yrs
Barney	Golden Lab.	male	Town dog	6 mths
Mutt	Sheep/?	male	Old farm dog, now a town dog	? yrs
Rascal	Terrier	male	Mature dog - stray	? yrs
Cindy	Sheep/ ?	female	Medium eye heading dog trained	5 yrs
Jodie	Sheep/ ?	female	Pup of Cindy (also Ben) training	5 mths
Tracey	Cocker spaniel	female	Breeding bitch - town dog pedigree	2 yrs
Jane	Mongrel	female	Timid town dog	2 yrs
Vicky	Sheep/ ?	female	Fully trained	2 yrs
Irvine	Irish setter	female	Town dog	9 mths
Gin	Terrier	female	Stray pup	9 mths ?
Mac	Sheep/ ?	female	Partly trained	9 mths

the additional day of training. With the results from only 15 dogs available for comparative purposes the conclusions for this species need further verification, and the sample size should be increased. It is of interest however to examine the pathways taken by the dogs during the training and test problems.

The tracks of dogs in the training problems are like pig tracks. Dogs have moved into the last squares on problem A and 3 of them have followed along the side of the baffles once they had been rounded before heading towards the exit gate. (See figure 34). In a similar way they put their noses to the ground and followed along the walls and baffles in problem B, probably using olfactory cues. One dog followed around the baffle into the bottom right corner in search of the exit gate. In problem C, 6 dogs moved around the barrier and followed the baffle line almost into the left hand corner before circling around and moving to the exit gate. Up to this stage there were few dogs showing any retracing of their steps but this became more common from problem D onwards. Curves, circles and twists are shown in the pathways of dogs in behind the bottom right hand blind. One dog followed this barrier round and made a two square error on the exit side of this group of baffles. Of the training problems, pathways in E are the most involved. Twenty-one dogs had trouble before finding the gap and 4 dogs moved in several circles after passing the gap and before making their exits. In problem F the dog patterns again follow closely that of the pigs (see figure 34). It was the general confusion created by problem E which necessitated the dogs running

an extra day in the training series before they reached the criterion of 8 runs out of 9 correct on two consecutive days, in this case on days 6 and 7.

In problem 1, 5 dogs moved behind the left top barrier and 6 went into the right diagonal corner. Similar numbers went left in problem 2, and 5 went right to the end of the right hand blind. Few dogs made errors in problem 3 but 15 went in behind the barriers in one combination or another in problem 4. Problem 5 showed rather complex pathways similar to that of the pigs. Three dogs became confused in the blind near the start gate and 17 ran straight into the top right blind before returning to the gap. In problem 6 all the errors were confined to the top left blind but two dogs, after moving through the gap, turned to the incorrect corner for the exit gate. Problem 7 was not as difficult for dogs as for the other species tested and only 9 dogs showed real penetration into any one of the blind corners. Problem 8 was more difficult and the pathways roam over most of the arena, though there was no retracing of pathway or moving over the same ground again. Dogs still move into the last square of a blind before returning to find the correct path. Seven dogs went into the bottom right cul-de-sac in problem 9 but only two moved slightly off course after this barrier was negotiated. This was not so in problem 10 where animals showed very complicated pathways with penetrations into both blind alleys. In problems 11 and 12 the dogs tended to run to the right from the start gate but correct themselves in time to have a clear view of

the gap in the barriers and so move to the correct pathway with ease. Only two dogs in each of problems 11 and 12 made errors in the region of the top barrier. In general it can be said (a) that dog and pig pathways on run 1 are similar and (b) once an area of the arena has been explored it is not entered again; as in problems 7 and 8.

Table 54 shows the errors committed by the 15 dogs in problems 1 to 6. The dogs show the most rapid elimination of errors. Having once gone over the ground they seldom move across it again, though they may twist and curve on the original trial run. The range for dogs is generally low and only in problem 5 did the entire group of 15 dogs make errors in the first run. Less than one third of the subjects were making errors by the second run. They show the highest number of runs without error for any animals though it must be recognised that the sample is small compared with that of the other species tested.

Table 55 shows similar results for problems 7 to 12, for 12 dogs. Problem 10 proved most difficult on the first run, giving the highest average score, and the widest range of error. For dogs it was as difficult to master as problem 7. Very few dogs made any errors at all after the 4th run for the day; i.e., five out of the 72 possibilities. The error groupings are shown for dogs in tables 56 and 57. They show even more clearly that few errors are made after the third run of the day. In general, it seems clear that the problems provided very little difficulty for dogs as a

Table 54 : Summary of total errors made by 15 dogs tested on problems 1 to 6 of the closed-field test.

run no.	Problem no.						total % of	
	1	2	3	4	5	6	1-6	total
1 Ss in error	10	5	11	13	15	13	67	74%
total error	172	38	28	84	110	230	662	
dog av.	17.2	7.6	2.5	6.5	7.3	17.7	9.9	
range	0-60	0-10	0-4	0-16	0-16	0-52		
S.D.	15.66	2.83	1.91	5.68	10.92	40.12		
2 Ss in error	3	3	3	5	4	2	20	22%
total error	14	16	12	42	18	28	130	
dog av.	4.7	5.3	4.0	8.4	4.5	13.5	6.1	
range	0-8	0-8	0-8	0-22	0-6	0-18		
S.D.	2.10	2.41	2.04	5.10	1.30	4.98		
3 Ss in error	1	3	-	3	-	1	8	9%
total error	4	26	-	28	-	10	68	
dog av.	4.0	8.7	-	9.3	-	10.0	8.5	
S.D.	1.00	4.31	0	5.49	0	2.49		
4 Ss in error	1	2	2	4	-	1	10	11%
total error	6	10	6	12	-	2	36	
S.D.	1.49	1.74	1.08	1.00	0	0.50		
5 Ss in error	1	1	-	-	1	-	3	3%
total error	4	10	-	-	2	-	16	
S.D.	1.00	1.99	0	0	0.50	0		
6 Ss in error	-	2	-	-	1	1	4	4%
total error	-	10	-	-	4	8	22	
S.D.	0	1.74	0	0	1.00	1.99		
7 Ss in error	-	-	-	2	1	1	4	4%
total error	-	-	-	6	4	10	20	
S.D.	0	0	0	1.08	1.00	2.49		
8 Ss in error	2	-	-	-	1	-	3	3%
total error	14	-	-	-	2	-	16	
S.D.	3.00	0	0	0	0.50	-		
Ss in error 1-4	15	13	16	25	19	17	105	
total error 1-4	196	90	46	166	128	270	896	
dog av. 1-4	13.1	7.0	2.8	6.6	6.7	15.9	8.5	
total error 5-8	18	20	-	6	12	18	74	
Ss in error 1-8	18	16	16	27	23	19	119	
total error 1-8	214	110	46	172	140	288	970	
dog av. 1-8	11.9	6.9	2.9	6.4	6.1	15.2	8.2	

Table 55 : Summary of total errors made by 12 dogs tested on problems 7 to 12 of the closed-field test.

run no.	Problem no.						7-12 overall		% of 7-12	% of 1-12
	7	8	9	10	11	12	total	total		
1 Ss in error	11	12	7	12	8	6	56	123	78%	76%
total error	196	222	68	232	140	40	898	1560		
dog av.	17.8	18.5	9.7	19.3	17.5	6.7	16.0	12.7		
range	0-48	0-70	0-22	0-68	0-42	0-16				
S.D.	16.05	7.49	9.42	36.44	14.29	3.55				
2 Ss in error	6	4	-	7	2	2	21	41	29%	25%
total error	22	22	-	74	12	10	140	270		
dog av.	3.7	5.5	-	10.6	6.0	5.0	6.9	6.6		
range	0-10	0-12	-	0-22	0-8	0-6				
S.D.	2.92	2.88	0	4.50	2.37	1.86				
3 Ss in error	5	3	-	4	1	2	15	23	21%	14%
total error	14	30	-	38	4	14	100	168		
dog av.	2.8	10.0	-	9.5	4.0	7.0	6.3	8.0		
range	0-6	0-14	-	0-14	0-4	0-8				
S.D.	1.84	16.20	0	5.00	1.10	2.64				
4 Ss in error	2	-	1	3	1	-	7	17	10%	10%
total error	6	-	4	38	2	-	50	86		
dog av.	3.0	-	4.0	12.7	2.0	-	7.1	5.0		
range	0-4	-	0-4	0-16	0-2	-				
S.D.	1.18	0	1.10	5.74	0.55	0				
5 Ss in error	1	-	-	-	-	1	2	5	3%	3%
total error	2	-	-	-	-	4	6	22		
dog av.	2.0	-	-	-	-	4.0	3.0	4.4		
S.D.	0.55	0	0	0	0	1.10				
6 Ss in error	-	-	-	-	-	-	-	4	-%	2%
total error	-	-	-	-	-	-	-	22		
7 Ss in error	-	-	1	-	-	-	1	5	1%	3%
total error	-	-	10	-	-	-	10	30		
8 Ss in error	-	1	-	1	-	-	2	5	3%	3%
total error	-	14	-	8	-	-	22	38		
Ss in error 1-4	24	19	8	26	12	10	99	204		
total error 1-4	238	274	72	382	158	64	1188	2084		
dog av. 1-4	9.5	14.4	9.0	14.6	13.2	6.4	12.0	10.2		
total error 5-8	2	14	10	8	-	4	38	112		
Ss in error 1-8	25	20	9	27	12	11	104	223		
total error 1-8	240	288	82	390	158	68	1226	2196		
dog av. 1-8	9.6	14.4	9.1	14.4	13.2	6.2	11.8	9.8		

Table 56 : Summary of individual error scores of 15 dogs in problems 1 to 6 of the closed-field test.

Run no.	Problem no.						Total
	1	2	3	4	5	6	
1. errorless	5	10	4	2	-	2	23
2-10 errors	5	5	11	12	13	5	51
12-20 errors	2	-	-	1	2	5	10
22-50 errors	2	-	-	-	-	2	4
50+ errors	1	-	-	-	-	<u>1</u>	<u>2</u>
						15	90
2. errorless	12	12	12	10	11	13	70
2-10 errors	3	3	3	4	4	1	18
12-20 errors	-	-	-	-	-	1	1
20+ errors	-	-	-	1	-	-	<u>1</u>
							90
3. errorless	14	12	15	12	15	14	82
2-10 errors	1	2	-	2	-	1	6
12-20 errors	-	1	-	-	-	-	1
20+ errors	-	-	-	1	-	-	<u>1</u>
							90
4. errorless	14	13	13	11	15	14	80
2-10 errors	1	2	2	4	-	1	<u>10</u>
							90
5. errorless	14	14	15	15	14	15	87
2-10 errors	1	1	-	-	1	-	<u>3</u>
							90
6. errorless	15	13	15	15	14	14	86
2-10 errors	-	2	-	-	1	1	<u>4</u>
							90
7. errorless	15	15	15	13	14	14	86
2-10 errors	-	-	-	2	1	1	<u>4</u>
							90
8. errorless	13	15	15	15	14	15	87
2-10 errors	2	-	-	-	1	-	<u>3</u>
							90
Errorless 1-8	102	104	104	93	97	101	601
2-10 errors	13	15	16	24	21	10	99
12-20 errors	2	1	-	1	2	6	12
22-50 errors	2	-	-	2	-	2	6
50+ errors	1	-	-	-	-	<u>1</u>	<u>2</u>
						120	720

Table 57 : Summary of individual error scores of 12 dogs in problems 7 to 12 in the closed-field test.

Run no.	Problem no.						7-12 total	overall total
1. errorless	1	-	5	-	4	6	16	39
2-10 errors	6	4	5	3	4	5	27	78
12-20 errors	2	5	1	6	-	1	15	25
22-50 errors	3	2	1	2	4	-	12	16
50+ errors	-	1	-	1	-	-	2	4
						12	72	162
2. errorless	6	8	12	5	10	10	51	121
2-10 errors	6	3	-	4	2	2	17	35
12-20 errors	-	1	-	2	-	-	3	4
20+ errors	-	-	-	1	-	-	1	2
							72	162
3. errorless	7	9	12	8	11	10	57	139
2-10 errors	5	1	-	2	1	2	11	17
10+ errors	-	2	-	2	-	-	4	5
20+ errors								1
							72	162
4. errorless	10	12	11	9	11	12	65	145
2-10 errors	2	-	1	1	1	-	5	15
10+ errors	-	-	-	2	-	-	2	2
							72	162
5. errorless	11	12	12	12	12	11	70	157
2-10 errors	1	-	-	-	-	1	2	5
							72	162
6. errorless	12	12	12	12	12	12	72	158
2-10 errors	-	-	-	-	-	-	-	4
							72	162
7. errorless	12	12	11	12	12	12	71	157
2-10 errors	-	-	1	-	-	-	1	5
							72	162
8. errorless	12	11	12	11	12	12	70	157
2-10 errors	-	-	-	1	-	-	1	3
10+ errors	-	1	-	-	-	-	1	2
							72	162
Errorless 1-8	71	76	87	69	84	85	472	1073
2-10 errors	20	8	7	11	8	10	64	163
12-20 errors	2	9	1	12	-	1	25	37
22-50 errors	3	2	1	3	4	-	13	19
50+ errors	-	1	-	1	-	-	2	4
						96	576	1296

group.

The pathway and error analysis above should lead to a low Total Error Score (TES). This ranged from 455.4 to 88.4 with a mean of 244.0. This parallels the range and mean for cattle. Similarly, on the % R score 53% of the dogs scored 100.0%; i.e., they did not make any errors in the last four runs of each test series. The lowest score is 73.3% and the mean is 93.2%. The % P score ranges from 23.0% to 72.3% with a mean of 44.2%.

On the average, dogs provide the fastest times for maze running. The first run takes little more time than the remainder of the runs, as they tend to explore at a rapid pace. One dog gave persistent trouble by jumping out of the return raceway and running off during the experimental session but as she was a farm bitch she was called back and continued without difficulty.

Cats in the closed-field test. Originally it was hoped that a sample of cats could have been tested. The only species which has been tested by Pollard in the smaller sized closed-field (1961) and which could be tested in the large arena appeared to be the cat. This would have provided some data on the influence of size on performance (Pollard et. al., 1965). A number of difficulties were experienced which have precluded the insertion of such data for cats. Firstly, they were very

difficult to obtain. Whereas people were relatively unconcerned about lending their dogs for 2 weeks for behaviour trials, only 2 people would lend their cats in this way. Although many cats are taken to the veterinary clinics during the period of long vacation in the summer, labour was not available to conduct the trials at this time. As the cats cannot be relied on to move in the return raceway of their own initiative each cat had to be carried carefully in a carrying cage from the food box to the start box and this necessitated additional labour. Thirdly, the arena could not be made cat-proof. Three of the initial experimental group of 5 scaled the 7 foot wall with ease and escaped during the early training runs. When wire netting was extended over the outside walls to prevent this, the cats dug holes in the shavings and squeezed under the start or finish gates. Although considerable time was spent with these subjects in attempts to run a successful trial, only one cat completed the full experimental period without mishap and she gave birth to kittens before the trial was complete. The food reward provided was very attractive to the cats and was eaten quickly and quietly though some hesitation was shown to step through the gate into the food cage on some trials. The cat ran freely through the arena and made no attempt to squeeze under the baffles acting as barriers though it could have scaled them if it had wanted.

The results from the cat are as follows.

% P = 39.8, % R = 81.3 and total error score = 361.3.

It is hoped that with careful orientation and training it may be possible to run cats in the apparatus in the future.

Children in the closed-field test. An opportunity arose during the visit of a party of infant children to obtain some information on the basic pathways and general performance of children in the test. The children paid three separate visits to the site and the results are taken only from those children which were present on all 3 days. On the first day, they were given a brief picture of what the apparatus was used for and where the start and exit gates were. After this they were taken through the arena without barriers to the exit gate and round the return raceway and through the apparatus again until they were familiar with the main features of the test situation.

On day 2, they were run individually through problems 1, 4 and 5 until they had run 3 runs without error, or, in the case of children making error, until they refused to run through again. After each run they were provided with small coloured sweets which were either eaten or bartered with other children. One week later they ran problems 2, 3 and 6. One difficulty was the time spent changing the baffles between each problem.

There was little to do, but the teacher in charge took the children away from the site.

As the trial was conducted with children aged 4 to 8 years and was carried out in school hours, it was not possible to spend time on the training problems before the test. However, the results provide some evidence for the reactions of children in the large closed-field arena. Table 58 gives the results for the 19 subjects tested. No results from standardised intelligence tests were available from children of this age group but a teacher's assessment was obtained. There is no correlation between this assessment and the TES for children ($\rho = 0.03$). The periodic verbal exclamation made spontaneously by children after entering a blind alley provided some additional information not available for the other species tested. Table 58 indicates that problem 4 was the most difficult, followed closely by problem 6. No error was made on problems 3 and 5. 31% of the children made errors in the first run and this dropped to 11% by run 2. The %P was 1.9; %R = 99.0 and TES 79.1 for this sample.

Table 58. Summary of individual scores of 19 children
(aged 4-8 yrs) in problems 1-6 of the closed-field test.

run no.	problem no.						Total	
	1	2	3	4	5	6		
1. errorless	17	14	19	7	19	3	79	
2-10 errors	2	5		12		16	35	31%
						19	114	
2. errorless	19	17	19	12	19	16	102	
2-10 errors		2		7		2	11	11%
12 errors						1	1	
							114	
3. errorless	19	19	19	11	19	17	105	
2-10 errors				7		2	9	8%
							114	
4. errorless	19	19	19	16	19	19	111	
6-8 errors				3			3	3%
							114	
5. errorless	19	19	19	18	19	19	113	
8 errors				1			1	1%
							114	

Run 6, 7 and 8 all had perfect scores.

run	Total errors for 19 children in series 1-6.					
1.	6	18		82		74
2.		4		38		12
3.				46		4
4.				22		
5.				8		
	<u>6</u>	<u>22</u>	<u>0</u>	<u>196</u>	<u>0</u>	<u>90</u>
	3.0	3.1		6.5		4.3
						5.2

No errors after run 5 for children.

General Behaviour. During the handling of the stock for both open and closed-field testing, certain behavioural activity which appeared rather unusual was noted and in this section it is proposed to record and discuss such aspects of behaviour.

The first day trial in the open-field was in fact the first time each subject had been introduced to the general area of the arena, its raceways and compressed air system. During the five minute trial each subject was isolated from the experimental group in which it had been for 4 or 5 days prior to the trial. It was during the 3 days open-field tests that certain facets of behaviour of each species were so clearly shown. The summary of these aspects of behavioural activity are shown in Table 59 for cows, Table 60 for sheep and Table 61 for pigs.

Almost one third of the dairy cows tested during their five minutes in the arena began scraping the shavings on the floor and defecated or urinated during this period of pawing with one of the front feet (see plate 5, p.105). In several cases the defecatory response preceded the pawing but in the majority of animals pawing began first. The animals for any one day's trials tended to paw shavings within twelve feet of the pawings of the previous animal and defecated in the same general area after sniffing and pawing at the fresh and old dung pats; i.e., pats left from the day before. Nine of the 15 cows which gave examples of pawing did so on the first day of testing and four of these cows continued to do so

Table 59. Behavioural activities recorded during the trials of 44 cattle in the open-field test.

Activity	no. of animals
Pawing shavings - day 1 only	3
- day 2 only	1
- day 3 only	2
- day 1 and 2	2
- day 2 and 3	3
- day 1, 2 and 3	<u>4</u>
Total pawing shavings	15
active fast running	10
prancing (excited)	4
shows abrupt startle movements	5
sniffing objects	1
licking objects	1
displacement grazing	2
inactive; immobile	6
freezing behaviour	1
lying down	1
soft lowing (vocalisation)	1

Table 60. Behavioural activities recorded during the trials of 32 sheep in the open-field test.

Activity	no. of animals
pawing shavings	6
pawing exit gate	3
"dog-sitting" after pawing (rams only)	2
scratching belly with hoof	1
displacement grazing	3
charging exit gate	1
creeping out exit gate on belly	2
shaking body	1
heavy breathing and snorting	1

over the three days of testing. In two cases only did the animals continue to paw and throw shavings over the back and withers during the trials of the closed-field test which followed. An additional six animals began pawing and defecating on day two or three although no response was given during the initial exposure to the strange field.

This type of behaviour was not anticipated and it appeared to have something to do with marking out an area or leaving an identification in a strange environment. Once one animal had given this response it is likely that other cows were stimulated to do the same. In males, similar behaviour is related to social dominance and precedes the act of mating, being woven into the courting patterns. It is of interest that similar patterns are shown by females during open-field testing. Other behaviour such as female mounting during oestrus is shared in common with the male. The presence of shavings on the floor may have contributed to the occurrence of such behaviour as soft dusty areas of broken turf help elicit similar reactions in bulls. The general elicitation of the defecatory response during such behaviour might be put to some practical use for farmers in that a small shavings pad in raceways might stimulate the defecatory response before the dairy cows actually reached the yard of the milking shed. Further verification of this is needed.

Fast active running with prancing of the animals was witnessed in a number of the trials. The typical prance of cattle where the head and forelegs are thrown upwards and then the tail and hind

Table 61. Behavioural activities recorded during the trials of 44 pigs in the open-field test.

Activity	no. of animals
Jumping up against exit gate	8
standing still with nose against the wall	3
eating leaves and shavings	9
lying down	14

Table 62. Behavioural activities recorded during the trials of 73 sheep in the closed-field test.

Activity	no. of animals	times occurring
shaking body in dry weather A/9*;B/7;C/14;D/9;E/10;F/9.	58	107
displacement grazing A/5;B/3;C/3;D/2;E/2;1/2;4/1;11/2.	20	41
skip jumps with snorting A/2;C/4; and D.1,2,3,4,5,6 and 8 = one subject (same sheep)	14	50
eating leaves	2	
chewing plastic wiring	1	
scrapping shavings with foot	4	14
kicking at belly or scratching ear	3	8
rubbing head or body against baffles (shown in 5 rams)	6	13
teeth grinding	2	
startled by wind, birds, etc.	6	
rapid running in circles	1	
feigning lameness	4	
slow moving and lying down	6	10
swinging head on approach to choice points	10	
low creeping movements on belly	5	
tail fanning	1	

* The letter or figure preceding the bar refers to the problem number and the figure following, details the number of subjects involved; i.e., nine sheep shook the body in dry weather while running problem A.

quarters are similarly elevated was displayed four times during the 132 testing periods. Similarly, a sudden startle after a period of slow exploration of an object in the arena was recorded five times. In one case the reaction of the cow was so great that balance was lost and the animal rolled sideways and only regained her feet after several seconds of rapid leg movement.

Only one case of a cow lying down during the five minute period was recorded. Generally the third day pattern showed minimum ambulation and the subject stood quietly near the "expected" exit gate. One cow showed the outstretched neck and soft lowing which is sometimes part of the investigatory behaviour of bulls during courtship. This was in complete contrast to the regular bellowing of the animals during their tests which has been shown in the earlier tables during the open-field discussions (see table 14). The freezing behaviour by one animal has already been discussed.

General investigatory behaviour, sniffing objects and licking them or nosing them, was not a common occurrence, though it did occur during both the open and closed-field testing. Of more interest were the cases of what has been termed "displacement grazing" shown by only two cows during the open-field tests but shown by another nine cows during the closed-field tests. (Table 63). This activity, which was seen in the A and B training trials, was only seen again after a cow was seriously confused in problems 1 and 3. The head was lowered to within an inch or so of the shavings and was swung back and forwards across the top of the floor with the lip movements

Table 63. Behavioural activities recorded during the trials of 79 cattle in the closed-field test.

Activity	no. of animals	times occurring
pawing shavings A/2; [*] B/1;C/1;E/1;F/1;2/1; 3/1;9/1;12/1.	10	24
sniffing or licking barriers A/6;B/3;2/1;3/1;6/1;7/1;12/2.	15	22
licking flanks A/2;F/1;2/2;4/1.	6	6
sniffing ground D/2.	2	10
prancing E/1;2/1;4/2;5/1;7/1;8/1;11/2;12/2.	11	11
displacement grazing A/3;B/3;1/2;3/1.	9	11
snorting D/2.	2	2
head in shavings 2/1.	1	1
showing signs of oestrus	4	4
jumping fences	2	4

* The letter or figure preceding the bar refers to the problem number and the figure following, details the number of subjects involved; i.e., two cows pawed shavings in training problem A.

Table 64. Behavioural activities recorded during the trials of 63 pigs in the closed-field test.

Activity	no. of animals	times occurring
rooting (Displacement) A/1; [*] B/4;D/1;E/2;3/1;4/1.	10	23
eating chips, leaves, dung etc. A/2;D/1;E/2.	5	5
pawing or rolling in shavings	2	3
pushing under baffles	3	5
lying down	3	10

* The letter or figure preceding the bar refers to the problem number and the figure following, details the number of subjects involved; i.e., one pig showed rooting behaviour in problem A.

imitating grazing. While this was occurring the cow made slow movements forward, usually along-side a wall towards an opening or gap in the barrier. Similar descriptions of this type of grazing activity have been recorded by Schein and Fohrman (1955) and Dalton et al. (1967) for cows and bulls. Following their precedent it was considered that such activity arises in situations of conflict and the term "displacement grazing" has been used.

