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AN ANALYSIS OF DISCRIMINATION REVERSAL PERFORMANCE DIFFERENCES BETWEEN CHICKENS AND PIGEONS

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AN ANALYSIS OF DISCRIMINATION REVERSAL PERFORMANCE DIFFERENCES BETWEEN CHICKENS AND PIGEONS

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ABSTRACT

An Analysis of Discrimination Reversal Performance Differences Between Chickens and Pigeons

Michael Eberlin

The serial discrimination reversal (SDR) methodology has been demonstrated sensitive to taxonomic separation with many different species (Gossette, 1967, 1968; Gossette, et.al., 1966). SDR is sensitive to differences in ability level as measured by mental age with both normal (Berger, 1975) and retarded children (Ansheutz, 1973; Newman, 1976).

Two species which have consistently shown different performance levels on SDR tasks were studied. Twenty pigeons and twenty chickens underwent complete and partial reversals of a simultaneous green/red discrimination. Two control groups were included to calibrate the difficulty of the partial reversal conditions for each species. Since previous research (Levine, 1974) demonstrated that the SDR performance of these species is differentially effected by deprivation level, the species were equated for level of optimal performance; the pigeons at 86% and the chickens at 78% ad lib body weight.

Based upon previous research and the differential extinction hypothesis (Gossette, 1970) which explains SDR differences as arising from differences in the ability to inhibit previously reinforced responding, it was hypothesized that:

1. Pigeons would make fewer errors than chickens on the Complete Reversal task.
2. Pigeons would make fewer errors on the S+ Partial Reversal.
3. Greater negative transfer for both species would occur on the S+ Partial Reversal than the S- Partial Reversal.

Hypotheses 1 and 2 were partially supported by the data. Plots of error reduction and differences between means conformed to expectation for the interspecies comparisosn of the Complete Reversal and S+ Partial Reversal. The S- Partial Reversal was found to be significantly more difficult for the chickens. The difficulty of this condition for the chickens may have been exaggerated by a stimulus preference demonstrated in the control comparisons.

Hypothesis 3 could not be supported. The suspected preference obscured negative transfer effects for the chickens. Negative transfer could not be adequately demonstrated for the pigeons.

The data suggested that future research may extend the applicability of the differential extinction hypothesis. Further research into inhibitory capacity in explaining ability level differences was recommended.

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I. INTRODUCTION

One of the major dilemmas that confront comparative psychologists is the discrepancy typically found between indeces of general problem solving ability whether measured by mental age (MA) among humans or suggested by such factors as phyletic level or brain complexity among animals on the one hand and measures of problem solving ability obtained in the laboratory with traditional measures of problem solving on the other hand.

Since Thorndike's (1911) initial puzzle box experiments, many techniques have been utilized in an attempt to find a widely applicable taxonomically sensitive measure of interspecies learning differences. In the following pages, these methodologies will be reviewed. First the tasks which proved to be insensitive to phyletic differences, second, those which have shown promise in such an endeavor.

SIMPLE CLASSICAL AND OPERANT PARADIGMS

The acquisition of a classically conditioned response has been demonstrated to be insensitive to phyletic differences in learning ability (Marx, 1970). In a very early study, Hilgard and Marquis (1936) found that classically conditioned eyelid responses of canines and humans were more similar than those of primates and humans. According to Marx (1970), later studies also demonstrated inconsistent species differences. He noted that the assessment of species differences with a classical conditioning paradigm was risky because of extreme interspecies variability, differences in sensory capacities, and great diversity in the experimental designs of the researchers. The acquisition of a simple operant response has also failed to show consistently meaningful species differences (Clark, 1961, Kelleher & Cook, 1959). Warren (1965), in a comprehensive review of the available literature, concluded that the rate of conditioning of different species varies greatly, within the same species or individual, and over many experimental conditions.

Skinner (1956) maintained that the cumulative operant response learning curves of rats, pigeons, monkeys, cats, dogs, and children were very similar. He noted, "It doesn't matter... once you have allowed for differences in the ways in which (these species) make contact with the environment, and in the ways they act upon the environment, what remains of their behavior shows astonishingly similar properties (pg. 203)." This was reiterated by Ferster and Skinner (1967) in species comparisons under different schedules of partial reinforcement.

SIMPLE DISCRIMINATION LEARNING

Initially, there was some evidence that the acquisition of a simple visual discriminative response might provide a measure of differences in species learning ability in early experiments with dogs (Karn & Munn, 1932) and with chimpanzees (Nissen, Blum & Blum, 1949). As more studies were undertaken, contrary evidence became manifest (Siegel, 1953). In a summary of the available literature, Waters, Rethlingshafer, and Caldwell (1960) concluded that "the rate of formation of simple discrimination habits does not increase regularly from the so called lower to higher phyletic levels (pg. 212)." Empirical validation for this conclusion was found by Gossette (1968) in an examination of the serial discrimination reversal (SDR) data from seven mammalian and ten avian species. It was noted that "despite the greater interspecies differences in total error scores, there are relatively small differences in error scores on both final and original problems (pp.1148-1149)." The original problem can be considered a simple discrimination , thus there is strong evidence that simple discrimination acquisition is insensitive to interspecies learning differences. Two other procedures, probability learning, and oddity learning had initially demonstrated promise as phyletically sensitive measures of learning ability, but as investigations proceeded, this promise was not fulfilled.

PROBABILITY LEARNING

In probability learning, the two discriminative stimuli differ with respect to reinforcement ratio akin to multiple schedules of reinforcement (eg. RF left 70%, RF right 30%). Bitterman (1965, 1975, 1976, 1980) has argued that certain species "maximize" their responding by invariantly choosing the more frequently reinforced stimulus; this results in an optimal level of reinforcement. A less optimal strategy, matching, occurs when the organism responds differentially to both stimuli in an attempt to "match" the reinforcement schedules in effect for each stimulus. Many investigations with monkeys (Meyer, 1960; Wilson, Oscar, & Bitterman, 1964) rats (Bitterman, Wodinsky, & Candland, 1958), pigeons (Bullock & Bitterman,

1962) and fish (Behrend & Bitterman, 1961) indicated that monkeys and rats generally maximized, pigeons maximized on simpler spatial but not more complex brightness tasks, and fish merely matched. Examination of the data, however, revealed significant overlap of performance (Warren, 1965). Mackintosh (1969) demonstrated that chicks maximized just as quickly as rats on a 75:25 brightness discrimination problem. Warren (1973) cited seven studies done between 1963 and 1968 that failed to demonstrate maximizing by the rat using different discrimination apparatuses. Probability learning also failed to show significant differences between the performances of rats and monkeys (Warren, 1965), or between cats and monkeys (Warren, 1980). Warren (1973) concluded that probability learning was of no value in differentiating the taxonomic status of vertebrates.