During the closed-field tests similar behavioural activity was shown as in the open-field, but certain types of activity increased in incidence. One cow continued to paw shavings during the runs for the training problems and the test problems. Only on days D, 1, 5 and 6 did this not occur. Sniffing and licking of objects also increased but was not seen after training problem B until the more difficult test problems were encountered. The turning and licking of some part of the flank was shown on the days of problems A, F, and problems 2 and 4, both non-visual problems. The prancing of cows, though occurring 11 times, was spread throughout the various days of testing and was not easily predicted. This is in contrast to other activities such as pawing or sniffing. Two cows jumped raceway fences during the trials and 4 cows showed signs of oestrus mounting during the closed-field testing period, though speed and performance in the arena when the animals were isolated did not appear to be affected.

Two of the activities recorded can be considered to be related to some sort of tension in the subjects during testing; i.e., sniffing or licking of objects or the floor of the arena and the

"displacement" type grazing activity. Pawing is considered to be related to establishing some rights to a specific area in an unfamiliar arena and having a carry-over in the case of one animal, while prancing is a short burst of activity which cannot be predicted. Table 63 for cows was drawn up directly from the original data sheets.

Figure 36 provides an example of the day's score sheets for cow 7172, for training problem A with the key indicating the various activities which occurred in the nine runs of the morning. Pawing the shavings was shown in trials 2, 3 and 6; vocalisations in 1, and 6; sniffing at baffles and other objects in 1, 2, 3 and 6; displacement grazing in run 8 and urination and defecation where marked. Some licking of the walls occurred in trial 4. Only in the last run of the day was the 7 minute time limit exceeded, and this cow was disturbed enough to make her run from the arena from the point shown near the exit gate.

In the open-field, sheep did not show many behavioural activities apart from ambulating and vocalising. Table 62 shows the additional activities recorded. In a number of cases, when the sheep stopped at or near the exit gate of the day before, they engaged in some type of scraping of shavings with one or other of the front feet. Others reared up onto their hind legs and pawed the exit gate with their front feet for short periods. Only three animals spent time in "displacement grazing" across the top of the shavings. As far as can be ascertained no material was ingested by either sheep or cows during this activity. Two sheep, on moving out the exit gate after the finish of the five minute trial, did so by lowering the whole body and crawling out in a manner reminiscent

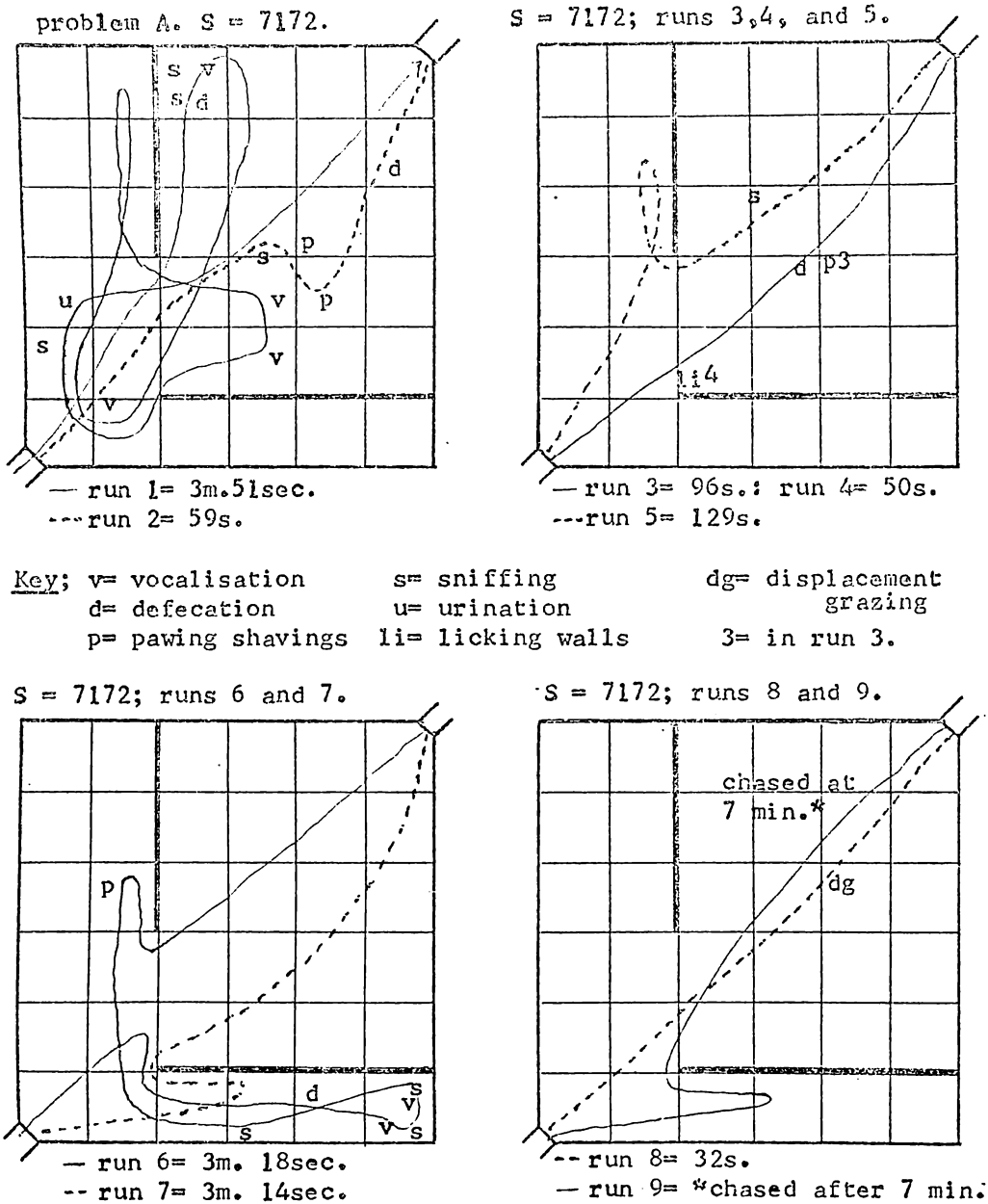


Figure 36: The activity and pathways of dairy cow 7172 on day 1 of the training problems in the closed-field test.

of the posture described by Geist (1964) for the subordinate mountain goat. Five of the rams spent some time rubbing their heads up and down the edge of the baffles of the closed-field test, and two rams were observed to sit for small periods in the dog-sitting position on completion of the open-field test.

Certain of the infrequent activities during the open-field testing were much more frequently observed during closed-field recording. From the single recording of a subject shaking the body on a completely dry day in the open-field, 58 sheep were recorded as shaking the body vigorously during the training trials only. It was considered that this activity was a sign of some stress in the animals concerned, and it is of interest that the 3rd day of training; i.e., problem C, was the day on which it occurred most. This provides some objective assessment of the subjective judgments that the third day was always the most difficult day in the whole experimental session for most subjects, but most of all for sheep.

Next came "displacement grazing" involving a total of 20 sheep. (see plate IV.p.105). In this case the first day of training gives the highest incidence. In some cases the sheep used "displacement grazing" as a ploy for moving up to and through the final exit gate. Sheep as individuals and as a mob show a great deal of reluctance to move out through a corner gate, especially for the first few days of training. In a typical case, a sheep (usually low in the dominance ranking) would stop about 6 to 8 feet short of the exit gate, pause for several seconds (10 to 25), and slowly begin

"displacement grazing" up to and through the gate whereupon it would immediately run right to the far end of the food box area. Most of these animals had not yet begun taking food. Though the majority of the cases of this type of behaviour occurred during the training trials, it also occurred in a few sheep which had difficulty with any particular problem; e.g., problem 1, as it was considerably more difficult than any of the training problems; problem 4, which was ranked the most difficult for most species in the series 1 to 6; and problem 11 where some sheep found it particularly difficult to find the gap.

Although the short jumping gait of sheep was seen on a number of occasions in the early training period, only in one sheep did this type of behaviour persist into every run up to problem 8. The first occurrence of feigned lameness of a subject during a run caused considerable distress to the experimenter but on close examination no evidence of footrot or other cause could be found. The major portion of the run in the problem was perfect and only at a particular point in a trial did feigned lameness occur. On exit from the arena the animal ran normally without evidence of any limp. This type of behaviour was shown by four animals. Figure 37a shows the pathway of one sheep in problem I when feigned lameness was shown. She rounded the final barrier 10 times and then turned back. Finally she limped out. Kicking at the belly, scratching at flanks or ears and teeth grinding were also recorded during the early

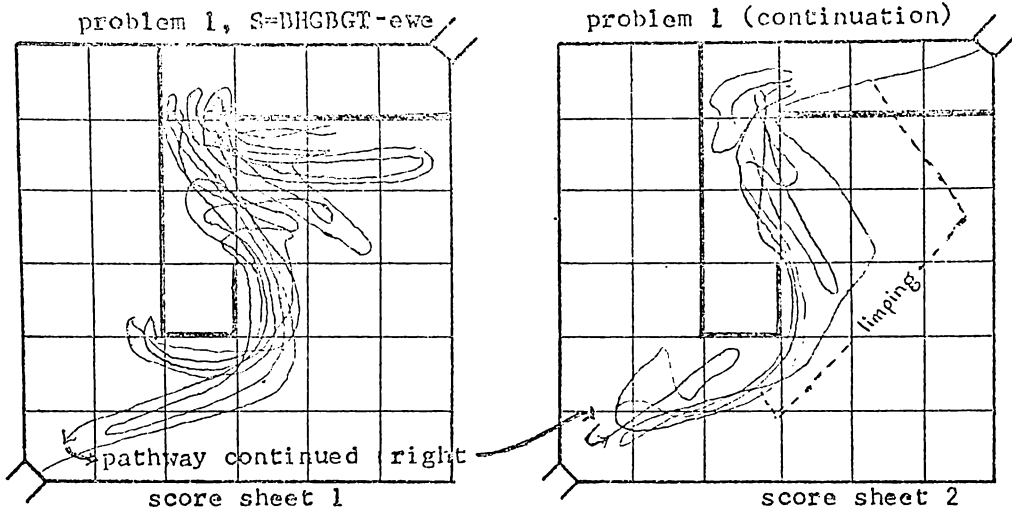


Figure 37a: The pathway traversed by BHGBGT (ewe) on run 1 in problem 1 showing the portion where limping occurred (in red).

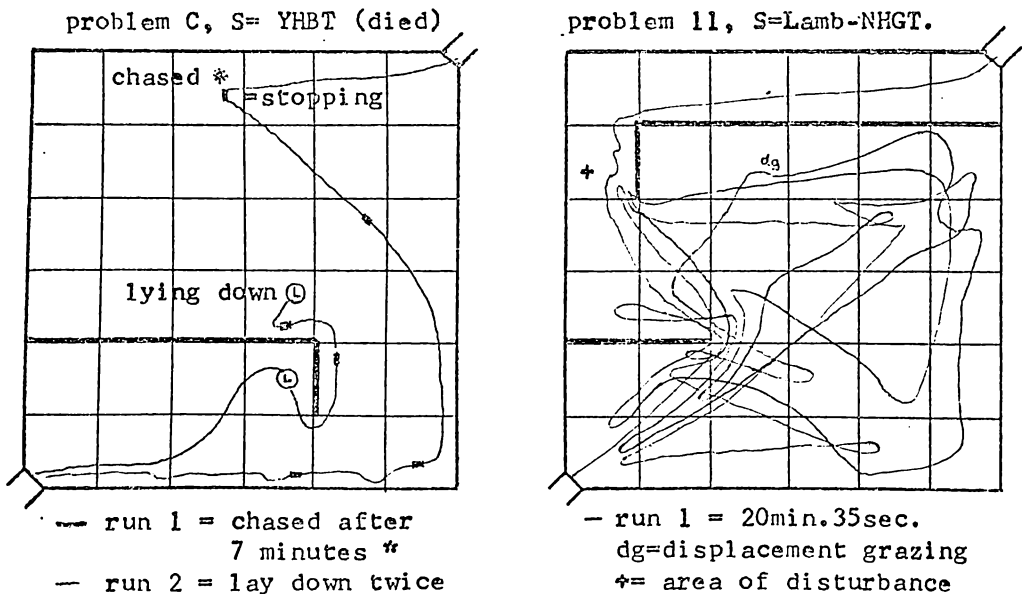


Figure 37b: left. Pathways of subordinate ewe YHBT on day 3 of training. Subject died a day later.

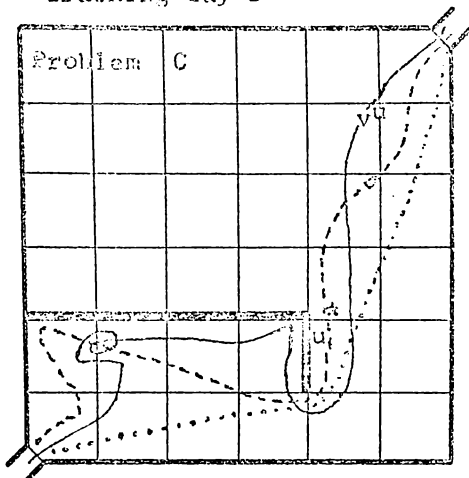
right. Pathway of lamb NHGT after being disturbed by shavings blown by wind in run 1.

training trials and not thereafter. Scraping shavings with forefeet and rubbing heads against the barriers were recorded in several sheep and in five of the sample of twenty-four rams tested. Startle patterns gave some trouble with sheep. This is illustrated in figure 37b where a lamb was disturbed by a small whirlwind of shavings in problem 11. Being an outside arena the flight of a bird across the path of a sheep could be very disturbing to the subject and this would cause some hesitation on all runs on that particular day but did not inhibit the performance on the following day.

In contrast to the behaviour described above the head swinging as a sheep approached a point where a decision had to be made to move on the left or right side of a barrier, was a very pronounced pattern of behaviour in some sheep and occurred in specific problems where such choice points were encountered, such as problem 12. Tail fanning was shown by one subject which was cycling during a period of the trials.

A sample recorded of sheep NHGT on training day C is shown in figure 38, together with the symbols for the various activities recorded during the 9 runs for this day. Body shaking occurred though the day was fine and sunny and the rubbing of head and body along the walls. NHGT began to lie down in the arena at strategic points where she could monitor both points of exit and entry. The experimenter entered the arena as soon as this occurred and the

Training day 3



— run 1= 94 sec. 6 errors

-- run 2= 88 sec. 2 errors

... shortest pathway

Key. v= vocalisation

sn= sniffing ground

dg = displacement

grazing

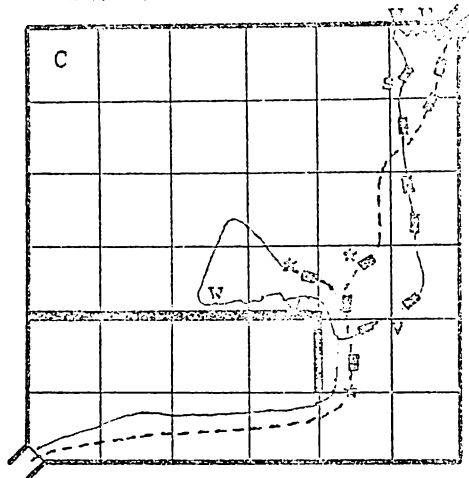
u= urination

s= shaking body

⊙= lying down

s= scratching body

Ewe NHGT 12-9-67.



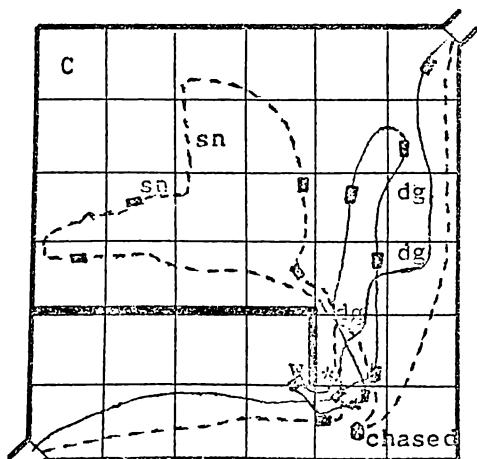
— run 3= 10m 17sec. 8 errors

-- run 4= 1m 39sec.

w= rubbing or licking

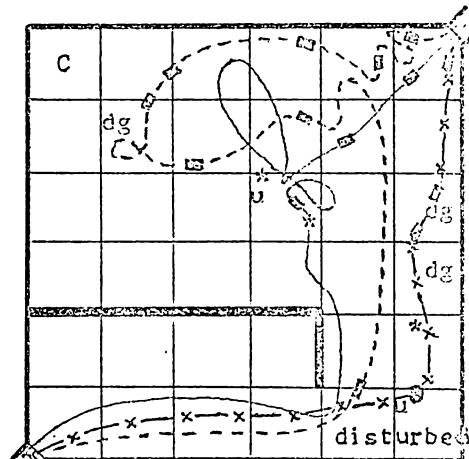
walls or barriers

⊞= remaining stationary



— run 5= 9m 50sec. 12 errors

-- run 6= 8m till ⊙ 18 errors



— run 7 = 1m 12sec. 10 errors

-- run 8 = 2m 56sec. till ⊙.

x—run 9 = 9m 23sec. 10 errors

Weather. Heavy rain over night: overcast and warm with rather infrequent light showers.

Figure 38 . Recorded pathways and activities of sheep NHGT on day 3 training problem in the closed-field test.

animal was roused. Displacement grazing is also shown in the sheet records. This sheep improved her performance on the next day and reached the standard criteria of performance on days E and F.

In the preliminary trials and the first experimental group two sheep died during the course of the closed-field testing. YHBT is shown as typical of performance on day C of training, (fig. 37b). This sheep appeared highly excited on both previous days and crashed into gates or fences in her attempts to rejoin the flock. On several occasions she was able to push through behind a gate and had to be singled out from the mob to continue the trial runs on day A and B. On day 3 (problem C) she was chased out at 7 minutes after standing 40 feet away from the exit gate watching intently in that direction. On the second run she was almost impossible to drive back via the return raceway and got down on her forelimbs in corners. After entering the arena she moved behind the main barrier line and lay down. On arousal she turned the corner, doubled back and lay down again. She had not begun to eat large amounts from the food box though her weight loss was not great. She was returned to pasture in a mob of sheep but would not eat and died the next day. No positive post-mortem findings after routine investigations could be found. Other cases of death followed a very similar pattern. It was realised with the death of a second animal that this subject was lowest in the dominance-subordinance hierarchy and that it may have died from the stress of experimental routine and isolation. The third animal provided a blood sample for cortisol analysis a few hours before death and recorded a level of 23 micrograms

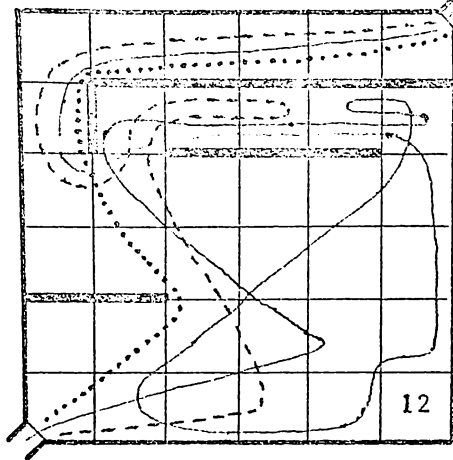
per 100 millilitres of plasma; i.e., the highest level of blood cortisol so far obtained in husbandry procedures such as shearing and dipping. (Kilgour and de Langen, 1970). Considerable care was then taken to minimise any disturbance to sheep, especially during the first four days of training trials, and since that time no further experimental subject has died. Although this evidence is not conclusive it has been assumed that the third day of training in particular is the peak of stress for sheep in the closed-field testing and that the great variety of behavioural activities exemplified at this time are signs of such stress. Sham grazing, which occurs at this time, has been labelled "displacement grazing".

That additional factors are involved in behavioural activities of sheep and cattle during the early training period is clearly illustrated by data from the pig, a non-ruminant. Table 64 shows the few activities recorded for pigs in the open-field. The most common reaction was to lie down in the shavings on the floor after a minute or two in the arena. Other pigs spent their time eating leaves or bits of organic matter which had blown into the arena, especially in the autumn, or picking up little pieces of wood chip and holding them in the mouth. This was more clearly seen during the closed-field test when such matter was ejected from the mouth before the pigs ate the meal provided in the food box. The troughs soon became full of bits of chewed wood, and not infrequently small round pebbles, though these had been picked up in the raceways en route to the arena before the trials for the day began. Jumping up and pawing the exit gate was shown by 8 pigs and three took up a

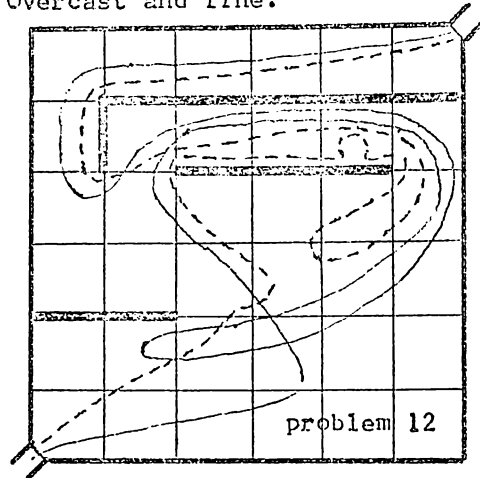
posture of standing still with their noses facing or up against a wall for short periods before active movement again. It appeared to the experimenters to be a type of vigilance behaviour.

Once the pigs were hungry, lying down in the arena became less common and was recorded for only 3 pigs during closed-field testing in the early training trials. Three pigs, after being confused by one of the more intricate problems; e.g., problem 12, pushed under the 138 lb. baffles and escaped through to the exit gate to obtain food. Two pigs were recorded as pawing and rolling in the shavings. The majority of recorded activity of pigs in the closed-field related to eating objects (5 pigs) and a type of rooting behaviour. The first experimental group was fed with a solid nut food. These four pigs settled very well into the routine and then suddenly, during the last few days of the test session, began to interrupt their rapid running sequence in the arena. It was found that they were taking their food into the mouth, returning via the return raceway, then tossing out the nuts into the shavings and rooting around until they found them before proceeding with the run. The first recorded group for this study, Group II (see p.103) was reinforced with a porridge-like meal to overcome this problem but even so, rooting of pigs was the most frequent activity recorded in later trials. This is fully discussed by Breland and Breland (1966). Fig.39 records the pathways taken by subject No. 30 in problem 12. After continuing to take the incorrect gap in 4 runs this pig pushed through under a baffle on run 5. On run 6 she was unsuccessful but tried at the same spot, and after a very confused pathway in run 7 she tried again. With extra effort on run 8 she pushed through again. Fortunately

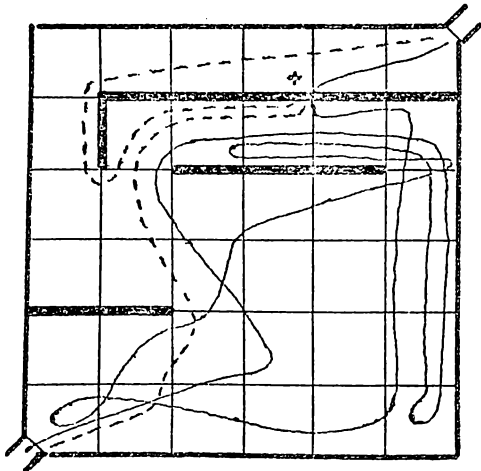
pig 30 - Group II. 24-4-68. Overcast and fine.



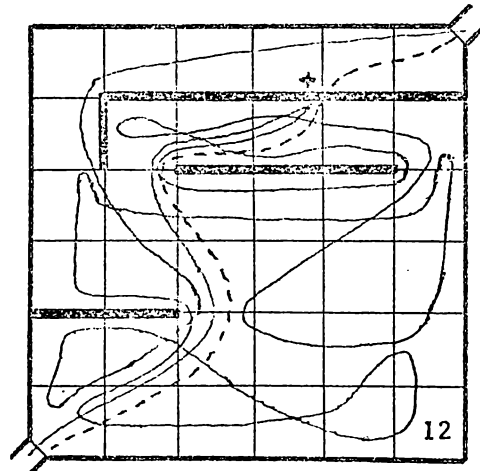
... shortest pathway
 — run 1= 75 sec.
 -- run 2= 36 sec.



-- run 3= 53 sec.
 — run 4= 56 sec.



— run 5= 139 sec. -
 *got under barrier
 -- run 6= 66 sec.-tries again



— run 7= 202 sec.-tries again
 -- run 8= 40 sec.-
 *got under barrier

Figure 39. Recorded pathways of pig 30 in problem 12 of the closed-field test.

it was the last day of testing when this pushing behaviour took place.

In general, pigs work so well for a food reward, in contrast to the ruminants studied, that their trial times are very short and there is little time for any other activity but ambulation except in the first day or two of training. This suggests that a more successful method of motivating cattle and sheep might well eliminate much of the behavioural activity recorded during this study which occurred during the closed-field testing. In this case the greater motivation would override the conflict arising from fear or need to escape from isolation and join flock or herd mates, and there would be correspondingly less "displacement type" activity.

The Closed-Field Test : Species comparisons

In a number of the earlier tables and charts the data for the different species has been displayed together for ease of comparison. It is important to examine these species differences and similarities in more depth. From an experimenter's point of view the actual time and speed differences of species is of considerable interest. Figure 40 gives the average speed in seconds for each of the eight runs for the major species tested after excluding those subjects which had stopped for considerable periods or had been confused and were making serious errors. This was done to attempt to get some index of the average speed of performance which could be expected of the domestic animals in the arena, a situation which in many ways parallels the yards and sheds of N.Z. farms.

Lambs were the slowest of any of the experimental groups, though with their retests after 6 months and one year (Lambs II) they showed a different time graph from that of any of the naive animals. By the eighth run these retest animals were very similar in speed to the other adult ewes and rams varying by only a few seconds in average speed. Lambs, ewes and rams show rather similar increases in speed between run 1 and run 2 but the rams presumably because of the hot weather and their greater body weight, showed a greater decline in speed with each ensuing run. Each of the groups reach a speed "plateau" by the third run though the pigs which take longer to master the problems, do not show this until the fourth run.

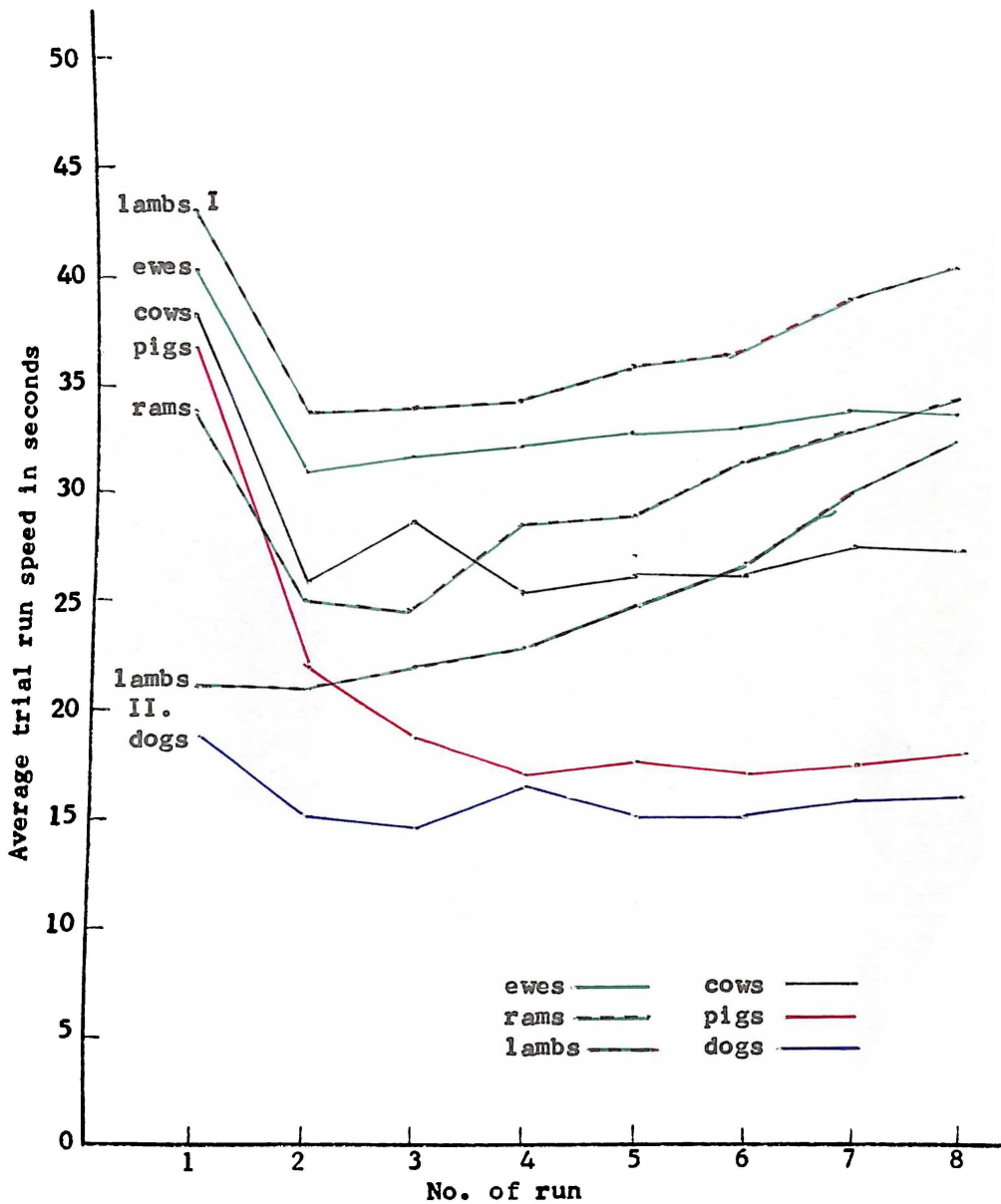


Fig. 40. Graphs of the average speed of each run for the species tested in problems 1 to 6 of the Closed-field Test.

Dogs run at the fastest overall speed and pigs show the greatest difference between initial speed on the first runs and final speed from run no.4 onward. Average time differences between any of the first six problems vary little and for this reason only the time for the complete series has been portrayed. It could be reasonably established that cows will move through a raceway following a known pathway to reach milking stall and food reward at the speed of approximately 30 seconds per 100 feet. Four of the cows tested broke into a run when entering the last straight of the pathway having passed around the last barrier in any test run. The speed of animal movements and flow patterns is becoming increasingly important in the design of facilities for more intensive husbandry units, particularly in the field of dairy cattle management.

The range of speeds for selected runs and problems of each species tested has been plotted in histogram form in figures 41 and 42. Problems 1 and 6 have been chosen; problem 1 as an example of the first encounter with the more complex test problems after completion of the training series, and problem 6 because it was ranked the most difficult of series 1-6 problems. Runs 1, 2 and 6 have been selected to show the immediate changes in early performances and the typical changes which occurred over several runs on the same problem.

On problem 1 cows and sheep peaked at 30 seconds and the pigs at about 50 seconds on run 1. By run 2 the range is considerably restricted from 15-30 seconds in cows; 10 to 60 seconds in sheep

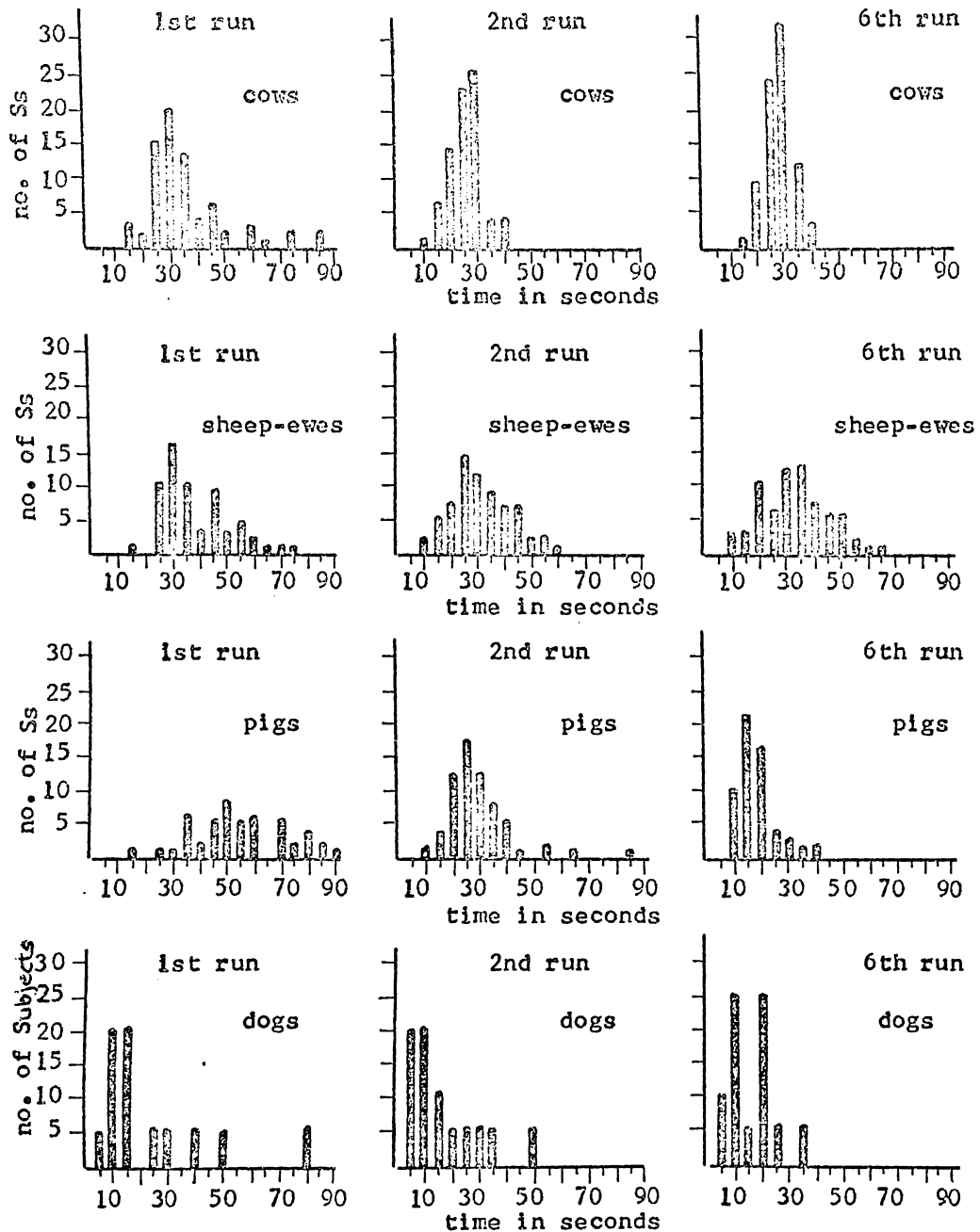


Figure 41. Bar graphs showing the time taken by subjects of the four species tested on runs 1, 2 and 6 of problem 1 in the closed-field test.

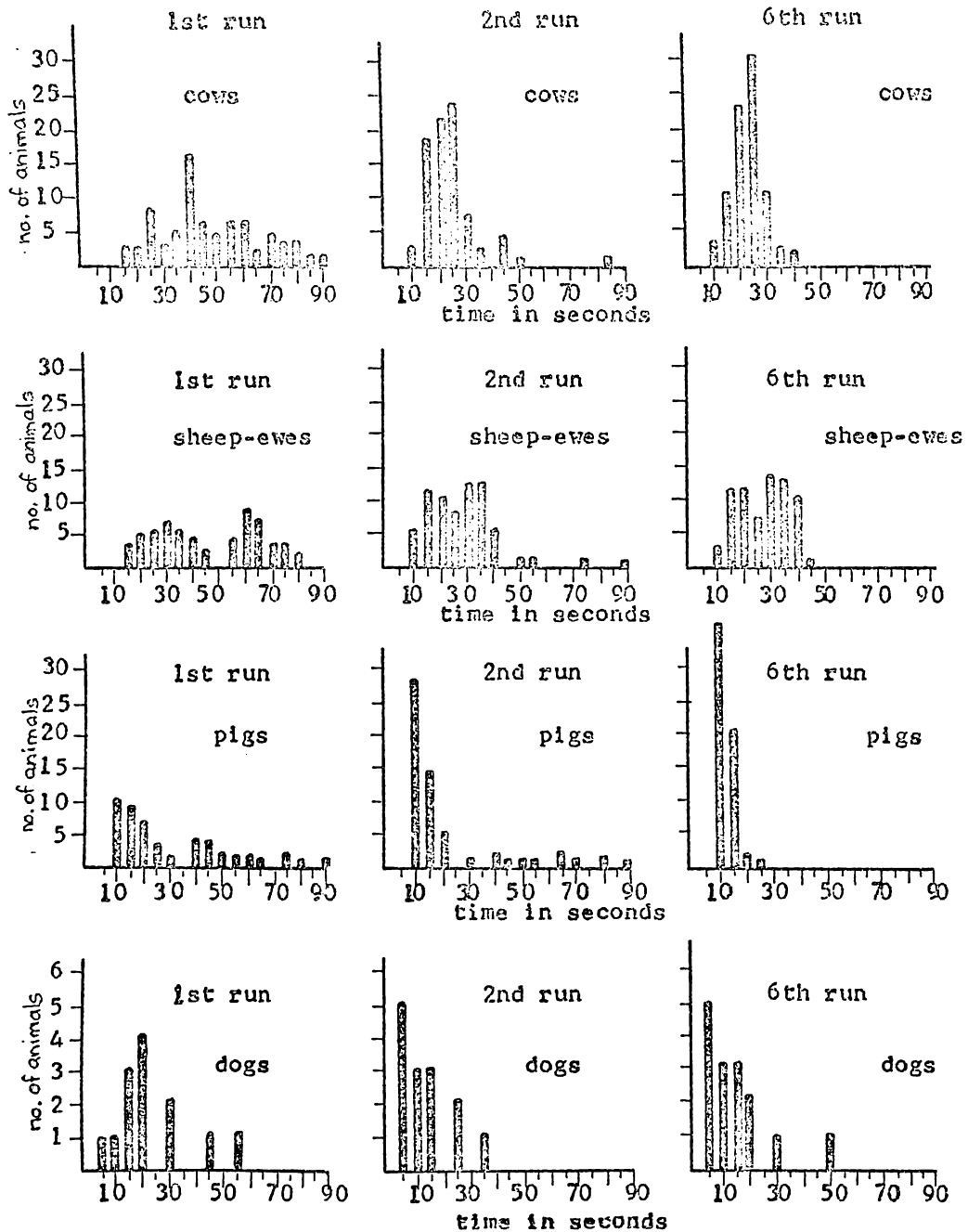


Figure 42 . Bar graphs showing the time taken by subjects of the four species tested on runs 1, 2 and 6 of problem 6 in the Closed-field Test.

and 15 to 45 seconds in pigs. By the sixth run the cows were showing a very small scatter and a clear-cut peak at 30 seconds per 100 feet of distance travelled; the performance of sheep was much more variable with peaks at about 30-35 seconds and the pig peak came at 15 to 20 seconds with very few pigs running outside this range.

In the more complicated problem 6, two peaks are found on the first run depending on how confused the subjects became during their running in the top left blind quadrant. The variability decreases rapidly in the second run. In particular the pigs have shown a marked increase in 10 to 15 second trial runs. The sixth run results indicate features similar to the sixth run of problem 1. A simple problem like problem 5 showed the same trends in speed of performance but these took place earlier. The limited scatter of the performance speeds provides further evidence that the speed of flow for the species can be abstracted for use in practical management situations.

Although the pathways taken by each group of animals has been discussed in the earlier sections, some of the overall considerations need to be highlighted. The analysis of pathways showed that each species had a strong tendency to move a specific distance into a blind cul-de-sac before the subject turned and retraced the track. This distance gave some indication of when the incoming visual sensory input affected the behaviour and prompted the turning back from the blind alley. This does not deny that sheep and cows see

over much greater distances, but does indicate that a barrier though "seen" does not bring about a change in the behaviour of the animal until within this critical distance. The cow will reverse from blind alleys at 20 to 25 feet from the end barrier; sheep at 9-15 feet; and pigs up to 4 to 6 feet. The distance for dogs is between 5 and 10 feet with the majority of dogs entering the last 12 foot square in a cul-de-sac.

Pathways show species characteristics in other ways. Cows made straight-line pathways and they were able to retrace their steps across the complete length of the arena. The sheep showed a greater variation in pathways with various turns and twists. They develop wavy tracks both in the arena and in the return raceway. As the Romney has considerable facial wool this wobble may enable the subject to obtain a view to the rear first with one eye and then with the other. Crofton (1958), from analysis of aerial photographs, provided evidence for the importance of visual contact being kept in groups of grazing sheep.

Pigs can make short range orientation adjustments. Some turned back into the blind part of the "J" in problem 1 and into the "L" to the right side of problem D. They also show movement "looking for" the exit gate in the incorrect corners in problems 5 and 11. Dogs ran very rapidly and showed a tendency to follow the line of the barriers. They used wider sweeping paths than other groups studied. Sheep, cows and children tend to show a hovering side to side head movement when approaching the choice point between

two alternative pathways.

Behaviour in the return raceway which was an integral part of the complete performance of this test, indicated some species differences. Cows had to be driven for four or five days and then would flow by themselves through the 190 foot return raceway. Occasionally a cow would stop in the final raceway just before the entry to gate A. If the return of a cow had to be delayed and gate D or C was shut, it would attempt to push past or in some cases to jump over these gates. Several were successful in this, one making a 4 ft high standing jump without breaking equipment or railings. Sheep took more time to train in the raceway and some of them always stopped on the side away from the food box out of vision of the Experimenter. Others would stop for varying periods where the raceway changed direction to enter the arena at gate A. This pause before entering the arena necessitated waiting for the subject to move again rather than attempting to chase it further, because this could seriously bias the subsequent pathway taken.

The pigs were most difficult to manage in the early training trials. They would turn and run against the experimenter who had been herding them. They were usually turned back by blows to the snout. After 3 or 4 days however, the pigs ran so well that if they were delayed by gate D they would push past it even when held by the full compression at 80 lbs per square inch. Gate C however swung up against a post and could not be by-passed by pigs.

The difficulties experienced with the two groups of dogs,

the farm trained and the town dogs, helped in the understanding of how critical the prior experience is, even to the experimental procedure. One worker had to be positioned near gate A to call the farm dogs to the entry point whereas with the town dogs this person was stationed near the finish gate to send the dogs back to the start position in a manner similar to the other farm animals. Only thus could satisfactory flow patterns in dogs be established.

Figures 43, 44 and 45 provide examples of the pathways of sheep, cows and pigs which made the greatest error score. In problem 1 (figure 43) the ewe YHRT penetrated no further than 15 feet off the correct path into the top left blind, though she came to this point three times during the first run, but she penetrated further in on run 2 and still entered this area on run 4. The pig no.17 in contrast, wove an intricate pattern of pathway in trial run 1 but had no difficulty with the problem in later runs. In problem 6 the rather direct pathway of the cow can be seen in comparison to the involved rapid turning and twisting type path of pig no.30. The paths for problem 4 (figure 44) clearly show the contrast between sheep and cow patterns and in problem 10 the cow retraces steps at about 20 feet from the blind end while the pig enters right into the blind corners. In problem 7 (figure 45) the U-shaped movements which occur around the point of the central baffles are shown for the sheep and the cow. The cow eliminates its exploration into the top right blind corner in the goal box direction after 2 penetrations but the sheep returns to this corner repeatedly. The visual animals

Problem 1.



Ewe. YHRT. 14-10-68

Runs. 1. 5m 19s —
 2. 1m 00s —
 3. 40s —
 4. 30s —
 5 to 8. 35, 36, 40 & 36s. —

Problem 1.

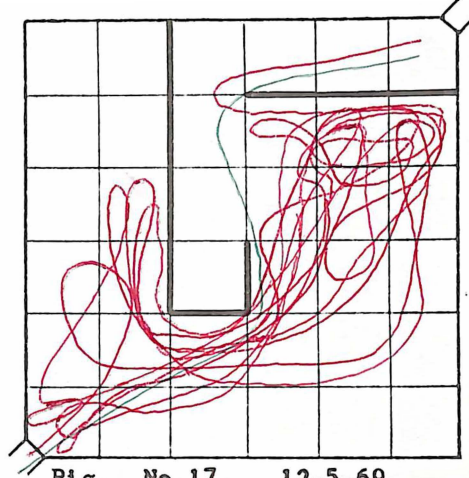
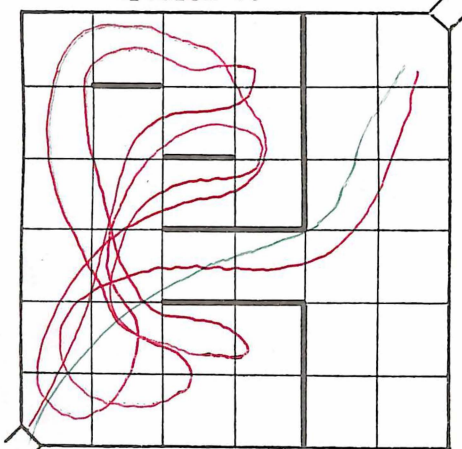


Fig. No.17. 12-5-69

Runs. 1. 10m 43s —
 2 to 8. 33, 12, 14, 14,
 13, 16, and 15 seconds. —

Problem 6.



Cow. No.425. 20-4-69

Runs. 1. 3m 13s —
 2 to 8. 24, 24, 23, 23,
 25, 24 and 26 seconds. —

Problem 6.

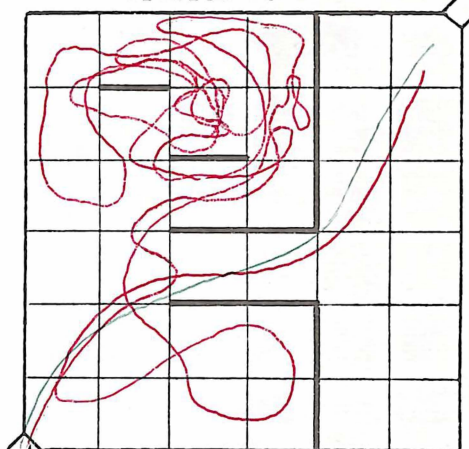
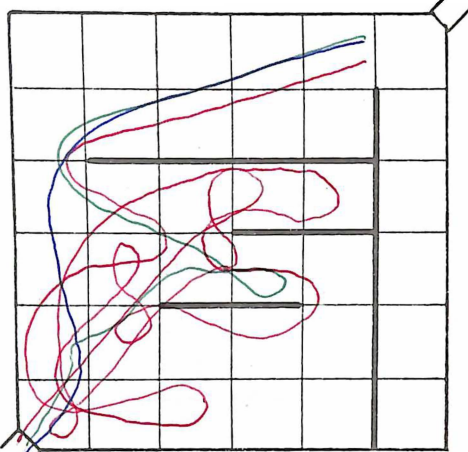


Fig. No.30. 8-4-68

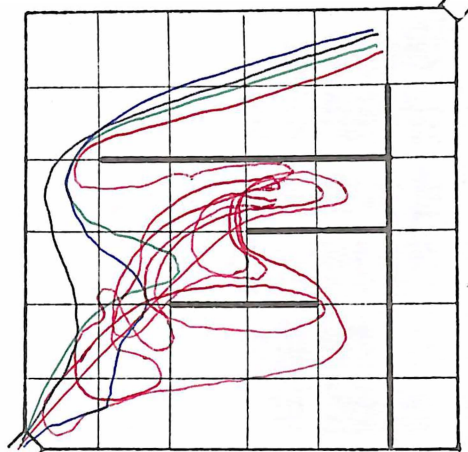
Runs. 1. 3m 24s —
 2 to 8. 18, 16, 15, 17, 17
 15 and 16 seconds. —

Fig. 43. Examples of pathways taken by subjects making large error scores in problems 1 and 6 of the Closed-field Test.

Problem 4

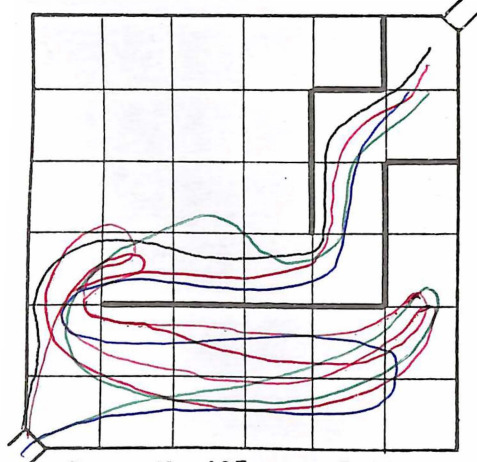
Cow. No.3077. 24-6-68

Runs. 1. 16m 00s -
 2. 2m 19s -
 3 to 8. 27,28,26,26,
 26 and 25 seconds -

Problem 4

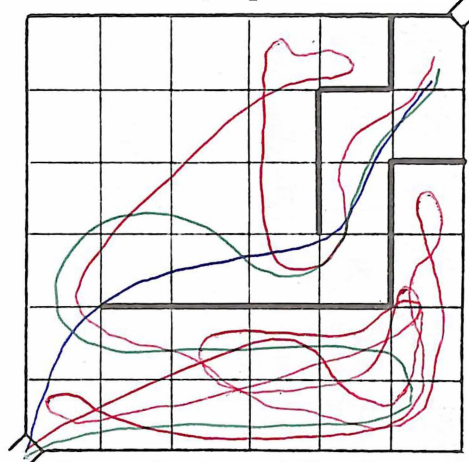
Ewe. BHGT 15-10-68

Runs. 1. 4m 35s -
 2. 16s -
 3 17s -
 4 to 8. 21,11,9,13 & 20s.-

Problem 10

Cow. No.407. 14-7-69

Runs. 1. 48s -
 2. 49s -
 3. 26s -
 4 to 8. 18,17,19,18,18s.-

Problem 10

Pig. No.5. 20-4-68

Runs. 1. 1m 51s -
 2. 30s -
 3.to 8. 12,12,12,13,12,
 and 12 seconds. -

Fig.44. Examples of pathways taken by subjects making large error scores in problems 4 and 10 of the Closed-field Test.