ODDITY LEARNING

In oddity learning, three stimuli are presented, and the different (odd) one must be selected by the organism. Rhesus monkeys were the first to be demonstrated to solve these problems successfully (Meyer & Harlow, 1949). This method was shown to be sensitive to differences between raccoons and two orders of primates (Strong & Hedges, 1966). Warren (1966), however, had demonstrated that cats performed quite similarly to Rhesus monkeys on such tasks. Also it was found that canaries could learn oddity problems while other "more advanced" birds could not (Stettner & Matyniak, 1968). Furthermore, rats required extensive pretraining before they could solve oddity problems (Woodinsky & Bitterman, 1953). It seems, therefore, that the oddity problem paradigm may be another method insensitive to interspecies learning ability differences.

II. PROCEDURES WHICH HAVE DETECTED MEANINGFUL INTERSPECIES LEARNING DIFFERENCES

As the previous discussion reflects, many experimental techniques have not consistently demonstrated the capacity to order interspecies learning differences according to traditional assumptions regarding taxonomy and phylogenesis. There are, however, two procedures which have shown promise for such an undertaking. These methods are: learning set (LS) and serial discrimination reversals (SDR).

LEARNING SET

In the learning set paradigm (Harlow, 1949), two objects differing in many dimensions are presented to the subject. After a predetermined number of trials, a new pair of different stimulus objects are presented. Position habits are avoided by presenting the correct stimulus in a quasi random left-right order. Performance is typically measured by the number of errrors per set of stimuli and across sets. Harlow interpreted the improvement seen across sets as a generalized ability of "learning to learn" thus the term learning set (Harlow, 1949). This improvement has also been referred to as positive transfer, whereas interference in the process of learning as a result of previous training is referred to as negative transfer.

The learning set methodology has been sensitive to ability level differences among primates. Phylogenetically more advanced Rhesus monkeys demonstrated more rapid error reduction (positive transfer) across problems than marmosets or squirrel monkeys (Miles, 1957; Miles & Meyer, 1956). Similarly, Riopelle (1958) found that spider monkeys performed superior to both squirrel monkeys and Rhesus monkeys. Superior performance on learning sets by normal and MR children over non-human primates was noted by Kaufman and Peterson (1958). Such results prompted Denny & Ratner (1970) to state that at the primate level,"...learning set has been entertained as a comparative psychology measuring stick of intellectual development (pg. 734)." While improvement over learning sets has been found for infraprimate species such as cats (Warren & Barron, 1956), birds (Plotnick & Tallarico, 1966), and skunks (Doty, Jones & Doty, 1967), the sensitivity of learning sets to inter-species differences in learning ability at these levels has been questioned (Gossette 1970; Stettner & Matyniak, 1968). Zeigler (1961) found that pigeons and chickens performed similarly to cats on learning set problems. Stettner and Matyniak (1963) found that chickens' learning set performance was superior to that of cats.

The inconsistencies of interspecies differences among the "lower" mammals and birds suggest that the usefulness of LS methodology may be quite limited to organisms possessing high levels of ability. However, a closely related methodology, serial discrimination reversal (SDR), offers the promise of applicability to a more diverse array of species.

SERIAL DISCRIMINATION REVERSAL (SDR)

SDR tasks have been extensively studied by Bitterman from the early 1960's to the mid 1970's. In an SDR task, an organism learns to discriminate between two stimuli which may be presented simultaneously or successively. The stimuli may differ in one or more dimensions. After a predetermined criterion has been attained (criteria by trials or by errors), the reinforcement contingencies are reversed (the S+ becomes the S-, and the S- becomes the S+), and the organism must once again reach criterion. Reversal training occurs across a series of reversal problems. Performance is evaluated by examining the changes in performance both within and across problems. Improvement across reversals can be defined as error reduction.

Many vertebrate species have been studied using the SDR paradigm. To date, the list includes: goldfish, (Reich, 1976; Schoel & Bitterman, 1971; Woodward & Bitterman, 1972; Woodward, Schoel & Bitterman, 1971), African mouthbreeder fish (Setterington & Bishop, 1967), Oscars (Squire, 1969), newts (Ellis, Craine, & Manton, 1982), banded geckos (Kirkish, Fobes, & Richardson, 1979), alligators (Gossette & Hombach, 1969), turtles (Bitterman, 1965), ducks (Wells & Lehner, 1977), pigeons (Birnbaum 1974; Levine, 1974; MacPhail, 1970; Woodward & Bitterman, 1976), chickens (Gossette 1966; Gossette, et.al.

1966), monotremes (Saunders, Chia-Sang, Pridmore, 1971; Buchman & Rhodes, 1979), rats (Pubols, 1957; Warren, 1965), mice (Jensen & Fuller, 1978), opossum (Kirkby & Williams, 1979), kangaroos (Munn, 1965), monkeys (Gossette & Inman, 1966; Harlow, 1950), orangutans (Davis & Merkowitz, 1978), mentally retarded humans (Ansheutz, 1973; Newman, 1976), and intellectually average children (Berger, 1975). It is important to note that while the above studies varied considerably with respect to methodology, most of the vertebrate species studies eventually showed improvement over reversals.

Several invertebrate species have also been studied using the SDR methodology. Longo (1964) studied cockaroaches,while Mackintosh & Mackintosh(1969) demonstrated error reduction by an octopus across reversal problems.

EVALUATING SPECIES DIFFERENCES IN SDR LEARNING

There have been two general approaches to the evaluation of interspecies performance differences both of which were described by Bitterman (1960). These were control by equation and control by systematic variation. Control by equation is a comparison of the absolute performance of different species on the same or equivalent task with all the important procedural variables that influence absolute performance calibrated for all species subject to comparison. Bitterman (1960, 1965, 1975) argued that comparisons of absolute performances were impossible because they are subject to so many variables that cannot be matched across species. He, therefore, abandoned the method of control by equation , and opted for control by systematic variation.

With control by systematic variation, you search for a behavioral phenomenon which is insensitive to procedural variables that differentiate between species. Thus, species are then compared by evaluating whether or not such behavioral phenomena (e.g., improvement across reversals) occur, or under what conditions these phenomena occur for both species. "In general, the wider range of circumstances under which a given phenomenon appears in one animal and fails to appear in a second animal, the more plausible is the assumption that it is not to be found at all in the second (Bitterman, 1975; pg. 703)." Bitterman (1965, 1975) interpreted the data he obtained on reversal tasks using control by systematic variation as demonstrating qualitative species differences in learning, which he hypothesized, reflected different underlying learning processes and discontinuity in the evolution of learning (also in Bitterman, 1976). Bitterman (1965) reported that pigeons and rats showed progressive improvement on both brightness and spatial problems, turtles only demonstrated improvement when spatial tasks were employed, while fish showed no improvement at any time in their performance over problems. The turtle data, he suggested, indicated that a transition from lower vertebrates to higher vertebrate ability occured among the reptiles.

However, subsequent improvement of apparatus and training procedure by the Bitterman group (Schoel & Bitterman, 1971;

Woodward & Bitterman, 1971; Woodward, Schoel, & Bitterman, 1971), confirmed the reports of critics (Setterington & Bishop 1967; Squier, 1969) that fish can, in fact, show improvement over reversal trials. Bitterman's qualitative distinction was thus no longer accepted (Brookshire, 1976; Demarest, 1983; Gossette, 1970; Warren, 1973). While the strength of the argument that qualitative species differences exist was reduced by the new data (and the previously mentioned data that demonstrated improvement in invertebrate species across reversals), Bitterman (1975, 1976, 1981) continued to argue on other bases for such differences.

In contrast, the research by Gossette and his associates (e.g., Gossette, 1968, 1970, 1974) concentrated on quantitative species differences, and employed the methodology of control by equation. In the preliminary studies, no attempt was made to control procedural variables. The initial concern was to examine SDR performances under conditions that appeared to be optimal for each species being studied. A large number of species representing various degrees of phyletic and taxonomic remoteness were studied with spatial,form, and brightness tasks. In later studies by Birnbaum (1974), and Levine (1974), in an effort to use control by equation , these authors attempted to establish the control ranges of incentive and motivation for pigeons and chickens.

Gossette (1968) showed evidence of meaningful quantitative variation in SDR performance reflecting taxonomic separation for both birds and mammals. Among birds, species that were often described as "more advanced" by ornithologists such as magpies, mynas, and parrots showed more pronounced interproblem improvement than that of "less advanced" species like quails, chickens, chukars, and ginnea fowl. Pigeons and doves on the other hand demonstrated intermediate performance levels. (Gossette, et.al., 1966; Gossette, 1967, 1968).

Similarly, among primates, the "more advanced" Capuchin monkeys demonstrated superior error reduction compared to squirrel or owl monkeys (Gossette, 1968; Gossette & Slonim, 1968). This led Gossette (1970) to support previous assumptions that contrary to traditional taxonomic practice which placed the squirrel and Capuchin monkeys within the subfamily Cebinae, similarities between the squirrel and owl monkey required the reassignment of the squirrel monkey to reflect that similarity. Simultaneously, Gossette (1970) proposed the "taxonomic distance hypothesis" which stated that "closely related species will display more similar error functions than will more distantly related species (pg. 302)."

SDR procedures have also been demonstrated to be sensitive to variation in levels of ability among humans. Ansheutz (1972) used a series of two choice visual object-color, object-form, and brightness discriminations to calibrate the SDR performance of mentally retarded subjects representing three different levels of mental age. She found that reversal performance was linearly related to MA. These findings were replicated by Newman (1976). Berger (1975) found similar results using intellectually average children at two levels of mental age (MA).

The comparative animal studies by Bitterman and Gossette discussed so far differentiated species according to traditional phylogenetic or taxonomic practices. In the human studies, MA, a measure of learning ability derived from standardized application of testing procedures to large samples of individuals, was used to differentiate ability levels. Riddell (1974,1975,1977) in an attempt to refine the independent variable in comparative analyses has examined the correlations of different learning tasks with various brain indeces. These indeces may or may not correlate with classifications based on phylogeny or taxonomy.

Riddell & Corl (1977) evaluated the data of Gossette, et.al., (1968), which compared the SDR performance of seven mammalian species on a spatial task across nineteen reversals. In their analysis, they found a Spearman correlation of .66 between Jerison's "Extra Neuron" index (Jerison, 1973) and the SDR performance of these species. They noted that "the failure to find a perfect correlation between performance and the "Extra Neuron" index was due to the reversal performance of the skunk which was considerably better than which would be predicted by the index (Riddell & Corl, 1977; pg. 394)." Regardless, this evidence suggests that SDR may be sensitive to interspecies learning ability differences as reflected by brain indeces. Ridell & Corl (1977) suggested that the use of such brain indeces may be the best continuum on which the comparative study of learning can be analyzed. Interestingly, SDR has also been found to be one of the few behavioral tasks that is sensitive to certain brain lesions in pigeons and certain mammals (MacPhail, 1971, 1972, 1975, 1976, 1982).

III. THEORETICAL INTERPRETATIONS OF INTERPECIES SDR DIFFERENCES

Two major theoretical interpretations of SDR performance have been offered. One was the retention decrement hypothesis (Gonzalez, Behrend, & Bitterman, 1967; Bitterman, 1968), the other was the differential extinction hypothesis (Gossette & Hood, 1968; Gossette, 1970). They will now both be discussed.

RETENTION DECREMENT HYPOTHESIS

According to this hypothesis, the improvement over a reversal series results from forgetting previous training on the reversal problem. Such forgetting was described as proactive interference, a term borrowed from the verbal learning literature. The retention of previous training (or the absence of proactive interference) was hypothesized to interfere with subsequent learning of different responses to the same stimuli .

In this account, the origin of the difference between lower and higher vertebrates was in their relative ability to retain previous training. As Gonzalez, et.al., (1967) noted, "fish could not forget;" they did not develop proactive interference and therefore, did not improve across the reversal series. Middle vertebrates, reptiles, did develop proactive interference and therefore, improved across reversals, but only on simple spatial tasks. Higher vertebrates such as pigeons and rats, however, demonstrated more rapid development of proactive interference and, therefore, progressive improvement over reversals.

As discussed previously, the demonstration of improvement over reversals in fish (Setterington & Bishop, 1968; Squier, 1969) and the octopus (Mackintosh, 1969), brought the utility of this dichotomization into question. Furthermore, certain findings such as one trial solutions occurring in later reversals (Gossette,1970), and the fact that later reversals may be learned faster than the original discrimination (Gossette, 1969; Sutherland & Mackintosh; 1971, Weiner & Huppert, 1968), are incompatible with the retention decrement view.