Problem 7



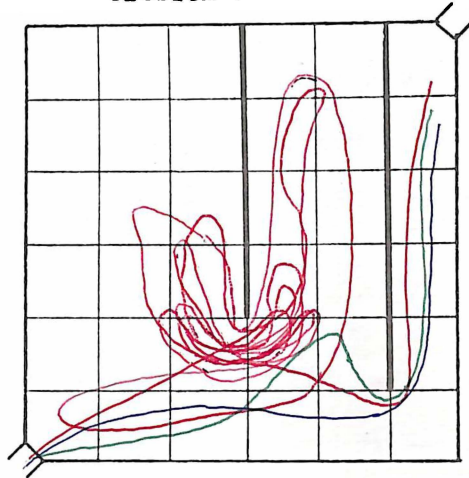
Ewe. RHRB. 21-4-69

Runs. 1. 15m 34s. —

2. 40s —

3 to 8. 35, 29, 41, 42, 34
and 37 seconds. —

Problem 7



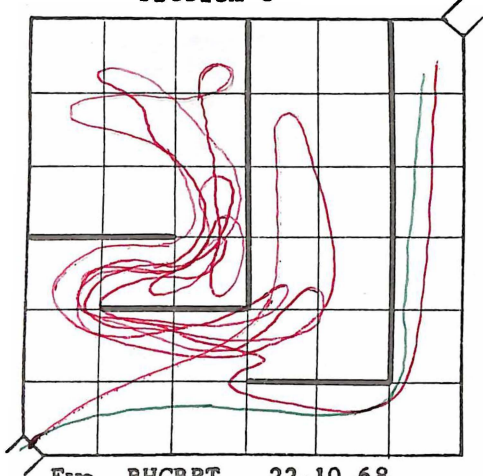
Cow. No. 482 21-4-69

Runs. 1. 2m 15s —

2. 18s —

3 to 8. 13, 17, 21, 19,
21 and 15 seconds. —

Problem 8

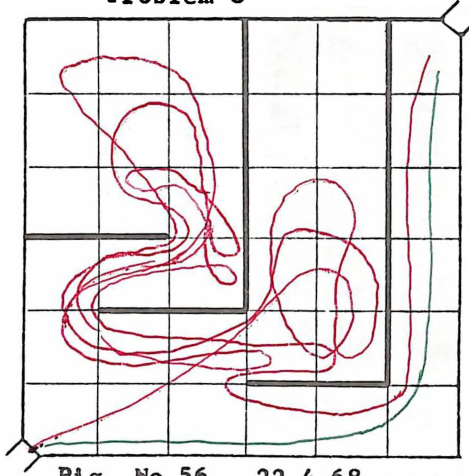


Ewe. BHGBRT 22-10-68

Runs. 1. 3m 17s —

2 to 8. 15, 15, 16, 19, 15,
20 and 25 seconds. —

Problem 8



Pig. No. 56 22-4-68

Runs. 1. 2m 02s —

2 to 8. 13, 12, 12, 13, 13,
13 and 14 seconds. —

Fig. 45. Examples of pathways taken by subjects making large error scores in problems 7 and 8 of the Closed-field Test.

are repeatedly drawn into error because of their visual responsiveness. In problem 8 the greater complexity of the problem makes it easier for the animals as it helps them to orient from a position near the start gate A after exploring the top left blind quadrant.

Having studied the pathways made by each species, knowing both the number of errors likely to be made in a cul-de-sac and the speed of error elimination over the first few runs, it is interesting to speculate if the total error score could have been predicted. Figure 46 shows the percentage of animals of each species which did not err on each of the eight runs taken for the whole series 1-12. Less than 18% of cows and pigs made perfect runs on run 1 and approximately 24% of dogs and sheep. By run 2 there is a divergence between species with sheep and cows about 70% correct, dogs a little higher and pigs much lower at 44%. By run 3 the curve begins to level out for sheep, cattle and dogs, but the pigs continue to gain and by the fourth run it is clear that all species have essentially mastered the problems concerned. After run 4 the greatest improvement is shown by pigs and by run 8 there is very little difference in the performance of dogs, cows and pigs. Sheep make few gains after run 4 and show the expected characteristic of rather erratic performance in the last 5 to 8 runs. It could have also been predicted that the pigs would begin poorly with few able to master the problems, but their performance in the later stages equals and surpasses those of sheep and cattle. From this graph it could be expected that the %R for sheep would be lowest and the

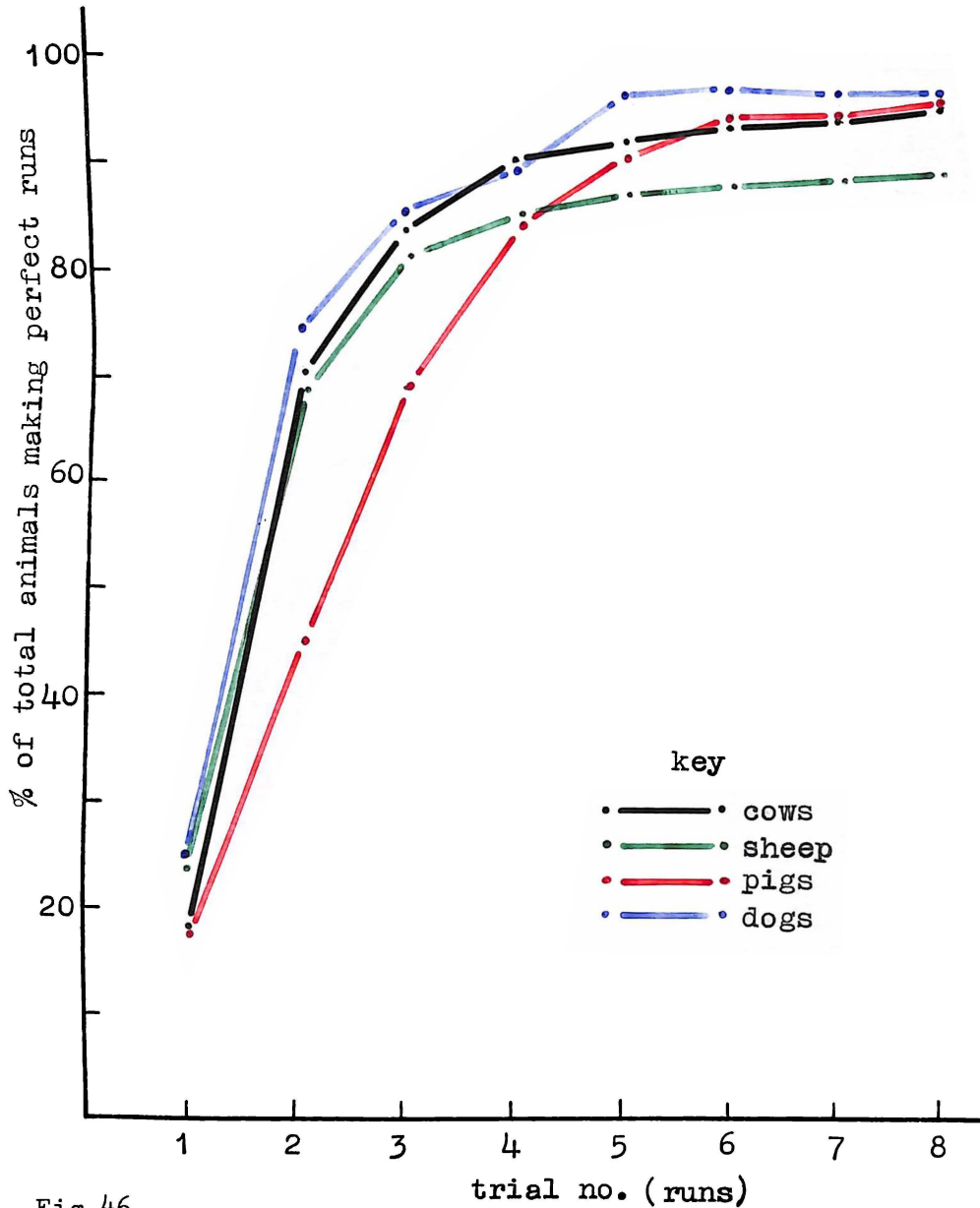


Fig.46.

Graphs comparing the performance of cows, sheep, pigs and dogs in the Closed-field Test. Each graph shows the percentage of the total animals tested which made an errorless performance on all problems 1-12 on each of the daily trial runs 1 to 8.

%P for pigs would be the poorest. As the pigs had made considerably more errors in the early runs they would be expected to have the highest Total Error Scores, TES. Some predictions could also be made about the problems which would be most difficult for each group.

In table 65 the problems are ranked in difficulty for each of the species. This was based on the average error per run for the first run, for runs 1 to 4 and for the total error made over all 8 runs. There are separate rankings for the problems series 1-6 and 7-12 and for all 12 problems. In the series 1-6, problem 6 was the most difficult for all species yet in the total for runs 1 to 8 sheep found problem 4 most difficult. Cows found the non-visual problems more difficult than the visual ones. This was less so for sheep, and pigs found problem 2 the easiest. In the series 7-12, problem 8 was the most difficult except for the dogs which found problem 10 the most difficult. In fact of all 12 problems, dogs register problem 10 as the most difficult in contrast to problems 7 or 8 by the other species. It would be interesting to see if this continues to be the case as the sample size for dogs is increased. Dogs found problem 12 to be rather easy in contrast to the other groups, with problem 3 the simplest in the 1-12 series. Pigs made less error on problem 9 over the whole test. In general it can be concluded that as the first run error provides the greatest component in the error score, the rank for the 1-4 run total and the 1-8 run total varies little from the score in run 1. When considering only the first run, problem 3 is generally the easiest though in overall total error, problems 3,

Table 65. The rank order difficulty for the different species tested of the problems used in the Closed-field Test.

	series 1-6						series 7-12					
errors on run 1.	1	2	3	4	5	6	7	8	9	10	11	12
cows	4	3	6	2	5	1	3	1	6	4	5	2
sheep	3	4	6	2	5	1	2	1	5	3	6	4
pigs	2	6	5	3	4	1	2	1	6	4	3	5
dogs	2	5	6	4	3	1	3	2	5	1	4	6
errors 1 to 4												
cows	4	3	6	2	5	1	3	1	6	4	5	2
sheep	4	3	6	2	5	1	2	1	5	4	6	3
pigs	2	6	4	3	5	1	1	2	6	3	4	5
dogs	2	5	6	4	3	1	3	2	5	1	4	6
errors 1 to 8												
cows	5	3	4	2	6	1	3	1	6	4	5	2
sheep	4	3	5	1	6	2	2	1	5	4	6	3
pigs	3	6	4	2	5	1	1	2	6	3	4	5
dogs	2	5	6	3	4	1	3	2	5	1	4	6
complete series 1 to 12												
errors on run 1.												
cows	9	8	12	7	10	4	3	1	11	5	6	2
sheep	7	8	12	4	10	3	2	1	9	5	11	6
pigs	4	12	10	7	9	3	2	1	11	6	5	8
dogs	5	11	12	8	7	2	4	3	9	1	6	10
errors 1 to 4												
cows	7	9	12	10	11	4	6	1	8	3	5	2
sheep	5	10	12	7 $\frac{1}{2}$ *	11	2	6	1	7 $\frac{1}{2}$ *	3	9	4
pigs	6 $\frac{1}{2}$ *	9	12	10	11	1	4	2	8	5	3	6 $\frac{1}{2}$ *
dogs	5	8	12	10	9	1	6	3	7	2	4	11
errors 1 to 8												
cows	11	8	10	7	12	5	3	1	9	4	6	2
sheep	8	6 $\frac{1}{2}$ *	10	5	12	6 $\frac{1}{2}$ *	2	1	9	4	11	3
pigs	7	11	9	4	10	3	1	2	12	5	6	8
dogs	5	9	12	7	8	4	3	2	10	1	6	11

$\frac{1}{2}$ * indicates a tie.

5, 9 and 11 share the honour for different species. These are all visual problems. The cows found problem 12 the second most difficult.

This variation in difficulty of problems for different species has also been noted by Pollard (1961) and by Livesey (1966) who criticise the test as not providing the homogeneous set of problems of increasing difficulty originally envisaged by Hebb and Williams (1946). This study provides evidence that several aspects of behaviour are being recorded and each species therefore scores differently on each group of problems.

When the errors made by subjects of each species on each run are averaged a different comparative picture emerges. Table 66 shows the average number of squares broken by cows, sheep, pigs or dogs in error on the first run of each problem for series 1-6, 7-12 and 1-12. On the average, cows making incorrect pathways in problems 1-6 extricated themselves after only 8 errors, compared with nearly 15 for pigs on run 1, but in series 7-12 they show similar error scores to pigs while sheep and dogs performed better. Overall, series 1-12 problem scores are almost identical for sheep, cows and dogs and poorer for pigs. If errors of animals making mistakes on runs 1 to 4 are considered; i.e., up to the time that 80% or more of all subjects in each group were making perfect runs, then in series 1-6 cows showed fewer errors in problem 1 and pigs more in problem 6. (Table 67). In series 7-12 pigs did less well on problems 7 and 11; cows less well on problem 8; sheep better on problem 11 and dogs much better on problem 12. The lower sheep

Table 66. The average score for subjects in error on the first run for the four species tested in the closed-field test.

	series 1-6						total	series 7-12						total
cow	8.6	8.8	3.8	7.6	4.6	14.8	<u>7.9</u>	16.8	32.5	7.7	18.0	15.2	21.0	<u>19.3</u>
sheep	12.3	7.7	3.9	11.4	4.5	16.8	<u>9.3</u>	15.7	26.4	8.0	18.8	7.7	15.2	<u>16.7</u>
pig	20.0	9.2	7.7	12.6	8.3	37.2	<u>14.7</u>	34.2	34.1	8.7	17.0	28.4	15.6	<u>24.1</u>
dog	17.2	7.6	2.5	6.5	7.3	17.7	<u>9.9</u>	17.8	18.5	9.7	19.3	17.5	6.7	<u>16.0</u>

Total series 1-12: cow =12.9; sheep=12.6; pigs=19.2; dogs=12.7.

Table 67. The average score for subjects in error on runs 1 to 4 for the four species tested in the closed-field test.

	series 1-6						total	series 7-12						total
cow	7.6	6.3	3.5	5.6	4.5	14.0	<u>6.5</u>	9.2	23.9	6.8	14.7	12.7	15.5	<u>13.8</u>
sheep	10.4	6.2	3.2	7.4	4.3	14.6	<u>7.3</u>	9.0	18.4	7.2	14.8	6.5	10.5	<u>11.5</u>
pig	11.9	7.5	5.3	7.3	6.8	29.8	<u>9.8</u>	15.3	25.7	7.9	13.8	21.4	11.9	<u>16.2</u>
dog	13.1	7.0	2.9	6.6	6.7	15.9	<u>8.5</u>	9.5	14.4	9.0	14.6	13.2	6.4	<u>12.0</u>

Total series 1-12. cow=10.1; sheep=9.4; pig=12.89; dog=10.2.

Table 68. The average score for subjects in error on runs 1 to 8 for the four species tested in the closed-field test.

	series 1-6						total	series 7-12						total
cow	7.0	5.8	3.6	5.5	4.4	13.8	<u>6.2</u>	7.6	21.5	6.7	14.4	11.2	14.7	<u>12.4</u>
sheep	9.2	5.7	2.9	6.2	4.0	14.1	<u>6.5</u>	7.3	14.5	6.9	13.4	6.0	9.6	<u>9.8</u>
pig	11.5	7.0	5.0	6.8	6.9	28.7	<u>9.2</u>	14.1	24.5	7.8	13.2	20.5	11.6	<u>15.2</u>
dog	11.9	6.9	2.9	6.4	6.1	15.2	<u>8.2</u>	9.6	14.4	9.1	14.4	13.2	6.2	<u>11.8</u>

Totals series 1-12. cow=9.3; sheep=8.2; pig=12.0; dog=9.8.

average over all 12 problems indicates that though a greater percentage of sheep continue to err after run 4, giving a high number with poor %R scores, the number of errors made by each sheep is small. Table 68 shows the average error scores in runs 1 to 8, and table 69 in runs 5 to 8 for all species.

If the total score made by each species in each problem is averaged for the total number of animals tested the results can be arranged as shown in table 70. Dogs show the best performance for any single problem on problem 3 with an average of only 3 square boundaries broken and pigs break on the average about 5⁴ square boundaries in problem 7. Cows average slightly better on the series 1-6 problems while dogs do best on series 7-12. Over all 12 problems, there are no significant differences between dogs, sheep and cows. Pigs do less well on 8 of the 12 problems and of the four where they better the other species, three are non-visual; i.e., 2, 10 and 12.

The average scores for each species on each of the 8 runs over the 1-12 series are displayed in figure 47. The total number of subjects tested has been used for this score. In the case of dogs, sheep and cows, the curves follow one another closely up to run 4 with the error spike for dogs on run 3. The pig curve reaches that of the other species by run 4. Because few animals erred after run 4 little can be inferred from the nature of the curves after this run but even on run 8 there is little difference in error between sheep, pigs and cows. The differences between pigs and the other species is shown in the performance up to run 4.

Table 69. The average score for subjects in error on runs 5 to 8 for the four species tested in the closed-field test.

	series 1-6						total	series 7-12						total
cow	4.1	4.1	4.2	4.3	3.0	11.0	<u>4.6</u>	2.9	5.7	4.4	10.4	4.6	8.5	<u>4.8</u>
sheep	3.9	4.1	2.2	2.1	2.3	10.5	<u>3.5</u>	3.3	5.3	5.3	8.6	4.2	6.9	<u>5.2</u>
pig	4.7	5.4	3.5	3.9	9.2	17.1	<u>5.3</u>	3.4	4.0	4.0	7.5	3.5	10.3	<u>6.3</u>
dog	6.0	5.0	0.0	3.0	3.0	9.0	<u>5.3</u>	2.0	14.0	10.0	8.0	0.0	4.0	<u>7.6</u>

Totals series 1-12: cow = 4.7; sheep = 4.5; pig = 5.7; dog = 5.9.

Table 70. The average total error score for each problem in the series 1-6 and 7-12 for the total number of subjects run in each species; i.e., 73 cows, 103 sheep, 63 pigs and 15 dogs.

cows	6.8	9.2	7.0	11.6	4.9	15.5	series 1-6 total	<u>9.2</u>
sheep	8.4	10.8	5.6	17.9	4.8	17.3	series 1-6 total	<u>10.8</u>
pigs	24.9	7.9	13.5	28.6	10.2	33.9	series 1-6 total	<u>19.8</u>
dogs	14.3	7.3	3.0	11.5	9.4	19.2	series 1-6 total	<u>10.8</u>
cows	23.2	38.6	8.1	20.5	13.7	25.8	series 7-12 total	<u>21.7</u>
sheep	26.0	36.9	8.0	18.5	5.2	24.7	series 7-12 total	<u>19.9</u>
pigs	53.9	43.1	7.9	27.5	26.0	21.1	series 7-12 total	<u>29.9</u>
dogs	20.0	24.0	6.8	32.5	13.2	5.7	series 7-12 total	<u>17.0</u>

Totals series 1-12: cows = 14.8; sheep = 15.1; pigs = 25.5; dogs = 15.3

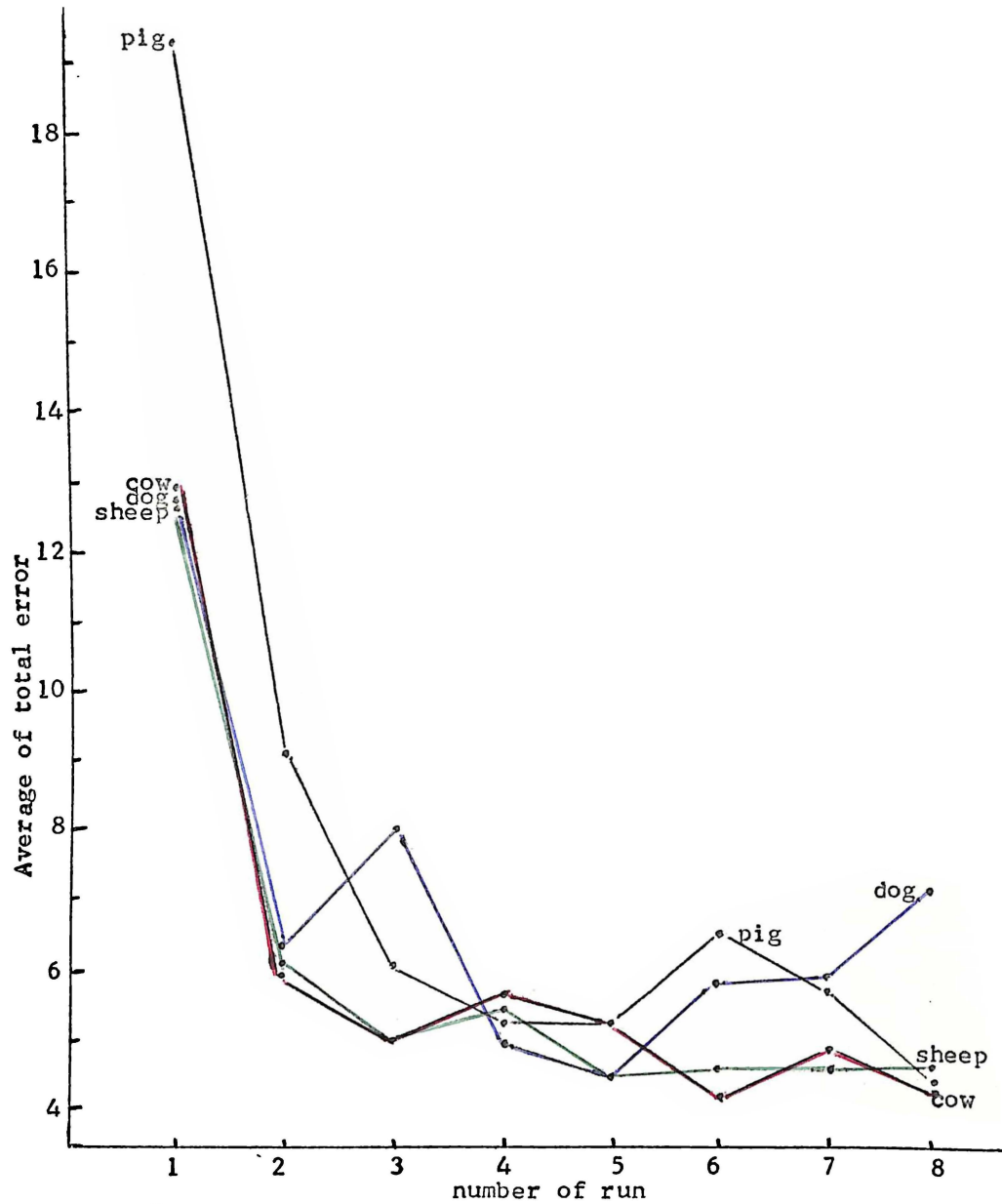


Figure 47. The average total errors made by sheep, cows, dogs and pigs for each of the eight runs in all 12 problems of the closed-field test.

An analysis of the scores made by each species on the visual form compared with those made on the non-visual form of the problems is illustrated by the next three tables. Table 71 shows the number of animals from each species making errors in each run in the visual problems compared with those of the non-visual problems, for series 1-6, 7-12 and over all 12 problems. In table 72 the percentage of animals making errors on run 1 only is compared for the visual and non-visual form of each problem, with separate totals for runs 1 to 4 and 5 to 8. Table 73 highlights the differences for the four species between the total summed error score on the visual and non-visual problems for series 1-6, 7-12 and 1-12.

As a species, pigs are at a disadvantage throughout these trials. In table 71 fewer sheep err on the visual forms in almost all of the 8 runs but cow and dog numbers are similar in the first few runs. More pigs erred on the visual forms than the non-visual forms in the series 1-6 and over all 12 problems, during the first few runs. When this is shown in percentages of subjects making incorrect runs in each of the pair of problems on run 1, in table 72, sheep and cows make the expected higher scores on the non-visual problems except on 5 and 6. In problems 9 and 10 pigs and dogs follow this pattern also but on the other problem pairs their scores are similar on difficult problems and are better for the non-visual problem in 1 and 2; 5 and 6 and 11 and 12. When runs 1 to 4 are combined the same trends are apparent though problems 5 and 6 show equal numbers in error for cows and sheep, problems 7 and 8 show the reverse trend

Table 71. Summary of the total subjects making error in each of the visual and non-visual group of problems for sheep, cows, pigs and dogs over the eight runs.

run no.	Problems 1 to 6				Problems 7 to 12				Problems 1 to 12			
	sheep	cow	pig	dog	sheep	cow	pig	dog	sheep	cow	pig	dog
1. visual	226	196	187	36	185	139	144	26	411	335	331	62
1. non-v.	263	190	126	31	212	148	146	30	475	338	272	61
2. visual	49	44	124	10	97	64	87	8	146	108	211	18
2. non-v.	106	61	94	10	130	62	88	13	236	123	182	23
3. visual	26	19	48	1	58	36	64	6	84	55	112	7
3. non-v.	65	31	74	7	60	37	39	9	125	68	113	16
4. visual	25	14	12	3	46	22	36	4	71	36	48	7
4. non-v.	45	17	38	7	43	16	23	3	88	33	61	10
<u>total</u> <u>1-4</u>												
visual	326	273	371	50	386	261	331	44	712	534	702	94
non-v.	479	299	332	55	445	263	296	55	924	562	628	110
5. visual	25	8	15	2	28	22	20	1	53	30	35	3
5. non-v.	33	13	19	1	47	16	12	1	80	29	31	2
6. visual	21	12	10	1	35	18	4	-	56	30	14	1
6. non-v.	39	14	16	3	38	6	9	-	77	20	25	3
7. visual	22	12	9	1	33	13	4	1	55	25	13	2
7. non-v.	32	14	16	3	45	5	9	-	77	19	25	3
8. visual	20	9	7	3	37	10	1	-	57	19	8	3
8. non-v.	38	12	14	-	27	9	8	2	65	21	22	2
<u>overall</u> <u>total</u>												
visual	414	314	412	57	519	324	360	46	933	638	772	103
non-v.	621	352	397	62	602	299	334	58	1223	651	731	120

Table 72. The percentage of the total animals tested which made incorrect runs in each of the problems 1 to 12.

% of animals in error on run 1											
Species	problem number										
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u> <u>12</u>
cows	56	75	93	99	92	86	100	96	73	75	75 89
sheep	57	72	77	100	85	75	100	97	60	74	50 74
pigs	98	44	100	100	98	56	100	100	79	90	68 60
dogs	67	34	73	87	100	87	93	100	67	100	73 60

% of animals in error on runs 1 to 4											
Species	problem number										
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u> <u>12</u>
cows	10	15	20	23	13	13	29	19	14	17	13 19
sheep	9	18	17	26	13	13	31	22	12	15	8 24
pigs	26	11	28	42	20	13	43	21	12	23	15 19
dogs	13	11	13	21	16	14	25	20	8	27	13 10

% of animals in error on runs 5 to 8											
Species	problem number										
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u> <u>12</u>
cows	2	5	4	3	1	1	10	3	1	1	3 3
sheep	2	5	6	10	2	2	13	9	2	4	3 8
pigs	1	3	6	8	1	1	5	1	$\frac{1}{2}$	2	1 4
dogs	3	3	0	2	3	2	1	1	1	1	0 1

Table 73. Summary of the differences between total error scores from each of the visual and the non-visual problems for sheep, cows, pigs and dogs over the 8 runs.

run no.	Problems 1 to 6				Problems 7 to 12				Problems 1 to 12			
	sheep	cow	pig	dog	sheep	cow	pig	dog	sheep	cow	pig	dog
1. visual	1428	918	2234	310	2190	1918	3530	404	3618	2836	5764	714
1. non-v.	3098	1962	2352	352	4432	3630	3454	494	7530	5592	5906	846
2. visual	136	172	528	44	606	310	946	34	742	482	1474	78
2. non-v.	526	218	986	86	1094	668	1098	106	1620	886	2084	192
3. visual	84	56	166	4	212	132	452	18	296	188	618	22
3. non-v.	290	114	426	64	468	312	332	82	758	426	758	146
4. visual	66	54	44	12	150	80	152	12	216	134	196	24
4. non-v.	236	90	180	24	428	172	204	38	664	262	384	62
total 1-4												
visual	1714	1200	2972	370	3158	2440	5080	468	4872	3640	8052	838
non-v.	4150	2384	3944	526	6422	4782	5088	720	10572	7166	9032	1246
5. visual	60	30	70	6	114	80	76	2	174	110	146	8
5. non-v.	144	52	112	10	270	146	118	4	414	198	230	14
6. visual	54	44	56	4	132	58	10	-	186	102	66	4
6. non-v.	148	68	124	18	260	38	62	-	408	106	186	18
7. visual	60	60	28	4	118	46	10	10	178	106	38	14
7. non-v.	92	78	72	16	318	28	106	-	410	106	178	16
8. visual	52	32	26	16	130	30	8	-	182	62	34	16
8. non-v.	206	64	70	-	174	22	32	22	380	86	102	22
overall total												
visual	1940	1366	3152	400	3652	2654	5184	480	5592	4020	8336	880
non-v.	4740	2646	4322	570	7444	5016	5406	746	12184	7662	9728	1316

with 7 remaining difficult, while 11 and 12 and 3 and 4 have simpler visual forms. The visual problems, except in 7 and 8, are all simpler in runs 5 to 8. In the problems of average difficulty, pigs are at a disadvantage because of their poor use of vision.

A consideration of table 73 shows that for sheep the visual errors are less than half of the non-visual; for the cows they are almost exactly half in each case; for dogs the ratio is approximately 2:3, while the pigs show similar total scores on run 1 and on the run 1 to 4 totals in series 7-12. Pigs also show least difference between their visual and non-visual total errors of the four species tested. Figure 48 shows the same results graphically. The average scores for visual and non-visual problems are plotted separately for each run, for sheep, cows, dogs and pigs. The visual score of the pigs which lies within the general region of the non-visual scores for the other animals during the first 3 runs, drops by the 4th run to within the expected range for visual problems for sheep, cows and dogs.

Differences between the sheep, cows and pigs are also shown when the results from the error groupings are compared. Figures 49 and 51 show the number of animals from each species in each error grouping in run 1 and figures 50 and 52 show the changes which occurred between run 1 and 2 for the same 12 problems. As the number of subjects in each species group is different the general shape for the graphs rather than the absolute numbers provide the contrasts.

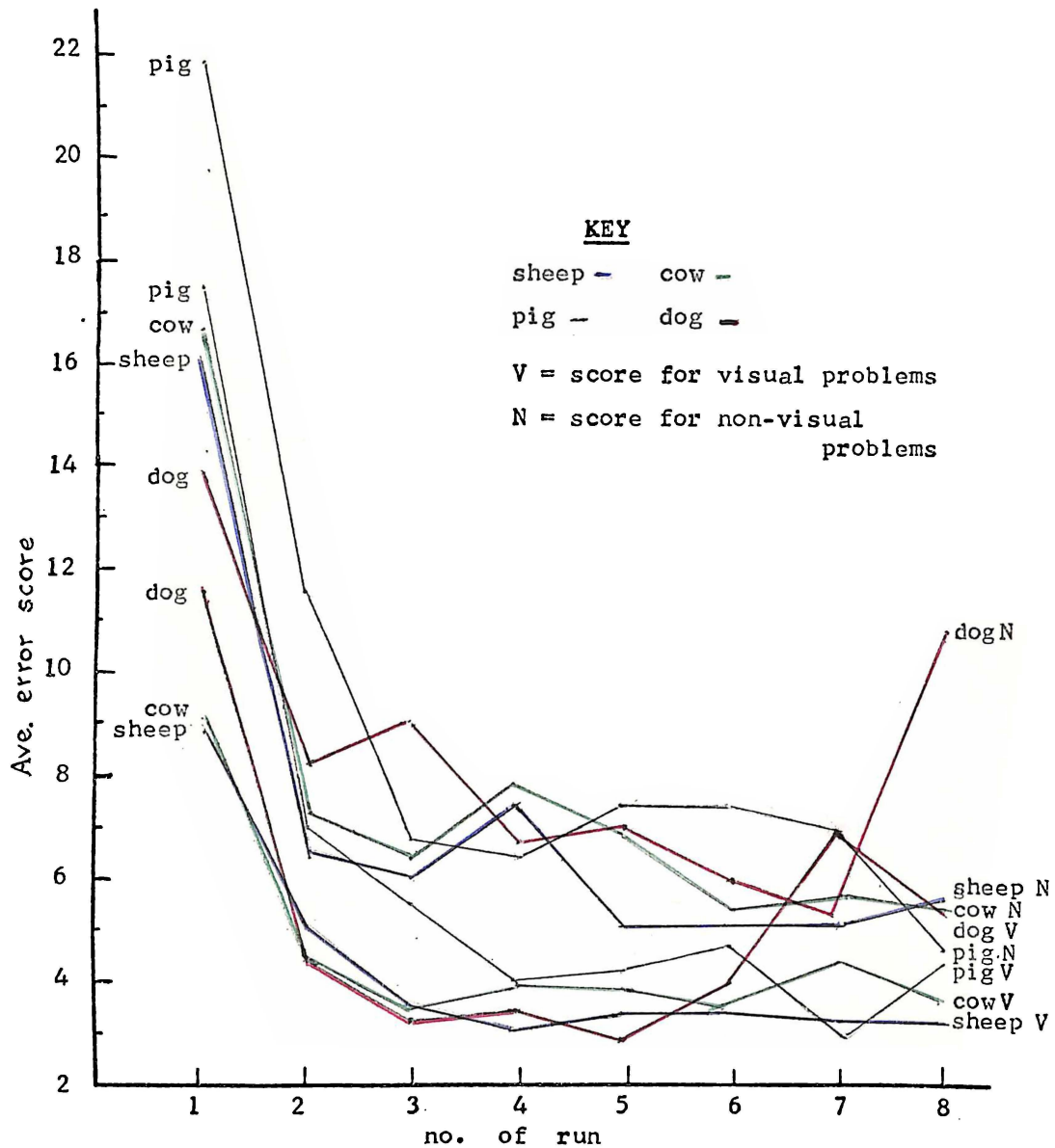


Figure 48. The average score for subjects of each species making errors in the visual (V) and the non-visual (N) problems for each of the 8 runs in the 12 problems of the closed-field test.

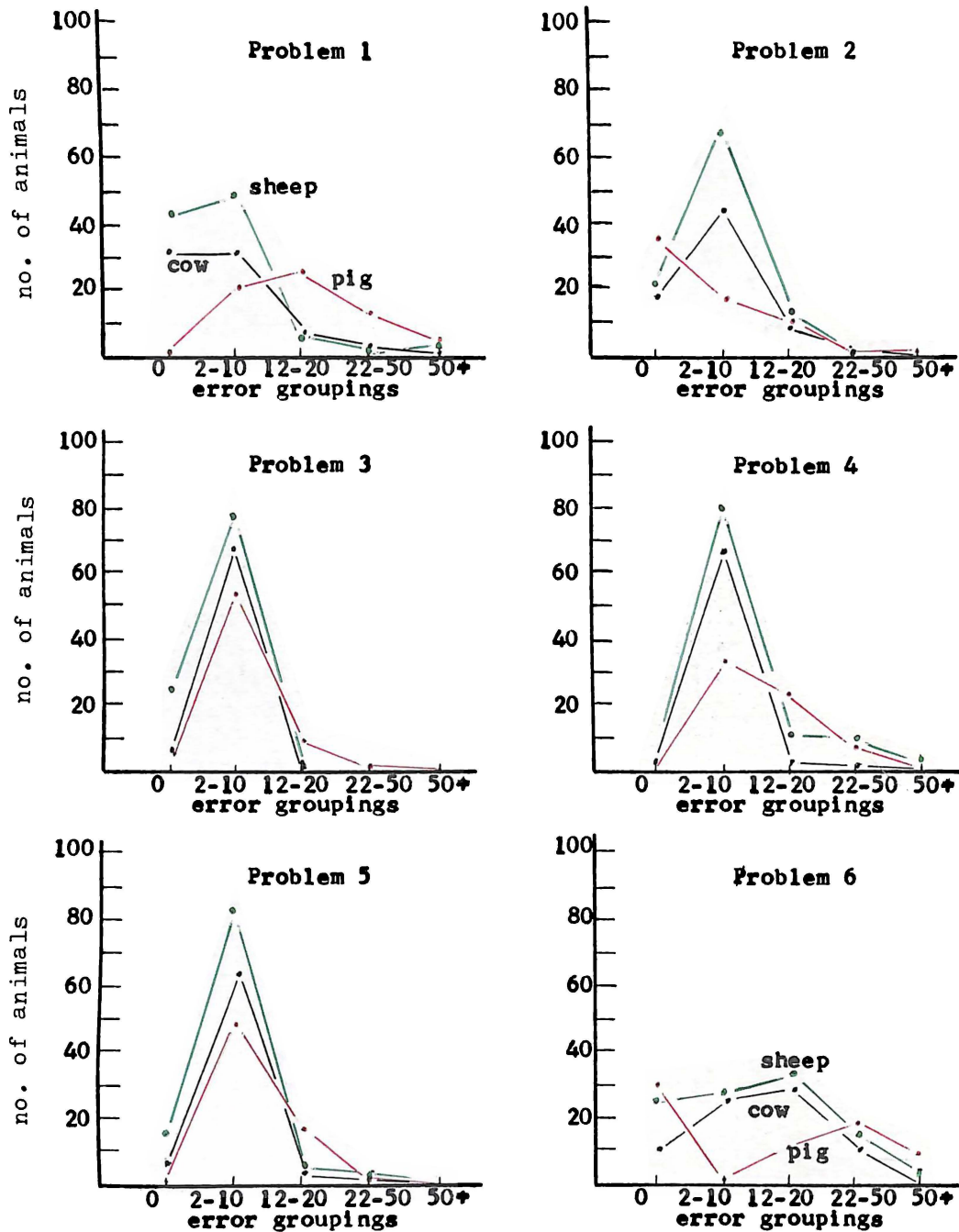


Fig.49.

Graphs comparing the performance of cows, sheep, and pigs in the Closed-field Test. Each graph shows the number of animals committing errors on the first run only in problems 1 to 6. Error groups used are without error; 2 to 10 errors; 12 to 20 errors; 22 to 50 errors and more than 50.

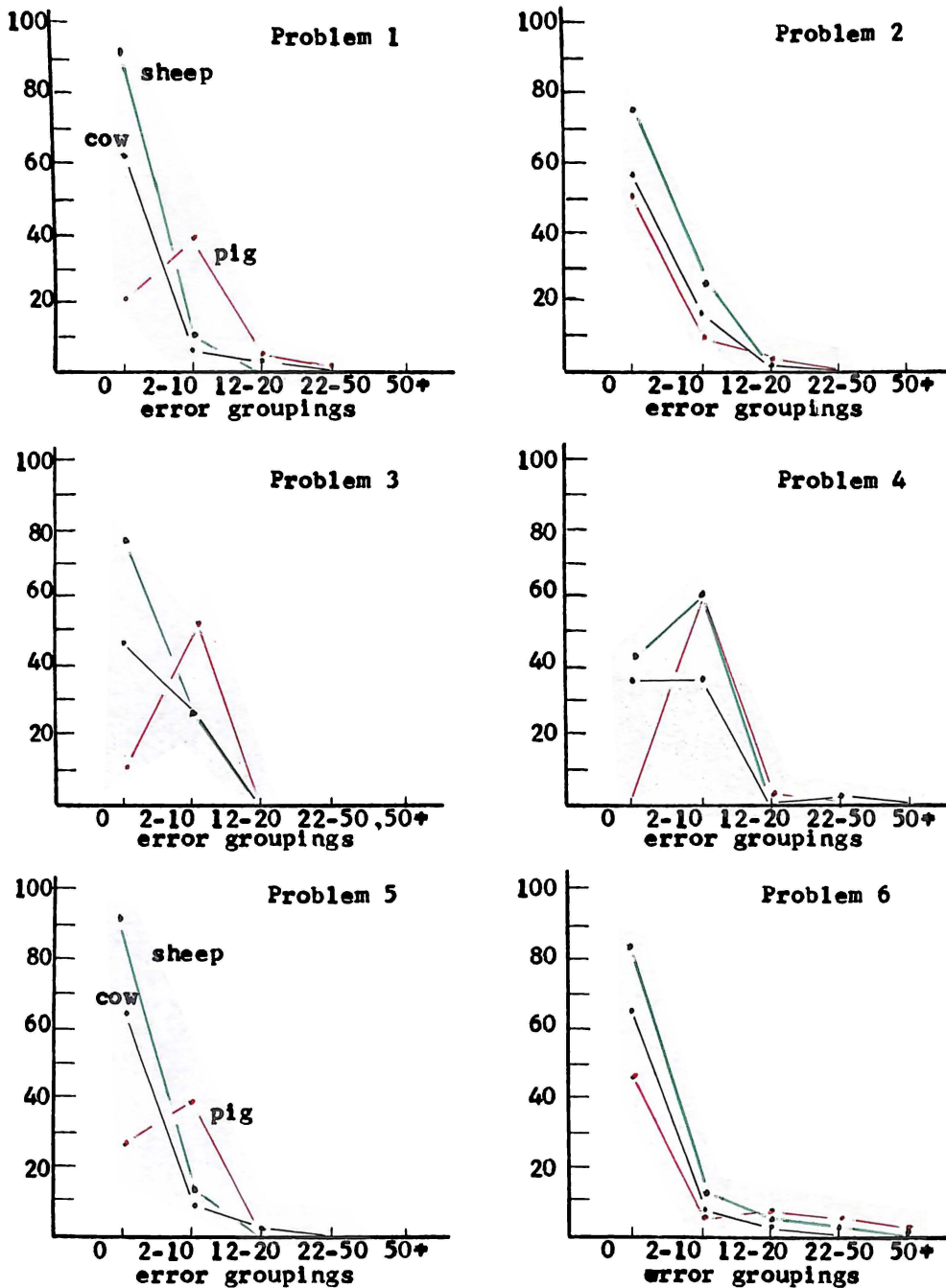


Figure 50.

Graphs comparing the performance of cows, sheep, and pigs in the closed-field test. Each graph shows the number of animals committing errors on the second run in problems 1 to 6. Error groups used are: without error; 2 to 10 errors; 12 to 20 errors; 22 to 50 errors and more than 50.

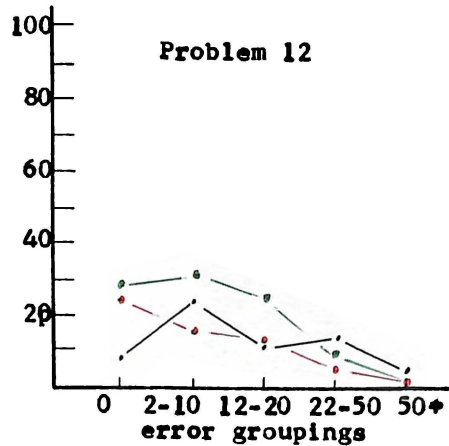
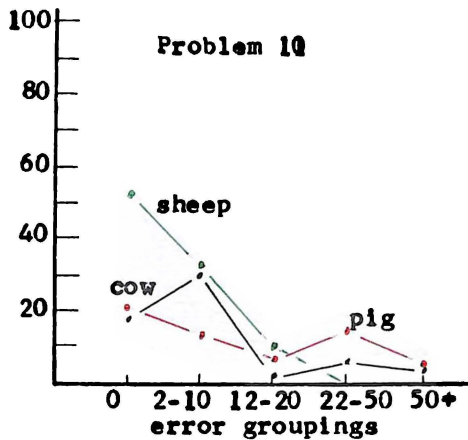
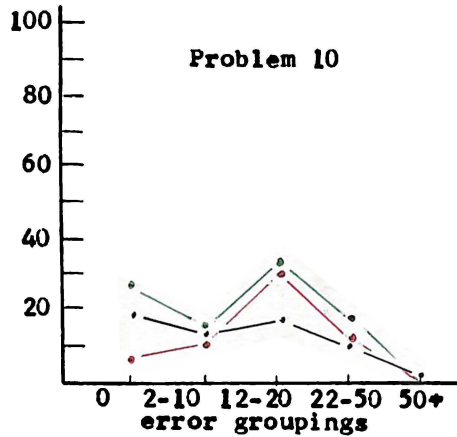
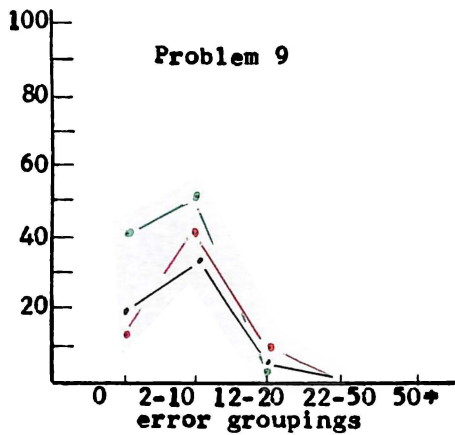
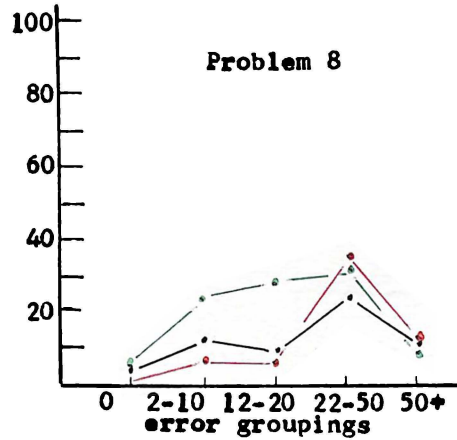
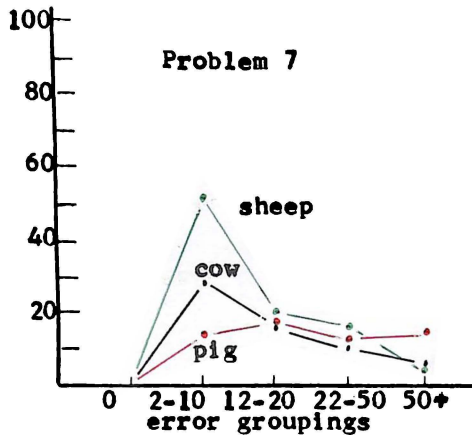


Figure 51.

Graphs comparing the performance of cows, sheep and pigs in the closed-field test. Each graph shows the number of animals committing errors on the first run in problems 7 to 12. Error groups used are: without error; 2 to 10 errors; 12 to 20 errors; 22 to 50 errors and more than 50.