Bitterman and his associates have more recently begun to examine the role of inhibition in reversal improvement. (Bitterman, 1972, 1979; Woodward & Bitterman, 1976). In a series of experiments using "unitary" or successive stimulus presentations and reversals with pigeons, these authors have attempted to explain reversal improvement on the basis of two Pavlovian processes; inhibition and excitation. In his analysis of the later asymptotic performance of pigeons, Bitterman (1979) noted: "The loss in retention from one session to the next is loss in the reluctance to respond to the negative stimulus of the preceding session. The increase in the speed of learning is an increase in the rate at which reluctance to respond to the negative stimulus develops in each session (pg. 436). " Woodward & Bitterman (1979) found that two computer generated models fit their data on asymptotic reversal performance well. One was a model based on the reduction of inhibition by reinforcement, the other was a reciprocal proposition that excitation is reduced by nonreinforcement. These authors then hypothesized that improvement in successive SDR tasks equally depends on experience with both S+ and the S-.

DIFFERENTIAL EXTINCTION HYPOTHESIS

This hypothesis attempts to explain the source of within and between species SDR learning differences as resulting from variation in the ability to inhibit responses to the previous S+ (Gossette & Hood, 1968; Gossette, 1970). Specifically "it is not the rate with which an organism learns to respond to a stimulus, but the rate with which it learns to inhibit responding as a consequence of nonreinforcement that distinguishes species of different taxonomic levels (Gossette,1970; pg. 101)."

This hypothesis is an elaboration of Voronin's (1962) Pavlovian formulations based on his work which demonstrated species differences in the ability to extinguish responding to different stimuli successively (successive acquisition and extinction of conditioned responses). He noted that it was the ease with which inhibitory control developed that differentiated species. The species Voronin studied were: " Fishes, tortoises, pigeons, rooks, hens, ducks, rabbits, rats, dogs, macaques (Macacus rhesus), green monkeys (Cercopitecus aetiops), baboons (Papto hamadrias), capuchins (Cebus apella), chimpanzees (Pan shimpanze), and human beings (Voronin, 1962; pg. 162)."

The differential extinction hypothesis is concerned with the magnitude of negative transfer across reversals. Negative transfer can be defined as an increase in errors on a discrimination as a result of previous experience with another discrimination problem. Conversely, positive transfer would be defined as a subsequent improvement in performance or fewer errors. Gossette (1968) observed that species differ systematically in the amount of negative transfer that is reflected by their performance. These differences are most pronounced in the early reversals, especially the first.

It is noteworthy that the differential extinction hypothesis is not entirely incompatible with Bitterman's (1972, 1976, 1979) later formulations. Gossette's hypothesis was developed mainly from studies using simultaneous stimulus presentations, while Bitterman's hypotheses arose from studies involving successive "unitary" stimulus presentations. There is evidence from brain lesion studies (MacPhail, 1972) that the inhibitory process operating in simultaneous reversals, especially in acquisition, is different than the inhibitory control developed in successive unitary procedures. Therefore Bitterman's focus on excitatory as well as inhibitory processes seems more justified. Furthermore, Bitterman's work was based on analysis of asymptotic performance, while Gossette concentrated more on improvement in early reversals. Also, Bitterman's later formulations were not involved with the comparative approach, only one species, the pigeon, was studied.

IV. CONVERGENT EVIDENCE FOR THE DIFFERENTIAL EXTINCTION HYPOTHESIS

Convergent evidence for the differential extinction hypothesis can be found by examining other methodologies that involve the development of inhititory control over responding. At the Hofstra Laboratories, differential reinforcement for low rates of behavior (DRL), successive acquistion and extinction (SAE), and partial reversals have been used to assess between and within species differences in the development of inhibitory control. Elsewhere, extradimensional reversals (ED) have been studied (Riddell, et.al., 1974, 1975, 1977), as has the extinction of a simple operant response (Levine, 1975).

DRL

In the DRL paradigm, the organism must refrain from responding during the DRL interval in order to obtain reinforcement. Any responding during the interval restarts the interval. This methodology should, thererfore, be sensitive to interspecies differences in the process of response inhibition. In DRL experiments performed at the Hofstra Animal Laboratory with chickens, chukar partridges, and pigeons, Gossette

(1972) found that magnitude of efficiency ratios (ratio of reinforced to nonreinforced responding) dropped rapidly as the DRL values were increased, with ratios of pigeons uniformly higher than those of the chickens and chukars. Powell (1972) found that crows outperformed pigeons on DRL tasks, as they emitted fewer responses during the DRL interval. Gossette (1972) reanalyzed Powell's (1972) data in terms of efficiency ratios, and found that the crows also outperformed the pigeons, chuckars, and chickens, especially at the longer DRL values, as would be predicted by the taxonomic distance hypothesis.

Gossette (1972) extended this analysis to mammals using capuchin monkeys, kinkajous, and possums. As phylogeny would predict, the performance of the kinkajous and possums was inferior to that of the capuchin. Additionally, it was noted that while pigeon's percentage of reinforced responding in DRL 20 sec. rarely exceeded 2%, rats and monkeys had demonstrated superior performance under more stringent DRL criteria (e.g., DRL 60 sec.).

SUCCESSIVE ACQUISITION AND EXTINCTION (SAE)

With SAE, the organism is successively trained and extinguished to criterion on a simple operant task. Rates of acquisition and extinction can then be compared. Davenport (1969) has demonstrated using SAE of a bar press response with monkeys and rats that monkeys extinguished more rapidly than rats. Gossette (1972) showed that pigeons extinguished more radiply than chickens, a pattern consistent with their SDR and DRL performance.

PARTIAL REVERSALS

The standard SDR reversal procedure involes the complete reversal of stimulus contigencies. In other words, the S+ of Problem I becomes the S- of Problem II and vice versa. In a partial reversal, only one of the Problem I stimuli is retained in Problem II. Thus, there are two types of partial reversals, the S+ partial, and the S- partial.

In the S+ partial reversal, the S+ of Problem I becomes the S- of Problem II, while the Problem II S+ is a novel stimulus which is chosen to avoid generalization effects arising from previous training. The S+ partial condition can be analyzed as reflecting the contribution of negative transfer as a result of the previous training with S+.

The S- partial reversal involves retention of the Problem I S- as the S+ for Problem II. The S- in Problem II is a novel stimulus. This type of reversal reflects the contribution to negative transfer that is made by previous training with S-.

Newman (1975) studied the complete and partial reversal performance of 81 mildly to severely retarded children. Subjects were divided into high MA (4-8) and low MA (2-4) groups. The complete and S+ partial reversals were more difficult for the low MA group than for the high MA group. The S-partial reversal, however, did not demonstrate differences between MA levels, suggesting it was insensitive to ability level differences.

Berger (1975) found similar results using the partial reversal methodology with intellectually average children (I.Q. 90-110) at two MA levels (MA 2-5, MA 5-7 years). The result of these two studies supported the differential extinction hypothesis because it was found that the S+ partial reversal condition accounted for a greater amount of the negative transfer found with the complete reversal condition than did the S- partial reversal. These studies demonstrate that the partial reversal methodology is an effective method for delineating the relative contribution of reinforcement and nonreinforcement to performance differences of organisms of different levels of ability.

EXTRADIMENSIONAL REVERSALS (ED)

In the ED procedure employed by Riddell (1974, 1975, 1977), subjects first learn a brightness discrimination, and then must shift to a position discrimination, then back to a brightness discrimination. The order can also be position-brightness-position. This method was specifically designed to test for species differences in the ability to inhibit responses to the previously relevant dimension and to minimize differences due to methodology or species specific abilities (Riddell, et.al., 1974). In their first experiment, Riddell, et.al., (1974) tested tree shrews, squirrel monkeys and college students using ED's. They found that these species meaningfully differed in number of errors per problem, but not in percentage of total errors per problem. This supported a quantitative vs. qualitative interpretation of species differences. The differences also conformed to an index of cerebral development designed by Sacher (1970). Similar results were presented by Riddell, Gravetter, and Rogers (1976), using kindergarten children, hooded rats, and cebus albifrons monkeys. Riddell and Corl (1977) collapsed the above data and obtained Spearman correlation coefficients that highly correlated (r = .88- .94) these species performances on ED's with three different cerebral indeces. They suggested that species ability differences as measured by learning set, SDR, and ED methodologies may be correlated with overall cerebral development, the amount of "extra neurons," and certain cortex/brain volume ratios (Riddell & Corl, 1977).

EXTINCTION OF A SIMPLE OPERANT

One more study involving retarded subjects which supported the differential extinction hypothesis deserves mention. Levine (1975) trained retarded subjects at three I.Q. levels (I.Q. = 50-60, 30-40, or 20 and below) to bar press for food reinforcement under either VR-2 or VR-4 schedules. Subjects were then exposed to extinction. Statistical analysis of the number of responses emitted during the nonreinforced extinction period revealed an inverse relationship between

I.Q. and resistance to extinction. These results demonstrated that at the human level, within species ability differences may involve differential inhibitory abilities (Levine, 1975).

V. METHODOLOGICAL CONSIDERATIONS

In the earliest attempts to compare absolute performances of different species (Gossette,1967, 1970; Gossette, et.al., 1966; Gossette & Hood, 1969) no attempt was made to equate those species on the procedural variables necessarily involved in measuring performance. To the extent that variation in a procedural variable might lead to variation in performance, an obtained interspecies difference might have been due to unequal contributions of that variable across species and not some more basic organismic dimension such as phyletic level, inhibitory capacity and the like. As apparently meaningful interspecies performance differences emerged, it became necessary to determine if they were, in fact, a result of a mismatch across species of procedural variables. Two major variables that were likely candidates for mismatch were motivational and incentive levels, both of which had been demonstrated to influence interspecies performances on discrimination tasks including SDR, extinction , and DRL. As a first step, Levine (1974) used four levels of deprivation (6%, 14%, 22%, and 30% body weight reduction) and two levels of incentive (2 sec. vs. 6 sec. hopper presentation). Chickens and pigeons exposed to simultaneous discrimination reversals were compared. Optimal error reduction for chickens occurred at 22% body weight reduction, while for the pigeons this was at 14%. When compared at these levels, pigeons still demonstrated superior error reduction at the .01 level (Levine, 1974). Birnbaum (1974) used identical methodology except with successive stimulus presentations. A curvilinear relationship between motivation and SDR performance similar to Levine's (1974) was observed.

Gossette and Hood (1968) found that higher incentive levels enhanced the reversal performance of birds. Gossette, Birnbaum, and Ramsey (1970), studied the SDR performance of chukar partridges and concluded that errors on SDR tasks were a decreasing function of incentive. In Levine's (1974) study, incentive was demonstrated to have little effect on SDR performance with simultaneous stimulus presentations for both pigeons and chickens. Birnbaum (1974) obtained similar findings using a SDR task with successive stimulus presentations.

VI. STATEMENT OF THE PROBLEM

Previous studies have demonstrated consistent superiority of the SDR performance of pigeons over that of chickens on simultaneous discrimination tasks (Gossette, et.al., 1966; Levine, 1974). These differences were apparent from the first reversal and represented variation in the amount of negative transfer. However, there are at least two distinct ways of interpreting observed negative transfer. In one view, the differential extinction hypothesis, the stress has been placed upon variation in resistance to extinction of responding to the previous S+ which in turn has been interpreted as representing variation in the ability to inhibit nonreinforced responding. An alternative interpretation, and one that is not incompatible with the first view is that the variation in negative transfer is due to a difficulty in overcoming the inhibitory control acquired from the previous S- (the reversal S+). Some such account seems to be emerging from Bitterman's analyses (Bitterman, 1972, 1980; Woodward & Bitterman, 1976) which, however, has been based upon the use of successive or "unitary" stimulus presentations.

The present study will attempt to isolate the relative contribution of each potential source of negative transfer with the partial reversal methodology and simultaneous stimulus presentations. In addition, this study will undertake the previously reported reversal differences between piegons and chickens with those values of procedural variables that have been demonstrated to produce optimal performance for both species.

HYPOTHESES

1) As previously demonstrated (Gossette, et.al., 1966; Gossette, 1968; Levine, 1974), it is expected that pigeons will make fewer errors than chickens on the Complete

Reversal task.

2) Based upon the work of Newman (1976) and Berger (1975) it is expected that pigeons will commit fewer errors on the S+ Partial Reversal.

3) Based upon the Newman (1976) work, it is expected that greater negative transfer for both species will occur on the S+ Partial Reversal than on the S- Partial Reversal.

METHOD

SUBJECTS

Representatives of two Avian orders, already well studied at this laboratory, Galliformes (chickens) and Columboformes (pigeons) were studied. Twenty Seabrite Bantam chickens (Gallus gallus) and 20 homing pigeons (Columbia livia) served as subjects. All subjects were young adults who had reached full growth potential, and all were experimentally naive. Chickens and pigeons were randomly assigned to one of three experimental (Complete Reversal, S+ Partial Reversal, or S- Partial Reversal) or two control (S+ Partial Control, S- Partial Control) groups (see Table A). Each group consisted of four subjects of one species for a total of 10 groups.