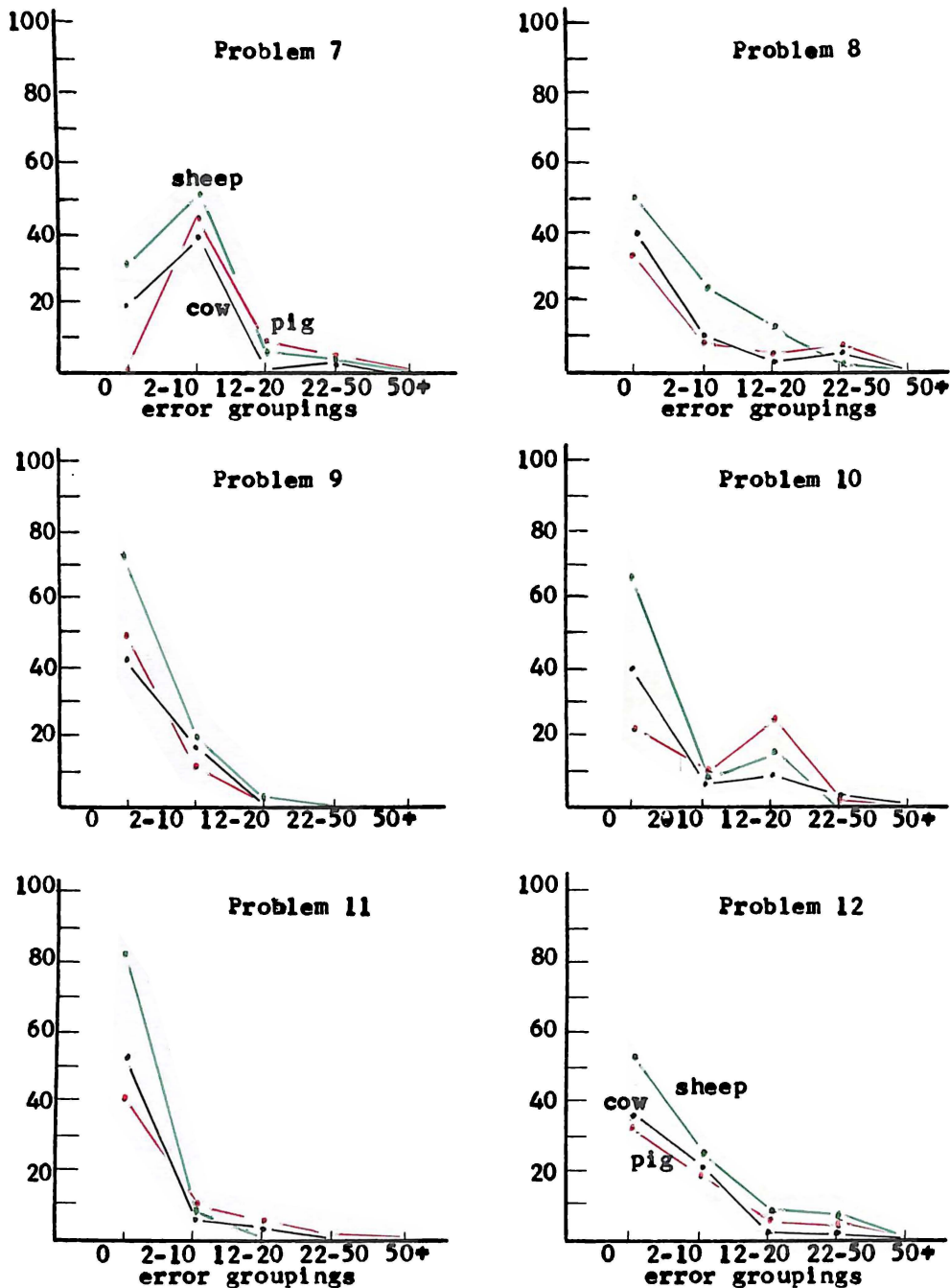


Figure 52.

Graphs comparing the performance of cows, sheep and pigs in the closed-field test. Each graph shows the number of animals committing errors on the second run in problems 7 to 12. Error groupings used are: without error; 2 to 10 errors; 12 to 20 errors; 22 to 50 errors and more than 50 errors.

The various progressions through which the graphs would move as the problems become simpler are illustrated in figure 53. The position of each of the 12 problems on run 1 is marked against the appropriate graph to gain some indication of the difficulty of that problem for the species concerned. Where the problem solution is difficult as in problem 6 or 8, the curves rise giving most animals in error in the 20 to 50 groupings for error. With easier problems most animals fall into the 2 to 10 error group and a typical spike results as in problems 2, 3, 4 and 5. By the second run in each problem the cows and sheep showed most animals getting the problem correct and a steeply falling graph ensues. This graph may further steepen with later runs but it has in essence reached its final shape.

Thinking in terms of this progression it can be seen that the pigs are in almost every case one run behind; e.g., in problem 1 on run 2 the pigs have reached the shape for sheep and cows on run 1. Similarly with problem 3 they remain similar in shape while sheep and cattle moved to their final form; in problem 4 they assume the graph shape for sheep and cattle on run 1; similarly with problem 5 and in problem 6 all groups have reached the final graph shape by run 2. The graphs for the series 7-12 for runs 1 and 2 show similar progressions. Figure 53 indicates the difficulty level of each problem.

Figure 54 contrasts the percentage of animals in error in each species group on runs 1 to 4 on the top graph and runs 5 to 8 on the

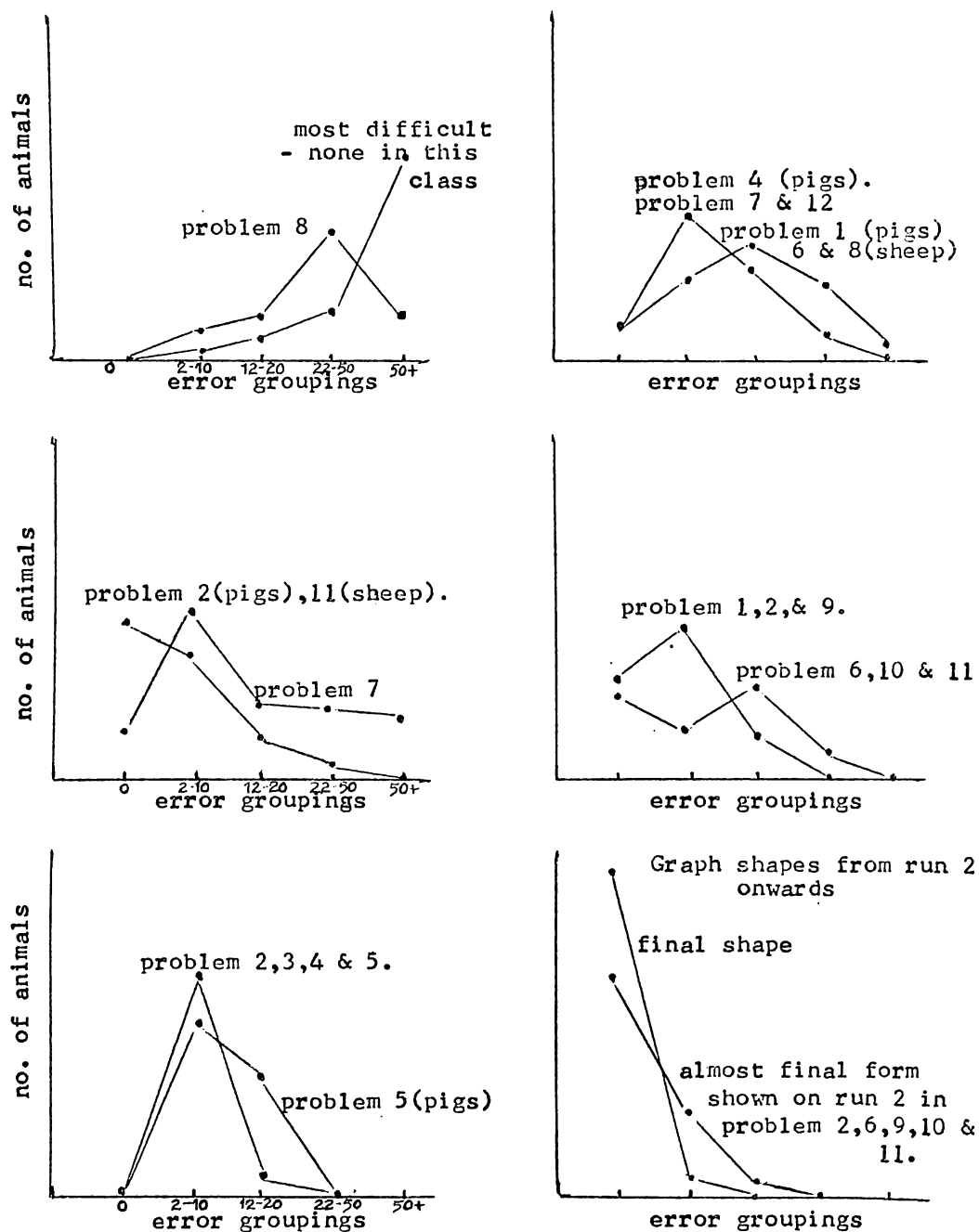


Figure 53. Twelve graphs summarising the variety of error grouping possibilities (figs. 49 to 52) ranked from the most difficult to the easiest indicating the approximate position on run 1 of each problem in the closed-field test.

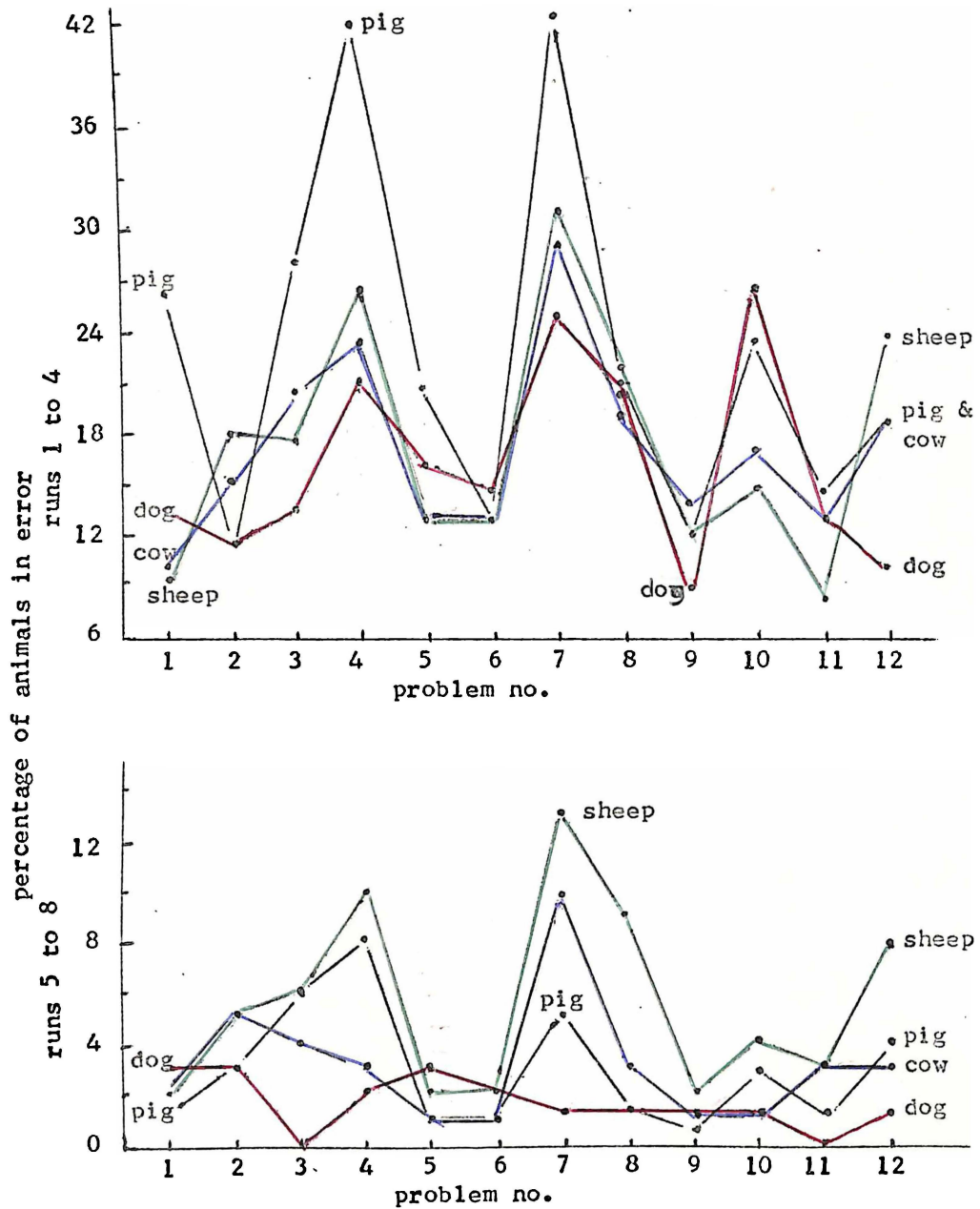


Figure 54. Graphs showing the number of animals making errors (as a percentage of the total sample) in runs 1 to 4 (top graph) and runs 5 to 8 (Bottom graph), for sheep, cattle, pigs and dogs in the closed-field test.

bottom graph. In no case do the two groups of graphs overlap. The contrast in graph movement for pigs on problems 1 and 2 compared with cows and sheep is clearly shown. The relative difficulty of problem 10 for dogs and problem 12 for sheep lifts their graphs above that for the pig on these problems. Problem 12 is comparatively easy for dogs. The graphs for sheep and cows show many parallel movements with rather similar ranges on runs 1 to 4. In runs 5 to 8 sheep show the highest percentage of animals in error while the pigs show considerable improvement. Very few dogs make errors on these runs.

The problems vary in their ability to differentiate between the species. The percentages in error on runs 1 to 4 on problems 6 and 8 for example are almost identical. Problems 1, 3, 4, 7, 10 and 12 in contrast, differentiate the four species very well. Problems 4 and 7 are difficult ones for the pigs and over 40% of all subjects were in error on the first 4 runs of the trials.

A summary table of species differences based on the raw error scores together with the main averages from the transformed scores is shown in table 74. In general run 1 scores have been selected. Cattle show the narrowest range of error of the 3 groups though sheep have more running correct on run 1 than cattle in 7-12. In the transformed scores pigs show the least change from series 1-6 to series 7-12. Tables 75, 76 and 77 show the %P, %R and TES results for sheep, cattle and pigs. On %P the mean scores for cattle and pigs remain similar to the series 1-6 scores, and the

Table 74. Species comparisons: A summary table of selected scores on the closed-field test.

problems series 1-6									
	% in error run 1	hardest problem	ave. error run 1	score range run 1	% of subjects disoriented	% with 100%R	average scores		
							%P	%R	TES
sheep	79%	6	9.3	0-150	2.3%	38%	31.4	85.0	266.8
cows	83%	6	7.9	0- 56	2.3%	53%	39.4	90.4	251.9
pigs	83%	6	14.7	0-128	8.1%	39%	48.9	92.6	422.6

problems series 7-12									
	% in error run 1	hardest problem	ave. error run 1	score range run 1	% of subjects disoriented	% with 100%R	average scores		
							%P	%R	TES
sheep	73%	8	16.7	0-174	5.0%	8%	38.4	78.6	412.7
cows	81%	8	19.3	0-118	4.5%	45%	37.6	89.2	428.7
pigs	82%	7	24.1	0-220	7.7%	32%	49.7	93.6	504.9

problems series 1-12					
	% in error run 1	hardest problem	ave. error run 1	score range run 1	
sheep	75%	8	12.6	0-174	
cows	82%	8	12.9	0-118	
pigs	82%	7	19.2	0-220	

<u>sheep</u>	<u>cattle</u>	<u>pigs</u>	<u>sheep</u>	<u>cattle</u>	<u>pigs</u>	<u>sheep</u>	<u>cattle</u>	<u>pigs</u>
10.9	11.6	.	38.4	.	.	.	.	59.1
12.7	.	.	39.1	.	.	.	.	59.7
17.5	.	.	39.1	.	.	60.3	60.3	60.0
17.9	.	.	39.3	.	.	61.0	61.5	61.0
19.0	.	.	40.3	40.2	40.7	62.9	61.7	62.2
20.2	22.0	21.5	40.5	40.3	41.0	63.9	62.1	62.2
20.5	25.8	22.2	42.2	40.3	41.3	.	64.6	62.9
21.9	27.6	26.3	42.4	40.3	41.8	.	68.6	62.9
22.6	27.8	.	43.3	40.4	42.7	.	.	63.3
23.4	29.2	.	43.5	40.8	43.0	.	.	63.8
23.5	29.9	.	43.9	41.0	43.3	.	.	68.3
24.7	.	.	44.4	42.6	43.8	.	.	69.4
25.4	.	.	44.5	42.8	44.5	.	72.2	71.7
26.9	.	.	44.7	43.1	44.5	.	.	72.2
27.0	.	.	44.9	43.3	45.6	N-83	N-60	N-59
29.7	.	.	46.2	44.8	47.2			
29.9	.	.	46.3	45.2	47.4			
30.4	30.0	32.3	46.4	45.9	47.5			
30.5	30.3	33.4	46.5	46.1	48.6			
30.7	32.5	35.7	46.7	46.6	48.8			
31.1	32.6	36.5	48.2	47.1	<u>49.4</u>			
31.4	33.8	36.8	48.7	47.2	.			
31.9	34.3	39.2	48.8	47.2	.			
32.0	34.4	39.2	48.9	47.3	.			
32.1	34.5	39.6	.	48.2	.			
32.3	35.2	.	.	49.1	.			
32.4	35.7	.	.	49.4	.			
32.5	<u>37.3</u>	.	.	49.4	.			
33.1	38.0	.	.	49.5	.			
33.3	38.0	.	50.3	51.9	50.0			
33.3	38.2	.	51.3	53.3	50.0			
33.3	38.7	.	52.7	59.6	50.1			
33.7	39.6	.	54.5	.	50.4			
33.7	39.8	.	54.8	.	50.7			
34.2	39.9	.	55.0	.	52.8			
34.0	.	.	55.6	.	53.3			
35.0	.	.	55.8	.	54.1			
35.7	.	.	57.7	.	54.3			
36.3	.	.	.	.	54.5			
36.4	.	.	.	.	55.3			
36.5	.	.	.	.	55.5			
36.7	.	.	.	.	55.9			
36.7	.	.	.	.	57.6			
36.9	.	.	.	.	57.7			
37.9	.	.	.	.	58.0			
<u>38.4</u>	.	.	.	.	58.5			
$\bar{x}$								

Table 75 showing
%P for sheep, cattle
and pigs in problem
7 to 12 of the
Closed-field Test.

Table 76 showing the %R for sheep, cattle and pigs in problem 7 to 12 of the Closed-field Test.

<u>Sheep</u>	<u>Cattle</u>	<u>Pigs</u>	<u>Sheep</u>	<u>Cattle</u>	<u>Pigs</u>
100%	100%	100%	84.7		
for 7	for 27	for 19	83.5		
animals	animals	animals	83.2		
(8% of	(45% of	(32% of	82.7		
sample).	sample).	sample).	82.6		
			81.8		
96.4	95.2	97.4	81.8		
95.6	94.8	97.2	81.5		
95.0	94.3	96.9	81.5		
94.3	94.2	96.9	80.3		
94.0	93.5	96.8	80.2		
93.8	93.2	96.8	80.0		
92.7	91.8	96.8	79.0	78.4	78.4
92.0	91.5	96.7	78.5	78.1	75.4
91.7	91.2	96.4	78.1	77.8	
91.6		96.2	77.7	77.6	
91.1		95.8	76.6	77.5	
90.3		95.6	76.1	76.3	
90.3		95.6	76.1	76.1	
		95.1	75.4	76.1	
		95.0	74.7	75.9	
		94.9	74.5	73.3	
		94.9	74.4	70.9	
		94.8	74.2		
		94.7	73.8		
		94.7	72.7		
		94.6	72.1		
		94.4	71.7		
		94.0	71.4		
		93.0	71.1		
		92.1	70.9		
		91.3	70.7		
		90.4	70.4		
89.9	89.8	89.9	70.1		
89.9	88.3	89.1	69.1	68.1	64.6
89.7	87.3	87.3	68.7		
88.7	85.0	86.6	67.6		
88.7	84.6	86.2	67.3		
87.4	84.1	85.5	67.0		
87.1	84.1	83.8	65.1		
87.0	83.2	82.8	64.8		
86.5	82.0	81.9	64.5		
86.4	81.9	81.6	64.3		
86.3			64.3		
84.9			62.8		
			61.5		
			61.3		
			61.0		
			55.4	59.8	
			53.4	53.7	
			39.5		

<u>Sheep</u>	<u>Cattle</u>	<u>Pigs</u>	<u>Sheep</u>	<u>Cattle</u>	<u>Pigs</u>
	98.2		423.8	431.6	460.4
161.0	100.9	.	425.5	442.1	466.1
195.4	174.6		437.6	451.5	470.0
210.8	215.5	266.5	438.1	470.9	480.4
216.6	234.6		460.2	473.0	484.3
220.7	244.5		466.9	478.8	488.0
228.5	252.0		474.0		488.8
236.9	256.0		478.3		490.4
237.8	269.1		478.8		492.1
240.0	293.5		480.5		497.7
242.1	297.0		481.2		
243.0	297.5		483.0		
276.8	298.0		484.3		
278.9			492.9		
287.0			501.5	501.5	502.1
295.2			503.0	503.1	<u>504.1</u>
296.5			517.7	507.7	509.2*
297.0			522.9	510.4	523.5
301.5	308.5	303.2	528.1	520.4	527.8
302.2	314.4	316.5	549.0	538.9	529.5
304.3	315.1	342.2	549.1	542.1	546.1
312.5	315.5	246.7	568.1	544.1	550.4
312.7	322.1	360.4	568.8	564.0	550.9
313.0	324.0	362.0	571.1	571.7	551.2
314.1	326.1	367.3	574.8		551.5
314.6	326.6	369.9	576.9		559.9
316.7	333.2	376.5	578.4		561.5
317.5	341.8		594.2		568.1
319.4	342.0		594.9		568.1
332.8	349.5				572.0
335.1	351.0				575.4
352.6	358.7				578.7
354.2	377.5				581.7
357.1	384.4				587.1
365.5	391.5				589.3
367.1	393.8				589.5
368.3	397.5				596.0
369.1					597.1
373.1					598.6
376.4			622.9	608.0	602.2
379.3			635.9	622.4	612.1
404.4	400.5	401.6	642.3	650.5	615.0
406.8	414.6	421.6	682.1	699.4	633.6
407.4	417.3	431.0	684.7		651.4
409.6	423.1	445.3			678.9
413.5	423.1	449.4		750.3	739.9
417.0	428.6	451.6	918.2		
421.4	<u>429.6</u>	454.0	1057.1		

Table 77
showing the
Total Error
Score for
sheep, cattle
and pigs in
problems 7 to
12 of the
Closed-field
Test.

range of %P scores for cattle and pigs is similar.

On the %R score the sheep scoring 100% drop sharply from 38% on series 1-6 to 8% of the sample. Pigs and cows drop 7 and 8% respectively. The actual score for sheep also drops 7 points and the range is extended. Only 24% of the pigs scored below 90.0% for this score. The %R score for sheep may be reflecting the effect of continued isolation on performance. Series 7-12 was always run after series 1-6.

Table 77 shows that the Total Error Score (TES) for pigs had a similar range to the series 1-6 and the mean shifts 80 points. The top scores for cattle moved upwards from 521.4 to 750.3 and the mean moved about 180 points, while the range for sheep began approximately 100 points behind and the top score is 1057.1 instead of 645.2. The individual performance is most erratic for sheep but the mean rises less than that for cattle. The series 7-12 which was originally designed as a stand in for wet weather, proved to be more difficult than anticipated especially problem 7 which appears deceptively easy to the human observer.

Tables 78, 79 and 80 provide the transformed scores for rams, lambs, dogs and children with the 3 groups of lambs distinguished by the use of asterisks. An asterisk before the score indicates lambs from the bottle-fed separately reared group; an asterisk after the score indicates lambs from the bottle-fed reared-together group and the unmarked scores those from the matched controls.

It is possible to take the mean scores from the transformed data for the series 1-6 for five species for an overall species

Table 78. Showing %P scores for lambs, rams, dogs and children in problems 1-6 of the closed-field test.

<u>Rams</u>	<u>Lambs</u>	<u>Dogs</u>	<u>Children</u>	<u>Rams</u>	<u>Dogs</u>	<u>Children</u>
14.7	*12.0		0.0	52.4		
18.5	16.0		for 18	53.1		
	16.5		subjects	56.7		
22.0	17.0		i.e., 95%			
23.0	*17.2		of group		60.0	
25.8	*18.3				61.3	
26.2	19.0*				61.3	
26.9	19.1					
27.3	*19.8				72.3	
27.6						
28.6						
28.7	20.9*	23.0		N=24	N=15	N=19
28.9	*22.8	24.5				
28.9	24.9*			$\bar{x}=33.7$	44.2	1.9%
	25.9*					
	*27.4					
	*27.5					
	*28.0					
	28.5					
	29.9*					
	$\bar{x}$					
32.2	*32.4	30.2	35.6			
33.0-	33.7	30.6				
36.1 ^x	34.2	35.1				
36.4	34.2	36.9				
37.8	34.5					
	34.6					
	35.2					
	*35.6					
	36.2*					
	36.5					
	37.0					
	37.9					
	38.2*					
	39.2					
45.9						
48.9	40.0	43.5				
49.6	41.0*	$\bar{x}$				
	44.9	44.4				
	46.6*	47.0				
	46.6	48.9				
	n = 37					
	$\bar{x}$ = 31.4					

* before %P = lambs from bottle-fed separate reared group.

* after %P = lambs from bottle-fed reared-together group.

no asterisk = mother-reared lambs - controls.

Table 79. Showing % R scores for lambs, rams, dogs and children in problems 1-6 in the closed-field test.