APPARATUS

Four scientific prototype (BRS-Foringer) pigeon test chambers, enclosed in modified wood boxes for sound and light attenuation were used. The interior dimensions were 19½" w X 14" h X 14" depth. On the front wall of the apparatus was the intelligence panel. On the intelligence panel were two plastic pecking keys. These keys could be illuminated by back projected red, green, yellow, or white light. A grain magazine was located below and between the keys. The environmental events (presentation of stimuli and food magazine) and response recording were controlled by electronic programming equipment. During reversal training stepping switches automatically pre-

TABLE A: GENERAL EXPERIMENTAL DESIGN FOR CHICKEN AND PIGEON GROUPS

Reversal Type	Stimuli in Problem I		Stimuli in Problem II	
	Positive	Negative	Positive	Negative
Complete:	gr	rd	rd	gr
S+ Partial:	gr	rd	--	gr
S+ Partial Control:	--	gr	None	None
S- Partial:	gr	rd	rd	--
S- Partial Control:	rd	--	None	None

Key: -- = horizontal white line on black background

gr = green light

rd = red light

sented the positive (reinforced) stimuli in the following Gellerman (1933) quasi random order (L=left, R=right): L, R, L, R, R, R, L, L, R, L, L, R, L, R, L, L, R, L, R, R. The negative (nonreinforced) stimulus appeared on the opposite side simultaneously.

PROCEDURE

The experiment consisted of three distinct phases: habituation, keypeck shaping, and reversal training.

I. Habituation: During their initial two weeks in the laboratory cage environment, subjects were given ad lib food and water. The birds were weighed daily until stable body weights were established. Subjects were then gradually reduced to their experimental weights. As previously discussed, in order to equate species motivationally for optimal reversal performance, different deprivational levels were employed. Based on Levine's (1974) findings, pigeons underwent 14% body weight loss (86% ad lib weight), while chickens underwent 22% body weight loss (78% ad lib weight). This way, any species differences in performance could not be attributed to the effect of arbitrarily chosen deprivational levels.

II. Keypeck Shaping: While experiencing initial food deprivation, the animals were habituated to the testing apparatus and trained to keypeck for the opportunity to feed from the hopper using an autoshaping technique. Chickens were reinforced with cracked corn, while pigeons received their regular pigeon feed. Half of the animals of each species were first autoshaped to the left key lit white while the other half received the white key on the right. After sixty responses to one side, the opposite key was illuminated and reinforced for sixty responses. Animals received twenty trials per day. During autoshaping, the stimulus remained illuminated for 10 seconds. If a response occurred, the stimulus immediately went off and reinforcement became available as the hopper containing the feed was presented. Reinforcement was available for three seconds. If no response occurred, reinforcement became available for 3 seconds after the 10 second stimulus presentation. The intertrial interval (ITI) was 30 seconds. Two pigeons failed to autoshape and were replaced. All of the chickens successfully autoshaped.

Following autoshaping, it was attempted to habituate the animals to simultaneous choice responding to two stimuli with a 10 second ITI. During this phase, a yellow/orange color lit both keys. This intermediate color was chosen to equalize generalization effects to the red/green dimension. Three days of 20 trials each were given in this condition. Responding had to occur for reinforcement to be delivered.

III. Reversal Training: After having reached their assigned weights and undergone the pretraining (phases I and II), subjects began discrimination training. With the exception of the control groups, for all subjects, one key was illuminated with red, the other with green. Counterbalancing for color was initially attempted, but the first four chickens given training on S+ = red, S- = green demonstrated 95% responding to red in the first session. It was decided at that point to abandon counterbalancing. The S+ was green and the S- red, therefore, for all Problem I training for both chickens and pigeons.

Pecking the correct stimulus (S+ = green) resulted in the presentation of the food magazine for 3 seconds for both species. A noncorrection procedure was employed: incorrect responses to red ended the trial without the opportunity to try the alternative stimulus. Following either a reinforcement period or an incorrect response, an ITI of 10 seconds commenced, during which both the house lights and stimulus light were off.

Subjects were exposed to 20 trials daily: the end of a trial was defined as the pecking of the response key with sufficient force to operate a microswitch behind it after the stimuli had been presented with the subsequent occurrence or nonoccurrence of reinforcement.

Daily sessions continued until the subject reached a criterion of at least 18 out of 20 correct responses in one day. This marked the end of Problem I which can also be referred to as the original discrimination or OD.

At this point, the following conditions were implemented and this phase was referred to as Problem II:

1) Complete Reversal: The contingencies of the stimuli from Problem I were reversed, i.e., the S+ from Problem I became the S- of Problem II, and the S- of Problem I became the S+ of Problem II. In this condition, then, red was the S+ and green was the S- for both species. Subjects continued under the Problem II contingencies until the criterion of 18 out of 20 correct responses was again attained.

2) S+ Partial Reversal: In this condition, the S+ of Problem I became the S- of Problem II. For both species, then, the Problem II S- was green. The Problem II S+ was novel; a horizontal white line on a dark background. It was important that this novel stimulus be orthogonal to the stimuli of previous training in order to minimalize generalization effects that would confuse the interpretation of the source of negative transfer (Rilling, 1977). There is evidence that training pigeons to respond to a white key results in preferences for wavelengths between 510 and 560 nanometers (Sekelman, 1973). However, Guirintano, Schaler, and Thomas (1972), tested pigeons on a line tilt dimension (white line on a black background) for generalization effects after training them to peck for either white or green light. Preference for the vertical was found for the pigeons trained on white, but no preference on the line tilt dimension with training on green was obtained. While Rilling (1977) noted that

"...it is unlikely that any two dimensions are completely independent (pg. 440)," these results (Guirintano, et.al., 1972) indicate that using the horizontal white line on a black background after training on red/green may have helped to minimalize generalization effects, at least for the pigeons. Therefore, for the purposes of this experiment, since white was used for autoshaping, and red/green for discrimination training, it seemed that the horizontal white line on a black background would be the best novel stimulus to employ for the partial reversal conditions.

Animals again experienced 20 trials daily until the 18/20 criterion was attained. This condition served to evaluate the potency of the original S+ as a source of negative transfer.

3) S- Partial Reversal: In this condition, the negative stimulus from Problem I became the positive stimulus for Problem II, therefore for both species the Problem II S+ was red. The Problem II S- was the novel horizontal line. This condition was included to assess the contribution of negative transfer provided by the original S-. Subjects were run until the 18/20 criterion was reached.

4) Control Groups: The control groups received training on only one discrimination. The S+ Partial Control group learned to discriminate the contingency of the Problem II condition of the S+ Partial Reversal group (S+ = horizontal white line, S- = green), while the S- Partial Control group

learned to discriminate the contingency of the Problem II condition of the S- Partial Reversal group (S+ = red, S- = horizontal white line). The performance of the control groups provided a baseline of the difficulty of these discriminations for both species against which the extent of negative transfer due to training on the original discrimination for the experimental partial reversal groups could be assessed. (Of course, there was also an effect of positive transfer operating in the experimental groups; the learning to learn phenomenon demonstrated in the learning set literature).