<u>rams</u>	<u>lambs</u>	<u>dogs</u>	<u>children</u>
100%	*100%**	100%	100%
for 6	for 7	for 9	for 17
animals	animals	animals	subjects
25% of	19% of	60% of	89% of
sample	sample	sample $\bar{x}$	sample
93.3	*94.2	91.7	
91.8	90.8*		
	*90.0		
89.3	89.2	87.6	81.0
88.8	*88.0	85.7	
85.5	86.7	81.3	0.0
84.9	86.5		
81.3 = $\bar{x}$	*84.8		
	84.7		N = 19
	84.0		$\bar{x}$ = 99.0%
	83.3		
	81.6* = $\bar{x}$		
	*81.6		
	80.8*		
78.2	79.9*	79.1	
70.9	*79.5	73.3	
72.9	77.5*		
70.4	75.6		
	74.6	$\bar{x}$ = 92.9	
	*72.5	N = 15	
	72.2		
	*71.9		
66.6	68.2		
66.4	67.6		
64.9	66.7		
62.0	64.3		
62.8	60.8		
	*60.7		
59.2	58.3		
55.3	N = 37		
N = 24			
$\bar{x}$ = 81.3	$\bar{x}$ = 81.6		

* before % R = lambs from bottle-fed separate reared group.

* after % R = lambs from bottle-fed reared-together group.

no asterisk = lambs reared by mother

Table 80. Showing Total Error Score (TES) for lambs, rams, dogs and children in problems 1 to 6 in the closed field test.

<u>rams</u>	<u>lambs</u>	<u>dogs</u>	<u>children</u>	<u>rams</u>	<u>lambs</u>	<u>dogs</u>
		88.4	0.0	415.0	412.4*	455.4
			17.6	432.6	*439.4	
			17.6	472.1	443.0	
			30.6	472.7	444.0*	
			48.3	484.0	448.9*	
123.8		101.4	53.0		*464.8	
162.0		108.6	53.0		465.5	
165.8		127.9	60.4			
		181.2	65.9			
			67.6		*512.5	
			85.3		558.0	
			87.1		577.6	
			87.8		583.0	
216.2	215.0	229.4	95.8			
240.6	227.3	<u>231.0</u>				
247.9	227.0	<u>245.7</u> $\bar{x}$	101.4		618.0	
263.9	*257.5	246.2	127.1		656.3	
283.4	264.9*		127.9		660.3	
289.6	269.5*		182.8			
297.0	274.2*		192.8			
298.1	284.9					
	288.0*				846.1	
	*288.8					
	*293.5					
			N =19	N =22	N =37	N =15
			$\bar{x}$ =79.1	$\bar{x}$ =332.4	411.6	244.0
317.6	*303.4	300.9				
323.4	305.6	309.0				
330.6 $\bar{x}$	312.9	315.4				
<u>341.1</u>	313.5	345.1				
367.5	*347.4	374.1				
391.5	350.9*					
	*353.4					
	*354.3					
	383.9*					
	394.5					
	<u>398.8</u> $\bar{x}$					

* before TES - lambs from bottle-fed separately reared group.

* after TES - lambs from bottle-fed reared-together group.

no asterisk = lambs reared by mother

comparison with performance in the closed-field test as recorded by other experimenters. The range of species already tested in the series 1-6 by Pollard and his co-workers (1961, 1962, 1967 and 1969) include the rat, the cat, ferrets and opossums and two bird groups, hens and pigeons. Twenty-one dairy goats and six mice have been tested in addition to the species described in detail in this study. The results from the small-sized closed field test together with results from this study are set out in table 81. They are ranked in order of increasing total error score (TES), the most reliable of the transformed scores. Children approach the score which must be considered as a baseline for TES. A hypothetical case showing the minimum "expected" errors that would be made by chance during the selection of the best pathway is shown in table 82. If it is allowed that one square might be broken in the visual problems then the %P score is 20.7%. %R will be 100% and four squares broken in problems 2 and 4 and 2 in problem 6 would give a TES of 85.6. If the error on the visual problem is eliminated, the TES will be 67.6.

The score of 79.1 for the TES for children is almost a baseline. At least one child made an error after run 4 and this pulled the %R score down to 99.0%. These errors were made in problem 4 where the children tended to run around the two detached baffles and did not, in one case, straighten this pathway till after run 5. Several errors were made in the visual problems and this meant the %P score was not zero as might be expected.

Table 81. The comparative results for various species tested in series 1-6 of the closed-field test ranked in order of increasing total error score (TES).

Species tested	No. of subjects	%P 0.0%	%R 100.0%	T.E.S. 67.6= baseline	Reference
children	18	1.9	99.0	79.1	this study
dogs	15	44.2	93.2	244.0	this study
dairy cows	73	39.4	90.2	251.9	this study
dairy goats	21	36.7	91.4	258.5	*subsidiary study
sheep - ewes	79	31.4	85.0	266.8	this study
pigs	63	48.9	92.6	422.6	this study
cats -house	6	7.9	84.5	283.7	Pollard, 1961
-alley		24.5	74.8	852.5	" "
-average		13.8	81.1	484.8	" "
	1	39.8	81.3	361.3	this study
rats - Wistar	24	39.4	75.8	673.4	Pollard, 1961
ferrets	8	36.3	70.0	989.5	Pollard & Lewis, 1969
hens	18	36.6	61.5	1009.9	Pollard <u>et al.</u> , 1971
pigeons	6	38.4	66.5	1177.7	Pollard, in press
guinea pigs	6	50.4	53.7	1267.2	*subsidiary study
mice	6	52.9	48.1	1430.5	*subsidiary study
opossum - brush-tailed	6	40.0	58.5	1768.3	Pollard & Lysons, 1967

* subsidiary study conducted after March, 1970

Table 82. Hypothesized "expected" minimum error to be made by any subject of any species on series 1-6 of the closed-field test

problem no.	runs				runs				totals	
	1	2	3	4	1-4	5	6	7	8	5-8
1	0	0	0	0	0	0	0	0	0	0
3	(2)	0	0	0	(2)	0	0	0	0	(2)
5	0	0	0	0	0	0	0	0	0	0
total visual	(2)	0	0	0	0	0	0	0	0	(2)
2	4	0	0	0	4	0	0	0	0	4
4	4	0	0	0	4	0	0	0	0	4
6	2	0	0	0	2	0	0	0	0	6
total non-visual	10	0	0	0	10	0	0	0	0	10
total 1-6	12	0	0	0	12	0	0	0	0	12

All the error scores are then transformed $\sqrt{\quad} \times 100$

$$\%P = \frac{141}{682} = 20.7 ; \quad \%R = \frac{682}{682} = 100\% ; \quad TES = \frac{682}{8} = 85.6$$

On the T.E.S., dogs, cows, goats and sheep are closely grouped, with the house-reared cats of Pollard's following with a TES of 283.7. On average, the pig and the cat score in the 400s, and the other species except the ferret and the hen are clearly delineated in rank order. When the %R scores are considered there is a general fall in this score as the TES score increases with two exceptions, the pig and the mouse. The %P score is the most difficult to assess but ranges in extremes from children and house cats with scores less than 10.0% to dogs, pigs, and mice with scores greater than 40.0%. The reliability of this score might improve if the visual and

non-visual form of each problem was separated by longer than 3 days, as it would be if the complete 12 problems were used to constitute the test. Table 82 shows that in the lowest scoring animal whose TES approaches baseline, breaking one square only during a visual problem trial will give a %P score of 20%.

It has been noted already how important the TES is in a ratio score and that the closer the TES is to baseline the less reliable the %P score will be. At least 2 of the sheep were able to equal the performance of both house-trained cats and come close to the %P scores for children, though overall the sheep average was 31.4. The dog score of 44.2% on %P can only be accounted for by the observations that dogs generally move so quickly in the arena that they overshoot the ends of barriers and tend to make equal errors in visual and non-visual problems. (see table 73).

The score for the one cat so far tested in the large arena though falling in reasonable range with Pollard's house cat in %R and TES gives a %P score which is little related to any of the other cats. It has been suggested by McBride (1968) that the hens were at a disadvantage in a horizontal maze and that to test their true potential in the test they should be run in a vertical form of the arena.

If the Total Error Score is considered to be the most critical score for the comparative ranking of the species it is interesting to note the position into which the domestic species fall. They are seldom included in lists of comparative ability records from other

experimental approaches. The species rankings from the multiple choice apparatus (Hamilton, 1911) are man, monkey, dog, cat, and horse or from Yerkes' (1916) use of the same modified apparatus, pig, monkey, crow and rat. Pavlovian type conditioning gives a rank order of pig, dog, sheep and goat; rabbit, guinea pig and opossum (Liddell, et al. 1934) while the results from Fink's maze are shown on table 4. Procedures such as the Reversal Index have not been applied to the domestic animals as far as is known. Overall the dog and pig appear in a few lists, the sheep and horse in very few and the cow has generally not been used at all. The closed-field test enabled an objective assessment to be taken of the ability characteristics of these larger animals and as table 81 shows they compare very favourably with the species tested previously. With some further refinement of problems and technique, the closed-field test could provide a very adequate test for large animal species.

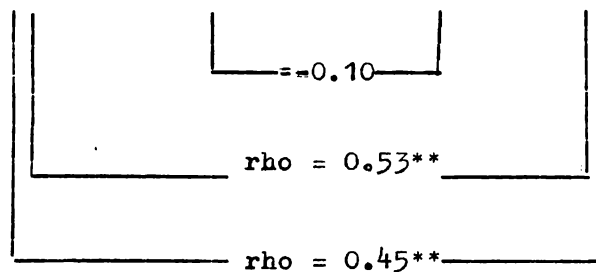
No significant differences can be shown between the TES of sheep, cattle and goats but pig scores are significantly different from these three species (Kruskal-Wallis $H = 64.4$; $df = 1$; $p = < 0.001$). It seems clear that the closed-field test has not the ability to discriminate between sheep and dairy cows, nor between sex, age, or breed differences of these groups. Using as it does relatively simple problems which can be mastered by a wide range of mammals, the scores for sheep, goats and cows are very similar. More difficult problems need to be devised for these animals.

The closed-field is in fact a more or less complicated open-field. Each training and test problem complicates the arena patterns and adds more or less difficulty to the detour problem. If this is so, the results from the training problems are just as pertinent to the subjects under scrutiny as the actual test results. It is as characteristic of a species that it takes two cycles of the A-F training problems before criterion is reached as it is for them to be ready in 6, 7 or 8 days. If it takes 3 complete cycles as it does in mice, this is also significant. The ease with which a species masters the training problems depends to some extent on how much fear is shown, whether they hug the walls or venture into the centre of the arena, or whether they wobble or take direct pathways. There appears to be a species-specific distance at which subjects will reverse course after entry into a cul-de-sac. Although it is historical to divorce the work and concepts of the open and closed-field tests, this seems unnecessary and indeed undesirable. The 3 days spent testing reactions in the open-field can be usefully included as part of the subject's orientation to the experimental procedure and apparatus.

It is of interest to turn and look at results from the open and closed-field tests for the subjects which had these two tests in common. The results for cows are shown in table 83 and for sheep in table 84. It is conceivable that the subjects making highest scores in the open-field ambulation may also be running in an excited manner and making more errors in the closed-field test.

Table 83. Scores of cows' performance on the open and closed-field tests.

cow no.	total ambulation	total vocalisation	%P	series %R	1-12 TES	TES rank
1	181	14	45.2	81.1	435.1	2
2	160	0	50.5	84.5	512.9	1
3	141	22	42.7	72.3	392.8	8
4	128	76	45.8	72.1	308.7	11
5	114	18	38.3	88.1	263.6	20
6	112	43	46.8	72.0	289.8	14
7	105	12	53.5	100.0 ⁺	237.6	22
8	96	23	40.4	100.0	414.1	5
9	91	12	43.8	91.0	351.5	10
10	91	9	35.9	96.8	284.9	16
11	90	37	35.7	74.2	269.1	19
12	89	5	35.9	100.0	396.4	6
13	87	70	39.2	85.5	426.1	4
14	84	13	38.7	85.2	431.3	3
15	77	13	37.0	100.0	307.5	13
16	76	18	56.6	100.0	307.6	12
17	73	2	41.5	100.0	254.0	21
18	69	15	38.7	100.0	221.0	23
19	68	5	47.8	100.0	282.7	17
20	56	16	45.9	76.5	394.6	7
21	53	3	39.7	97.2	377.4	9
22	52	22	43.6	100.0	274.8	18
23	50	17	41.3	79.2	190.5	24
24	44	8	52.8	100.0	107.1	25
25	33	0	44.2	100.0	288.9	15



** = significant at the 1% level of confidence.

⁺ = where several subjects all scored 100% on %R, ranks were defined with reference to the TES of the animal.

Table 84. Scores of sheep on the open and closed-field tests.

sheep no.	total ambulation	total vocalisation	%P	series %R	1-12 TES	TES rank
1	430	177	38.6	80.2	459.6	2
2	228	99	32.5	83.8	408.1	4
3	221	74	18.1	83.6	277.6	23
4	203	117	41.9	100.0	342.8	12
5	197	104	44.2	85.8	309.4	14
6	185	213	38.2	95.2	352.7	9
7	185	86	37.6	85.0	366.6	7
8	184	82	41.5	93.6	218.1	28
9	182	122	42.0	78.7	510.3	1
10	180	97	33.4	89.0	345.7	10
11	160	88	42.6	88.1	428.4	3
12	147	128	39.2	95.0	323.9	13
13	147	100	28.6	89.5	303.4	17
14	146	75	30.0	88.3	225.3	27
15	144	21	43.3	95.8	247.2	25
16	132	98	41.3	100.0	298.4	18
17	132	79	16.7	90.1	369.1	6
18	130	72	24.2	80.9	278.0	21
19	129	96	26.5	75.4	344.7	11
20	120	85	20.3	93.9	290.0	20
21	118	61	32.3	90.8	311.7	15
22	116	72	33.5	96.0	237.6	26
23	111	64	46.2	97.0	388.9	5
24	107	120	37.1	77.5	277.7	22
25	102	75	40.7	73.1	265.2	24
26	99	37	17.3	87.7	316.9	14
27	98	44	33.6	76.0	291.3	19
28	95	132	32.3	81.9	163.9	29
29	88	120	30.0	84.8	363.2	8

rho = 0.19

rho = -0.15

rho = 0.36*

* significant at the 5% level of confidence.

The correlations of TES and open-field ambulation (Column 2.) is 0.36* for sheep and 0.45** for cattle. It appears that in cows which give consistent trial times and regular performance, high ambulation in the open-field is related to a slower elimination of errors in the closed-field. This is just significant at the 5% level of confidence for sheep also.

This same consistency is reflected in the %R scores which were then examined. The correlation for cattle is 0.54** but for sheep is -0.15. In dairy cattle the fewer squares broken in the open-field, the better the performance on runs 5 to 8 of the closed-field test, but in sheep this was not so. Considering that sheep do not habituate well to the open-field during the 3 day testing period it must be considered that evidence of this deteriorating performance may be carrying over into the closed-field test and the scores in %R are rather erratic. Evidence for this has been provided with the dairy stock, which show rapid declines in both ambulation and vocalisation during the 3 days of open-field testing. Reliable correlations between the performances in both tests are found, in this case.

The final relationship examined was the vocalisation score and the %P based on the hypothesis that the animals which were giving poor visual reactions might be the animals emitting a high number of vocalisations. The correlation (rhos) for cattle was -0.10 and for sheep was 0.19. No significant relationship was found between these two scores.

It can be concluded from the results from cattle that the 2 tests having many common ingredients, could well be run together and would provide useful complementary pictures of the animal's performance. To this end the complete 12 problems constitute a better test than just the six used by Pollard (1961). From the point of view of experimental design 14 problems would be even better.

The individual subjects' error scores for each run on each problem in the closed-field test have not been included as an appendix to this thesis. Full summary tables have been provided for each of the species in the major study. It is proposed to publish individual scores for the main and subsidiary studies, together with the raw scores from the species tested by Pollard and his associates at the University of Canterbury sometime in the near future.

General Discussion.

At present the bibliography of research using the Hebb-Williams closed-field test includes almost 100 published papers (Pollard, 1970). Table 85 gives an analysis of these papers according to species used and according to purpose of the experiment.

Table 85. An analysis of the published papers relating to the Hebb-Williams closed-field test (a) according to species and (b) intent of each experiment. (based on Pollard's Bibliography, 1970).

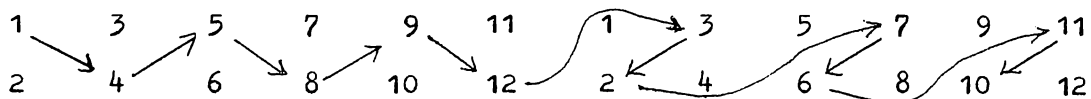
Species used		basic experimental rationale	
White rat	70	closed-field test per se	22
cats	8	early experience effects	20
dogs	3	brain lesions etc.	16
primates	2	drug effects	9
birds/hens	2	species per se	9
sheep	1	diet deficiencies	5
ferrets	1	genetics	4
opossums	1	exploration	2
fish	1	maturation effects	1
		infections	1
	89		89

Just over 20 studies have in some way been concerned with the closed-field test as a test per se, some dealing with scoring techniques, test modifications, size differences, types of reward used, etc. Nine studies have examined the performance of a specific species in itself, apart from effects of early rearing variables. In general however, the test has been used as a convenient objective assessment of genetic strain or abnormality, early deprivation or enrichment, brain lesions, dietary deficiency or drug effects. The large majority of tests have used the white rat and 8 studies have used the cat. Only in New Zealand has any extensive use been made of the test for an assessment of more than three species, and to this end the comparative data in table 81 draws exclusively on the New Zealand work. To this end also, the standard series 1-6 of Pollard's was followed during this study.

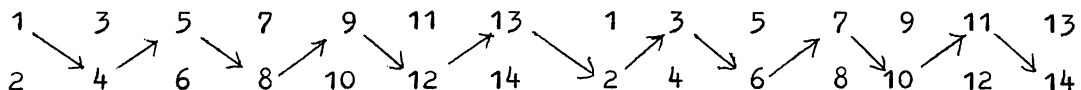
A number of criticisms have been levelled at the closed-field

test by various investigators in the past. Livesey and Pollard have both indicated that the problems of Rabinovitch and Rosvold are not the graded series of easy to more difficult that was earlier claimed. Pollard set out to exploit this by delineating visual and non-visual type problems, but only used 6 problems in his series. The additional information gained from a number of the problems in series 7-12 during this study however; e.g., the poor performance of visual animals on problem 7 and the ability of problem 10 to differentiate dogs from the other groups, warrants their inclusion in the series. It would be better from a methodological point of view to have 14 days of testing rather than 12 and this would give a full week between the performance of the visual and non-visual form of each problem. With only 12 problems it is not possible to move from problem 12 to problem 2 as they are both non-visual forms. This means that on day 7 problem 3 must be used and problem 2 the day after and so on. Table 86 shows the combinations to be used in a 12 problem and a 14 problem series.

Table 86. Problem sequences for 12 problems and 14 problems to allow maximum number of days between the visual and non-visual form of the same problem.



12 problem sequence



14 problem sequence

The difficulty with moving from problem 12 to problem 3 is that the solution to both lie in similar directions and the logic of the problems has been to avoid this pattern. Problems 13 and 14 should have a bottom right hand side pathway as problems 1 and 2 utilise a central pathway. Of greater importance is the need to complicate the visual form of the various problems so that they are, for the visual animals not difficult, but for the non-visual animals not too simple; e.g., problem 3 and 5 are uncomplicated type problems. The insertion of single baffles in places in these two problems could greatly enhance the %P score and perhaps even increase its reliability. With these changes the closed-field test as at present in use provides a very satisfactory assessment for species ability.

For the finer assessment of sex, age and breed differences it could well be possible to leave the series 1-6 as at present and substitute series 7-14 with 4 problems of increased difficulty and complexity. In this way the results for series 1-6 could provide the material for species comparisons as at present and the overall totals could delineate the finer differences required for assessing differences in age, sex or even changes due to variations in practical management of farm stock. The problems should be designed around a maximum of 20 baffles which would make the test mechanically feasible for use with large animals.

As a practical technique for the assessment of large animal ability the closed-field test appears in retrospect to have a

number of advantages. Reasonable numbers of subjects can be handled with a minimum of labour. With further automation of timing and scoring two people could manage experimental groups of up to 20 each three-weekly period. The animals adjust quite rapidly to the experimental procedure and even naive animals can be successfully managed. The dairy cows and goats had all been subjected to handling prior to experiment but several bulls, all of the pigs and most of the sheep could be considered naive experimental animals. Apart from the difficulty with sheep which become upset when run as individual subjects, all stock returned to the farm in reasonable health, and in no way suffering from any signs of experimental neurosis. Between trials the apparatus has been subjected to a wide variety of other uses as an outside laboratory.

Summary and General Conclusions.

In this study an attempt has been made to assess temperament and ability characteristics of sheep, cattle and pigs by adapting two of the objective tests developed for similar assessments in the rat and other small mammals. The open-field test suggested and originally developed by Hall, (1934) was used to test 30 sheep, 44 cattle and 28 pigs. The open-field arena was scaled to 72 foot square, and five minutes' assessment of behaviour was made on each day for a period of 3 days. The sizes of field arenas and the various procedures used by various experimenters in the past are fully discussed and reasons given for the selection of procedures for this study.

The closed-field test developed by Hebb and Williams (1946), and standardised by Rabinovitch and Rosvold (1951) was used to test 127 sheep including rams, ewes and lambs, 73 cattle, 63 pigs and 15 dogs over an 18 day trial period to assess performance of each species in a series of different detour problems. The sizes of field arenas, testing and training procedures and the types of detour problems selected for this test are discussed, as are the deprivation schedules and reinforcement used for each species.

Essentially the open-field procedures were little modified from normal practice, but for closed-field testing the procedures and problems of Pollard (1961) were used. The test was enlarged to include twelve detour problems as was the case with the

Rabinovitch and Rosvold revision.

The large size of the animal subjects tested presented the first major difficulty. Herding individual animals into the open-field in order to test reactions to a strange environment, was not easy and the two voiding reactions which it had hoped might provide a useful index of "emotionality" are invalidated by the amount of defecation and urination which occurred before the animals entered the arena. Two other behaviour scores were taken for cattle and sheep, the activity or ambulation and the vocalisation scores. In pigs, only the ambulation score could be accurately recorded.

In sheep, open-field scores continued to rise for ambulation and vocalisation over the three day test period and were still high in one experimental group after 9 days of testing. Attempts to relate sheep scores to blood plasma cortisol levels were unsuccessful. In pigs the very rapid habituation of the subjects to the arena meant that on day 2 most pigs did not ambulate in the open-field at all. Their scores could not be related to any meaningful independent assessment of temperament.

Several facts emerge from this section of the study. Large animals are difficult to herd singly into a strange enclosure. As they are social animals the first and last beast in the group have rather abnormal reactions, in one case due to being first, and in the other to having to remain behind without a companion while the second to last animal is being tested. Adding extra

animals to the experimental groups to overcome this problem increases the difficulty of separating the last few animals from the remainder of the group for testing. It becomes impossible to equate the degree of disturbance for subjects before the test proper begins.

Domestic animals being used to regular handling in yards with gates, after the first day's trial have developed certain "expectancies" regarding the exit gate position and this has an influence on the ambulation score on day 2 and 3. It is not possible however for top loading of the open-field for cattle and sheep as has been suggested for cats by Candland and Nagy, (1970). More emphasis must be given to the results from day 1. The daily range of scores and the consistency of each animal from day to day over the 3 day test period gave every indication that valid comparisons between animals could be made. The assessments of temperament made by two independent dairy technicians correlated at a low level only ($p = 0.10$, see p.133) showing that the assessment of temperament in dairy cattle depends largely on animal-man interactions and that this can change from milker to milker and from cow to cow. No meaningful relationships could be found with any of the open-field scores with the ratings made by either dairyman. Until some more reliable assessment can be made of the temperament of dairy cattle it is difficult to validate the open-field scores. It seems clear from the rapid drop in daily scores in cattle and pigs that the arena is not

truly a strange environment as is the open-field to a rat accustomed to a home cage. The field is intermediate in size between the smallest and largest enclosure with which cows are familiar. Various suggestions for increasing the strangeness of the test for domestic stock have been made and further work needs to be carried out in this area. Means of increasing the reliability of temperament ratings by dairymen and more sophisticated means of determining some physiological parameters of "emotionality" must be established for use in validating open-field scores.

Having been selected on the grounds of temperament for many generations, dairy cattle represent a rather homogeneous population in regards to placidity - excitability, and the test, to differentiate between these animals, has to be sophisticated to be satisfactory. The complete range of cattle types from wild steers to placid cows in milk may well be distinguished by the test as it is, but this has not been examined.

The most meaningful behavioural attributes for each species to be scored in the open-field test, need to be established by preliminary testing. This study underlines this conclusion of Candland and Nagy (1970) particularly in the case of sheep. An adequate sampling of sheep open-field behaviour requires more than 3 days as ambulation and vocalisation scores increased up to and beyond day 3 in the samples studied. The application of the open-field test without preliminary study of the new

species to be tested, is open to question. A number of workers have used the open-field test with pigs with very limited results. This same criticism would apply to scaling up other "rat" tests for use with large animals. Better results might be obtained by designing new apparatus to fit the specific species.

There is a need to standardise the procedures, sizes, colours of baffles and walls, problems and general apparatus for different species for both the open and closed-field tests. Not only is the apparatus large and expensive to build but the variety of procedures and techniques used with the white rat alone is an example of too much independent experimentation without reference to apparatus parameters which could be of great importance.

The need for an easy reliable test of temperament in dairy cattle in particular is urgent. The standardising of such a test would open up the possibilities for considerable work in the area of early experience using the potential of monozygotic cattle twin calves. Differential rearing procedures as they affect temperament and "emotionality" cannot be assessed accurately until such a test has been produced.

As all stock was already familiar with the apparatus from the open-field testing procedures, manipulating the large heavy animals did not present as many difficulties during the closed-field testing. The time involved in running more than 15 experimental subjects on any one day during the early training period precluded the amassing of large amounts of data rapidly.

Many months of work were required before adequate numbers for a valid sample could be tested.

Both the open and closed-field testing provided the opportunity to observe unusual aspects of behaviour exhibited under stress conditions and these included a type of sham grazing in sheep and cattle, feigning lameness in sheep, various activities related to pawing and defecating in cattle, rooting and chewing wood pieces in pigs and a type of belly crawl of sheep through gate ways. There was a disinclination to run well in some animals low in the dominance order in each experimental group. A number of the activities recorded appeared to have the marks of being "displacement activities" as defined by Tinbergen (1951). Overall, it can be concluded that when successful motivation of the species is achieved such as with the non-ruminant pig in this study, very little extraneous behavioural activity occurred. Most of these activities occurred before day 3 of the closed-field training and sheep showed a greater variety of activity than cattle or pigs.

The training problems of Rabinovitch and Rosvold (1951) are logical and well designed. It is suggested that with the domestic species which reach criterion within one presentation of the training problems, a preliminary test of greater difficulty should be run before problem 1 to introduce an element of complexity to complement the present training problems which are selected on changes in spatial orientation and the position of cul-de-sac entry.

This study provided an opportunity to assess the speed of

travel of each of the domestic species during an 18 day period where the detour problem changed each day. This speed of movement in a regular but changing task has a number of applications for the design of normal farming amenities for handling numbers of stock. Dairy cows can be expected to travel at about three feet per second while sheep are slower than this, at approx. $2\frac{1}{2}$ feet per second. Another useful figure for the design of animal yards and holding areas is the distance of visual reaction; i.e., the distance at which animals of each species will react and turn and retrace their steps after entering a blind alley. These distances are greatest in cattle (20-25 feet) and least in pigs (4-6 feet). Vision is still essential for the solution of detour problems in the pig. Although objects in the environment may be visually noticed at greater distances, changes in behavioural orientation towards them do not usually occur before these observed distances. The characteristic pathways taken were different from species to species, with the sheep invariably forming slightly wavy tracks during the 8 or 9 trial runs.

Only one person handled the stock during the training and testing period of the closed-field test over the four years. This was to minimise handling effects and slight changes in procedures which would invariably occur with different human operators.

The difficulty of each of the 12 problems for each species was assessed with reference to the subjects' error scores; i.e., deviation from the shortest correct pathway. In initial

difficulty; i.e., errors on run 1 or runs 1 to 4, problem 6 was the most difficult for all species in series 1-6. In series 7-12, problem 8 was the most difficult for cows, pigs and sheep, and problem 10 for dogs. Over the complete 8 runs, in series 1-6, sheep found problem 4 harder than 6, and in series 7-12, pigs found 7 harder than 8. In general, dogs found problem 12 and sheep found problem 11 rather easy. The species tested showed parallel rankings over the whole 12 problems with these few exceptions.

Pigs made similar numbers of errors on the visual and the non-visual form of the same problem, and with the transformed scores using the index of Pollard, (1961) their %P score was almost 50%. With most of the other problems (except 7 and 8) the other species had lower scores on the visual forms of each problem. On the rapidity of learning index which compared the errors made on runs 1-4 with those made on runs 5-8 in each problem, (%R), 53% of the cows did not err after the 4th run in any problem in the series 1-6 compared with 39% of pigs and 38% of sheep. In the series 7-12, cattle dropped to 45%, pigs to 32% and sheep to 8%. As the tests continued to increase in difficulty and extend in length, the performance of sheep began to deteriorate on later runs.

The graph of the percentage of each species which could undertake each run without error on the whole 12 problems of the test series (fig.46), indicates that cows, sheep and dogs provide

rather parallel results up until the 4th run of the day. After this, sheep remained about 86% efficient whereas dogs and cows reached 90% correct by run 5 and continued to gain slightly. Pig percentages were considerably poorer until run 4 when they passed sheep efficiency and run 6 when they passed that of cattle. After a slow start, pigs as a whole sample, reach and surpass sheep and cattle by run 6. The inability of the pig to see similar distances to sheep and cattle put them at a disadvantage in this type of test and a simple global score based on Total Error Score indicated a significantly poorer performance than either sheep or cattle ($p = < 0.001$).

Various groups of sheep were used in this study to examine if performance in the closed-field test might indicate differences resulting from early rearing experiences as lambs on later problem-solving ability; differences resulting from sex, or between rams of normal karyotype and rams with the chromatin positive Klinefelter syndrome (XXY chromosome karyotype), and the test-retest reliability of the closed-field test.

With the use of groups of experimental animals, dominance hierarchies are soon established in sheep and cattle groups. It was possible to rank the sheep in 3 experimental groups for dominance and leadership status in their respective groups. The relationship of social and leadership ranking to total error score in the closed field test indicated

(a) when the mean score for each experimental group was

equated and the animal ranked for TES, all the sheep with TES of 400 or above (except one animal) were subordinate animals in their respective experimental groups.

- (b) Leader animals during sheep movements were scattered throughout the TES range; follower animals at the rear of movements were found among animals with a TES higher than 200.0% while the leader animals were those making the fewest errors; i.e., those animals with the lowest Total Error Scores.

No significant difference could be found between normal and Klinefelter rams on the closed-field test, nor could differences be found between Romney Marsh and Southdown rams. The differences in performance between ewes and rams were significant at the 0.1% level of confidence. It is not clear if this is a difference due to current methods of handling ewes and rams under New Zealand farming systems, or represents a true sex difference.

The groups of lambs were not clearly differentiated in the closed-field test except on %P which is the most unreliable index of the transformed scores. Unfortunately with the groups kept for test-retest reliabilities, marauding dogs savaged a number and results were available for only 7 animals. It appeared that individual variations among animals decreased with retesting and as the animals mature. A number of changes to increase the sensitivity of the closed-field test have been suggested. The problem designs need to be examined carefully so that the non-visual

and visual forms of each problem are of similar complexity. In this way the %P score of Pollard's may come to have some predictive function. The logic of the test demands a 14 day test cycle rather than a 12 day cycle and when used as a completely integrated test, this would separate the visual and non-visual forms of each problem by 7 days. The present series 1-6 could well be kept to provide the species comparison scores and the series 7-12 could be made more difficult to discriminate between the large domestic species which score very well comparatively on this test. These harder problems may also provide evidence for breed differences within one species.

The open and closed-field tests are in reality one test of varying complexity and their integration has a number of advantages. The approach becomes more multivariate and new performance attributes can be analysed separately; e.g., the number of presentations of the A-F training problems sequence before the species reaches the rather stringent criterion of 8 out of 9 runs correct on two consecutive days could be a valid index of species difference, as well as the ratio scores already in use. The limitations of a ratio score when total error scores are approaching baseline scores are best seen by the separate examination of subjects with high and low %P or %R scores in this study. One error on a specific run could seriously bias the ratio score and provide a grossly exaggerated picture compared with a similar error on the same run committed by an animal making a

large number of errors through the experimental trials. The dilemma here for the comparative assessment of species groups is that the design of problems simple enough for ferrets or possums, would be much too simple for cows and dogs and the type of problems adequate for dogs may well be beyond the capabilities of a hen, rabbit or turtle. The breaking of the test into series 1-6 as constant to all, and 7-14 may help overcome this problem.

The comparative table 81 indicates that even when the global scores were extracted from the series 1-6 and the T.E.S. and %R scores were examined for the species so far tested, a progression of the rankings of these two scores was clearly present with few exceptions. It is offered as another comparative assessment of animal abilities without commenting further on current discussions relating to the meanings of comparative assessments, (Hodos and Campbell, 1969). The large domestic farm animals rank highly on the TES and it is clear that they possess considerable learning ability. A number of factors have been postulated why certain species have become domesticated, including the ability to adapt to sudden changes in environment; limited agility; precocial young; promiscuous matings and living in social groups with a social hierarchy. "Intellectual ability" must also be counted as one of the attributes which favour domestication. Further to this, it seems that sheep, cattle and pigs are well fitted to succeed despite the new demands which will be and are being made on them with increasing intensification

of farming systems and all the attendant complexities. One might raise some queries about the fitness of sheep on temperamental grounds to cope with these new processes, particularly their slowness to habituate to changing circumstances when managed as single animals.

The low similarity values for the monozygotic twins used during this study for both open and closed-field scores indicates that the component arising from rearing and environment is an important one for these scores at least. It is important to examine again the Twin Values of Hancock (1954), on behavioural scores in the grassed paddocks where no opportunity is possible for mutual imitation, to see what influence heredity has on these factors. This study lends some supportive evidence for the findings of Ewbank, (1967) that any paired calves raised in a similar manner to that used for monozygotic twins reared for research, might be expected to produce twin values of the order of those recorded by Hancock.

(i)

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(XOX)

Appendix 1. COMPARATIVE DATA SHEET.

[illegible]

11.

Score sheet for problem 11.

					F
S					

SPECIES: _____ SUBJECT: _____

GROUP: _____ DATE: _____

 Σ SCORE-ERRORS: _____T₁: _____ T₄: _____ T₇: _____T₂: _____ T₅: _____ T₈: _____T₃: _____ T₆: _____ T₉: _____

WEATHER: _____

COMMENTS: _____

Appendix 2. SUMMARY OF TOTAL ERRORS OF EWES, RAMS AND LAMBS
IN THE CLOSED-FIELD TEST

Summary of total errors made by 79 ewes tested on problems 1-6
of the closed-field test.

Run no.	problem no.						total 1-6	% of total
	1	2	3	4	5	6		
1 Ss in error	38	62	60	79	73	65	377	80%
total error	534	488	220	852	332	984	3410	
sheep ave.	13.8	7.9	3.7	10.7	4.5	15.1	9.0	
range	0-66	0-24	0-12	0-70	0-32	0-62		
2 Ss in error	8	19	22	43	8	12	112	24%
total error	36	74	44	140	34	120	448	
sheep ave.	4.5	3.9	2.0	3.3	4.2	10.0	4.0	
range	0-8	0-10	0-2	0-10	0-8	0-16		
3 Ss in error	3	19	11	24	4	6	67	14%
total error	16	82	28	78	14	64	282	
sheep ave.	5.3	4.3	2.5	3.1	3.5	10.7	4.2	
range	0-8	0-8	0-8	0-10	0-6	0-16		
4 Ss in error	1	11	9	14	2	3	40	8%
total error	2	36	18	60	8	26	150	
sheep ave.	2.0	3.3	2.0	4.3	4.0	8.7	3.7	
range	0-2	0-6	0-2	0-10	0-6	0-10		
5 Ss in error	3	9	10	11	4	3	40	8%
total error	14	38	20	24	8	42	146	
sheep ave.	4.7	4.2	2.0	2.2	2.0	14.0	3.7	
6 Ss in error	4	7	7	16	4	2	40	8%
total error	16	20	14	52	14	2	118	
sheep ave.	4.0	3.0	2.0	3.3	3.5	1.0	3.0	
7 Ss in error	3	8	9	12	4	3	39	8%
total error	10	22	22	26	8	14	102	
sheep ave.	3.3	2.8	2.4	2.2	2.0	4.7	2.6	
8 Ss in error	1	7	7	15	5	3	38	8%
total error	4	52	18	44	14	32	164	
sheep ave.	4.0	7.4	2.6	3.0	2.8	10.2	4.3	
Ss in error 1-4	50	111	102	160	87	86	596	
total error 1-4	588	680	310	1130	388	1194	4290	
sheep ave. 1-4	11.8	6.1	3.0	7.1	4.5	13.9	7.2	
total error 5-8	44	132	74	146	44	90	530	
Ss in error 1-8	61	142	135	214	104	97	753	
total error 1-8	632	812	384	1276	432	1284	4820	
sheep ave. 1-8	10.4	5.7	2.8	5.0	4.2	13.2	6.4	

(xxxiii)

Summary of total errors made by 69 ewes tested on problems 7-12
of the closed-field test.

run no.	problem no.						total 7-12	1-12 total	% of 7-12
	7	8	9	10	11	12			
1 Ss in error	69	67	37	54	30	47	304	681	73%
total error	834	1716	322	916	242	644	4674	8084	
sheep ave.	12.1	25.6	8.5	17.0	8.1	13.7	15.4	11.9	
range	0-102	0-140	0-18	0-46	0-20	0-36			
2 Ss in error	39	28	16	19	4	27	133	245	32%
total error	236	260	108	212	22	334	1172	1620	
sheep ave.	6.1	9.3	6.7	11.2	5.5	12.4	8.8	6.6	
range	0-22	0-24	0-10	0-18	0-10	0-40			
3 Ss in error	27	19	6	8	2	24	86	153	21%
total error	80	176	44	66	6	162	534	816	
sheep ave.	3.0	9.3	7.3	8.2	3.0	6.7	6.2	5.3	
range	0-8	0-26	0-10	0-12	0-2	0-28			
4 Ss in error	25	16	3	6	4	22	76	116	18%
total error	74	120	16	46	16	228	500	650	
sheep ave.	3.0	7.5	5.3	7.7	4.0	10.4	6.6	5.6	
range	0-6	0-26	0-8	0-14	0-6	0-34			
5 Ss in error	21	14	3	6	2	16	62	102	15%
total error	58	114	20	72	4	104	372	518	
sheep ave.	2.8	8.1	6.7	12.0	2.0	6.5	6.0	5.1	
6 Ss in error	21	15	4	3	4	14	61	101	15%
total error	60	112	16	18	16	124	346	464	
sheep ave.	2.8	7.5	4.0	6.0	4.0	8.9	5.7	4.6	
7 Ss in error	17	17	5	6	2	11	58	97	14%
total error	54	76	28	58	8	120	344	446	
sheep ave.	3.2	4.5	5.6	9.7	4.0	10.9	5.9	4.6	
8 Ss in error	15	12	3	3	7	8	48	86	12%
total error	42	82	16	22	24	48	234	398	
sheep ave.	2.8	6.8	5.3	7.3	3.4	6.0	4.9	4.6	
Ss in error 1-4	160	130	62	87	40	120	599	1195	
total error 1-4	1224	2272	490	1240	286	1368	6880	11170	
ewe average 1-4	7.7	17.5	7.9	14.3	7.2	11.4	11.5	9.3	
total error 5-8	214	384	80	170	52	396	1296	1826	
Ss in error 1-8	234	188	77	105	55	169	828	1581	
total error 1-8	1438	2656	570	1410	338	1764	8176	12996	
ewe average 1-8	6.1	14.1	7.4	13.4	6.1	10.4	9.9	8.2	

(xxxiv)

Summary of errors made by 24 rams tested on problems 1-6
of the closed-field test.

run no.	problem no.						total 1-6	% of total
	1	2	3	4	5	6		
1 Ss in error	18	21	19	24	15	12	109	76%
total error	202	148	88	320	62	306	1126	
ram ave.	11.2	7.0	4.6	13.3	4.1	25.5	10.3	
range	0-46	0-18	0-10	0-48	0-24	0-54		
2 Ss in error	2	6	4	20	3	21	56	39%
total error	8	52	8	74	6	66	214	
ram ave.	4.0	8.7	2.0	3.7	3.0	3.1	3.8	
range	0-6	0-16	0-2	0-8	0-2	0-28		
3 Ss in error	1	4	7	12	-	-	24	17%
total error	8	8	18	56	-	-	90	
ram ave.	4.0	2.0	2.6	4.7			3.7	
range	0-8	0-2	0-6	0-22				
4 Ss in error	2	6	9	7	-	3	27	19%
total error	4	38	26	28	-	32	128	
ram ave.	2.0	6.3	2.9	4.0		10.2	4.7	
5 Ss in error	2	5	5	6	-	-	18	13%
total error	6	22	10	22	-	-	60	
ram ave.	3.0	4.4	2.0	3.5			3.3	
6 Ss in error	1	4	5	8	-	2	20	14%
total error	4	18	10	26		22	80	
ram ave.	4.0	4.5	2.0	3.3		11.0	4.0	
7 Ss in error	2	2	5	6	-	-	15	10%
total error	10	4	12	16	-	-	42	
ram ave.	5.0	2.0	2.4	2.7			2.8	
8 Ss in error	2	4	6	6	-	3	21	15%
total error	6	12	14	18		48	98	
ram ave.	3.0	3.0	2.3	3.0		16.0	4.7	
Ss in error 1-4	23	37	39	63	18	36	216	
total error 1-4	222	246	140	478	68	404	1558	
ram ave. 1-4	9.7	6.6	3.6	7.6	3.8	11.2	7.2	
total error 5-8	26	48	46	82	-	70	272	
Ss in error 1-8	30	52	60	89	18	41	290	
total error 1-8	248	294	186	560	68	474	1830	
ram ave. 1-8	8.3	5.7	3.1	6.3	3.8	11.6	6.3	

(xxxv)

Summary of errors made by 24 rams tested on problems 7-12 in
the closed-field test

run no.	problem no.						7-12	1-12	% of
	7	8	9	10	11	12	total	total	7-12
1 Ss in error	24	23	14	12	10	19	102	211	71%
total error	628	658	92	136	72	362	1948	3074	
ram ave.	26.1	28.6	6.6	11.3	7.2	19.1	19.1	14.6	
range	0-174	0-146	0-10	0-22	0-14	0-154			
2 Ss in error	23	13	4	6	6	12	64	120	44%
total error	174	112	38	64	28	112	528	742	
ram ave.	7.6	8.6	9.5	10.7	4.7	9.3	8.3	6.9	
range	0-28	0-18	0-20	0-14	0-8	0-20			
3 Ss in error	16	4	5	1	3	4	33	57	22%
total error	42	20	34	14	12	24	146	236	
ram ave.	2.6	5.0	6.8	14.0	6.0	6.0	4.4	4.1	
range	0-4	0-12	0-10	0-14	0-6	0-8			
4 Ss in error	12	-	1	2	1	4	20	47	14%
total error	34	-	6	10	4	26	80	208	
ram ave.	2.8	-	6.0	5.0	4.0	6.5	4.0	4.4	
5 Ss in error	9	2	1	3	2	6	23	41	16%
total error	22	12	6	26	12	32	110	170	
ram ave.	2.4	6.0	6.0	8.7	6.0	5.3	4.8	4.1	
6 Ss in error	8	2	-	-	1	5	16	36	11%
total error	44	14	-	-	2	30	90	170	
ram ave.	5.5	7.0	-	-	2.0	6.0	5.6	4.7	
7 Ss in error	8	5	1	3	1	1	19	34	13%
total error	16	30	6	26	6	2	86	128	
ram ave.	2.0	6.0	6.0	8.7	6.0	2.0	4.5	3.8	
8 Ss in error	9	2	1	4	2	-	18	39	13%
total error	24	18	8	16	14	-	80	178	
ram ave.	2.7	6.0	8.0	4.0	7.0	-	4.4	4.6	
Ss in error 1-4	75	40	24	21	20	39	219	435	
total error 1-4	878	790	170	224	116	524	2702	4260	
ram ave. 1-4	11.7	19.8	7.1	10.7	5.8	13.4	12.3	9.8	
total error 5-8	106	74	20	68	34	64	366	638	
Ss in error 1-8	109	51	27	31	26	51	295	585	
total error 1-8	984	864	190	292	150	588	3068	4898	
ram ave. 1-8	9.0	16.9	7.0	9.4	5.8	11.5	10.4	8.4	

(xxxvi)

Summary of total errors made by 38 lambs tested on problems 1-6
of the closed-field test.

run no.	problem no.						total 1-6	% of total
	1	2	3	4	5	6		
1 Ss in error	13	33	37	38	38	21	182	80%
total error	132	508	146	718	134	462	2100	
lamb ave.	10.2	15.4	3.9	18.9	3.5	20.1	11.5	
range	0-54	0-150	0-10	0-108	0-52	0-42		
2 Ss in error	3	19	12	37	4	5	80	35%
total error	14	146	30	186	16	64	456	
lamb ave.	4.7	7.7	2.8	5.0	4.0	12.8	5.7	
range	0-8	0-20	0-4	0-14	0-6	0-24		
3 Ss in error	4	13	11	33	2	3	66	29%
total error	20	78	22	96	6	46	268	
lamb ave.	5.0	6.0	2.0	3.0	3.0	15.3	4.1	
range	0-10	0-18	0-2	0-6	0-4	0-24		
4 Ss in error	5	12	10	31	-	-	58	25%
total error	22	66	24	88	-	-	200	
lamb ave.	4.4	5.5	2.4	2.8			3.4	
5 Ss in error	1	7	12	22	1	1	44	19%
total error	4	64	30	64	2	10	174	
lamb ave.	4.0	9.6	2.5	2.9	2.0	10.0	4.0	
6 Ss in error	5	2	11	17	-	1	36	16%
total error	14	4	28	54	-	24	124	
lamb ave.	2.8	2.0	2.5	3.2		24.0	3.4	
7 Ss in error	2	2	10	21	1	-	36	16%
total error	10	8	20	70	6	-	114	
lamb ave.	5.0	4.0	2.0	3.3	6.0		3.2	
8 Ss in error	1	1	12	21	-	-	35	15%
total error	2	2	26	62			92	
lamb ave.	2.0	2.0	2.2	3.0			2.6	
Ss in error 1-4	25	77	70	139	44	31	386	
total error 1-4	188	798	222	1088	156	572	3024	
lamb ave. 1-4	7.5	10.4	3.2	7.8	3.5	18.5	7.8	
total error 5-8	30	78	104	250	8	34	504	
Ss in error 1-8	34	89	115	220	46	33	537	
total error 1-8	218	876	326	1338	164	606	3528	
lamb ave. 1-8	6.4	9.8	2.8	6.1	3.6	18.4	6.6	

(xxxvii)

Summary of total errors made by 32 lambs on problems 7-12
of the closed-field test.

run no.	7	problem no.				12	total 1-12 7-12	% of total 7-12
		8	9	10	11			
1 Ss in error	32	32	24	20	18	30	156	338 81%
total error	284	1246	310	350	236	936	3362	5462
lamb ave.	8.9	38.9	12.9	17.5	13.1	31.2	21.6	16.2
range	0-40	0-150	0-24	0-36	0-80	0-248		
2 Ss in error	21	16	3	6	4	22	72	152 38%
total error	114	228	24	62	16	366	810	1266
lamb ave.	5.4	14.2	8.0	10.3	4.0	16.6	11.3	8.3
range	0-24	0-46	0-10	0-16	0-6	0-80		
3 Ss in error	10	5	1	5	4	20	45	111 23%
total error	58	70	12	52	14	114	320	588
lamb ave.	5.8	14.0	12.0	10.4	3.5	5.7	7.1	5.3
range	0-20	0-46	0-12	0-12	0-6	0-40		
4 Ss in error	6	3	-	2	6	13	30	88 16%
total error	24	20	-	20	24	84	172	372
lamb ave.	4.0	6.7	-	10.0	4.0	6.5	5.7	4.2
range	0-8	0-12		0-12	0-6	0-14		
5 Ss in error	3	3	1	-	3	11	21	55 11%
total error	10	64	2	-	14	54	144	318
lamb ave.	3.3	21.3	2.0	-	4.7	5.0	6.9	4.9
6 Ss in error	4	1	-	3	4	5	17	53 9%
total error	18	8	-	34	28	26	114	238
lamb ave.	4.5	8.0	-	11.3	7.0	5.2	6.7	4.5
7 Ss in error	3	3	1	1	1	6	15	51 8%
total error	18	22	10	8	6	32	96	210
lamb ave.	6.0	7.3	10.0	8.0	6.0	5.3	6.4	4.1
8 Ss in error	4	3	1	3	-	10	21	56 11%
total error	12	16	10	34	-	46	118	218
lamb ave.	3.0	5.3	10.0	11.3	-	4.6	5.6	3.8
Ss in error 1-4	69	56	28	33	32	85	303	689
total error 1-4	480	1564	346	484	290	1500	4664	7688
lamb ave. 1-4	7.0	27.9	12.4	14.7	9.1	17.6	15.4	11.2
total error 5-8	58	110	22	76	48	158	472	976
Ss in error 1-8	83	66	31	40	40	117	377	914
total error 1-8	538	1674	368	560	338	1658	5136	8664
lamb ave. 1-8	6.5	25.4	11.9	14.0	8.5	14.2	13.6	9.5