RESEARCH DESIGN

Five dependent variables were chosen for analysis across two independent variables. The two independent variables were species (chicken or pigeon), and reversal type (Complete, S+ Partial, S- Partial, S+ Partial Control, S- Partial Control). The following three measurements were chosen as dependent variables to be assessed in both Problem I and Problem II:

1) Total Error per Problem. This was a measure of the cumulative number of errors committed in Problem I and Problem II respectively.

2) Total Mean Error per Session. This was calculated by dividing total errors by total sessions for Problem I and Problem II respectively.

3) Total Initial Error per Problem. Initial error was defined as the number of errors that occurred in each session before the first correct response was made. This was totalled for Problem I as well as for Problem II.

The final two dependent variables were chosen specifically to assess the magnitude of transfer that occurred in session one of Problem II. No equivalent Problem I measures were chosen for use in the data analyses. These dependent measures were:

4) Percent Error Session One Problem II. Since all sessions contained 20 trials, this variable was calculated by dividing the number of errors in session one of Problem II by 20, for each subject.

5) Initial Error Session One Problem II. This was the number of errors that were committed by each animal before the first correct response of session one Problem II. This variable can be viewed as an abbreviated measure of resistance to extinction to the previous S+, after Problem I training. For the control groups, these last two variables were based on Problem I performance as these groups received training on one problem only.

Each dependent variable was analyzed according to planned comparisons which were chosen apriori. Comparisons were made between and within species. In order to evaluate the first two hypotheses of this experiment, the following two between species planned comparisons were employed:

1) Complete Reversal (chickens) vs. Complete Reversal (pigeons).

2) S+ Partial Reversal (chickens) vs. S+ Partial Reversal (pigeons).

The relative difficulty for chickens and pigeons of the S- Partial Reversal was also of interest. The third between species planned comparison was therefore:

3) S- Partial Reversal (chickens) vs. S- Partial Reversal (pigeons).

To assess the existence of negative transfer, and to help explore hypothesis #3, the control comparisons were included. For each species respectively, the following two within species planned comparisons were therefore included:

1) S+ Partial Reversal vs. S+ Partial Control (each species respectively).

2) S- Partial Reversal vs. S- Partial Control (each species respectively).

Relevant to Hypothesis #3 also was the relative difficulty of each experimental condition within species. The following three within species planned comparisons allowed for the ordering of the difficulty of the three reversal conditions:

3) Complete Reversal vs. S+ Partial Reversal (each species respectively).

4) Complete Reversal vs. S- Partial Reversal (each species respectively).

5) S+ Partial Reversal vs. S- Partial Reversal (each species respectively).

In total then, there were three planned comparisons that compared chickens and pigeons, and five that compared groups within species for a total of 13 planned comparisons for each dependent variable.

RESULTS

1. Problem I Comparisons

Since performance on the reversal tasks, whether complete or partial, should be related to the amount of training received on the original discrimination (Problem I), it was necessary to examine Problem I differences between chickens and pigeons before undertaking Problem II between species comparisons. The data for Total Error Problem I, Total Mean Error per Session for Problem I, and Total Initial Error Problem I were therefore examined. Since all experimental groups received identical Problem I training, the performance of 24 birds were compared here.

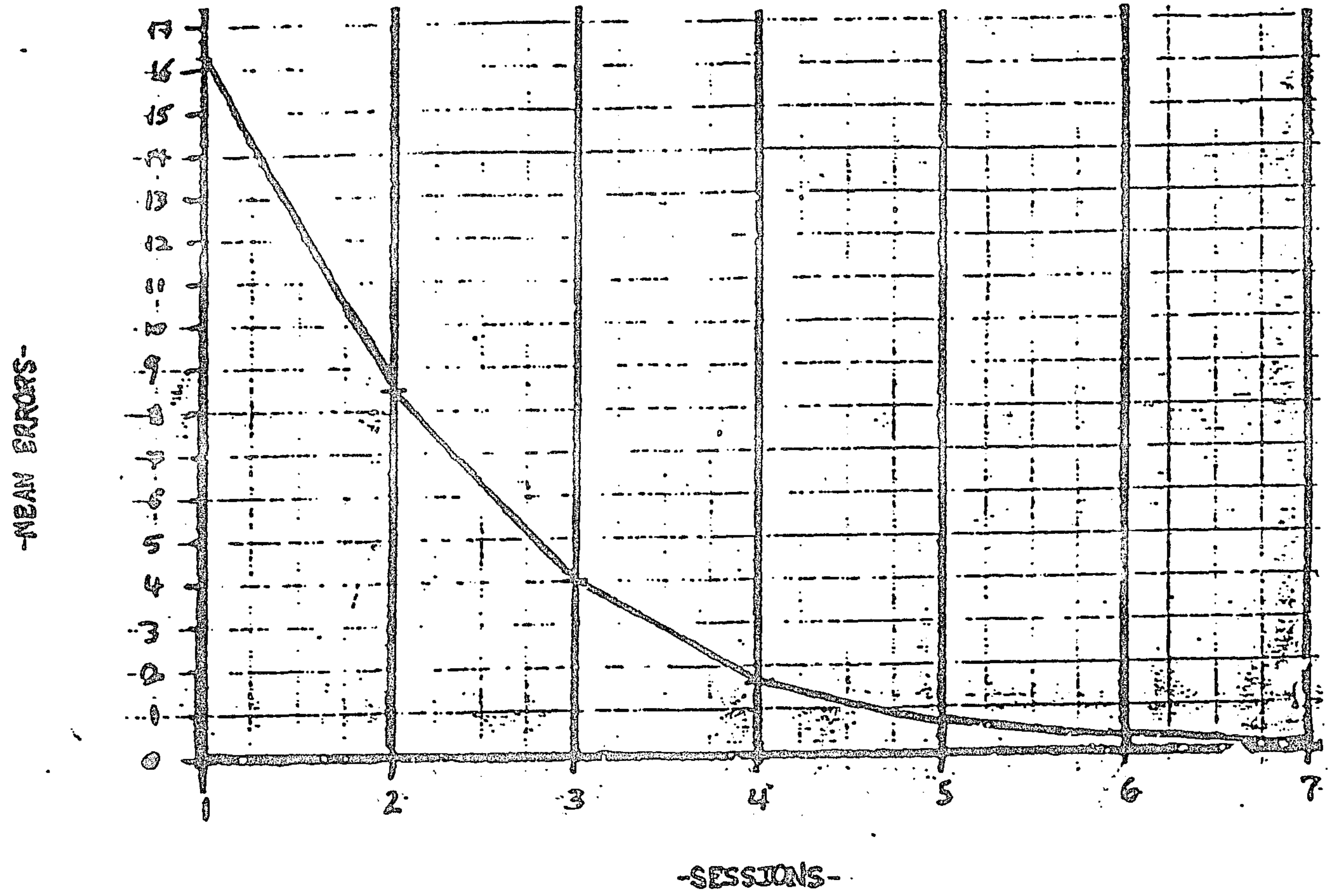
Results were plotted for Mean Error per Session. This was calculated by dividing the total number of errors for each group member per session, by the number of subjects per group (4). This resulted in a session by session depiction of error reduction for all groups except for the chicken S+ Partial Control group. In this group, all subjects reached criterion during the first session, and therefore graphical depiction was not possible.

-INSERT FIGURE 1 HERE-

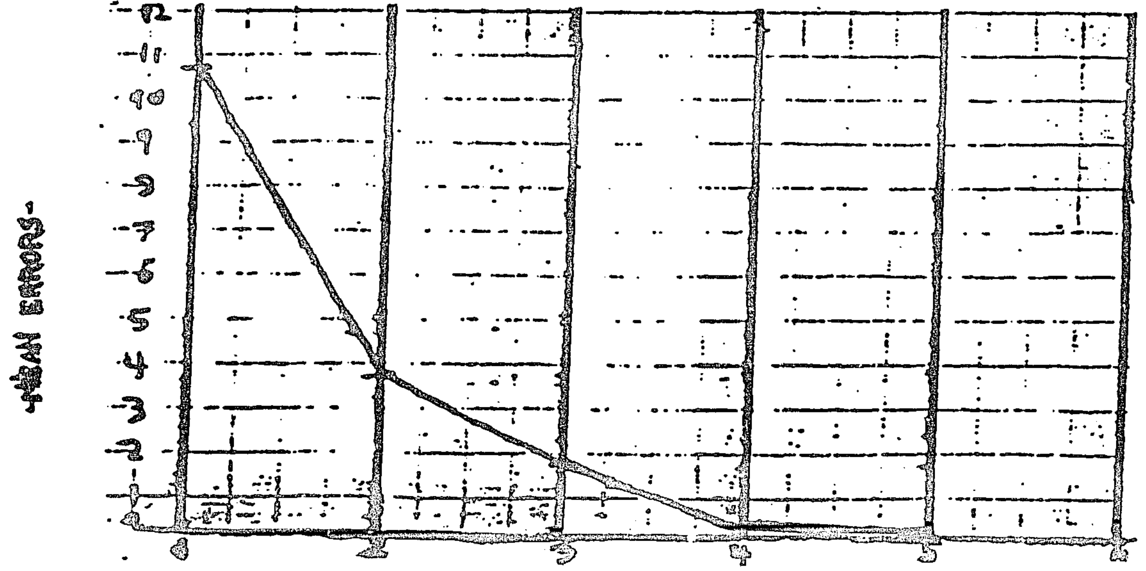
Figure 1 reveals that chickens seemed to begin at a higher level of error and took longer to reach criterion on the original discrimination. This was also supported by the

FIGURE 1:
MEAN ERROR PER SESSION PROBLEM 1
(averaged across all experimental subjects)

CHICKENS



PIGEONS



statistical analyses of the data (see Tables 1, 2, and 3 for raw data and statistical results).

-INSERT TABLE 1 HERE-

-INSERT TABLE 2 HERE-

-INSERT TABLE 3 HERE-

Examination of Tables 1, 2, and 3 reveals that the means for chickens exceeded the means for the pigeons for all three error variables. These differences were significant at least at the .006 level and explained between 28.1% and 41.7% of the variance. Since the level of errors of the chickens significantly exceeded pigeons on all three Problem I variables, it was decided that ANCOVAs be reported for the Problem II between species comparisons for these variables using Problem I performance as the covariate in an attempt to control for the effects of variation of Problem I performance upon Problem II performance. Otherwise, it could have been argued that between species Problem II differences could have been explained by Problem I between species differences.

II. Problem II: Between Species Comparisons

A. Complete Reversal: Chickens vs. Pigeons

This comparison was included as a direct test of Hypothesis #1 which stated that pigeons should make fewer errors than chickens on the Complete Reversal task. Results are plotted in Figure 2.

TABLE 1:

TOTAL ERROR PROBLEM I

	CHICKENS	PIGEONS
	Raw Data	Raw Data
Complete Reversal	25	14
	31	16
	34	18
	53	19
	$\bar{x}$=35.8	$\bar{x}$=16.8
S+ Partial Reversal	18	15
	19	17
	20	17
	24	18
	$\bar{x}$=20.3	$\bar{x}$=16.8
S- Partial Reversal	23	9
	31	16
	43	17
	52	20
	$\bar{x}$=37.3	$\bar{x}$=15.5
GRAND MEAN ± S.D. =	31.1 ± 12.3	16.3 ± 2.8

ANOVA: F (1.22) = 16.4, p. = .001, R^2 = .405

TABLE 2:

TOTAL MEAN ERROR PER SESSION PROBLEM I

	CHICKENS	PIGEONS
	Raw Data	Raw Data
Complete Reversal	8.3	4.0
	8.5	4.6
	8.8	4.8
	10.3	6.0
	$\bar{x}$= 9.0	$\bar{x}$=4.9
S+ Partial Reversal	5.0	5.0
	6.0	5.6
	6.3	5.6
	8.0	6.0
	$\bar{x}$=6.3	$\bar{x}$=5.6
S- Partial Reversal	7.4	4.5
	7.6	5.6
	7.8	6.6
	10.8	8.0
	$\bar{x}$= 8.4	$\bar{x}$=6.2
GRAND MEAN ± S.D. =	7.9 ± 1.6	5.5 ± 1.1

ANOVA: F (1.22) = 17.2, $p = .001$, $R^2 = .417$

TABLE 3:

TOTAL INITIAL ERROR PROBLEM I

	CHICKENS	PIGEONS
	Raw Data	Raw Data
Complete Reversal	0	0
	8	2
	12	3
	21	3
	$\bar{x}=10.5$	$\bar{x}=2.0$
S+ Partial Reversal	3	0
	4	2
	4	2
	16	2
	$\bar{x}=6.8$	$\bar{x}=1.5$
S- Partial Reversal	1	0
	3	1
	7	1
	21	3
	$\bar{x}=8.0$	$\bar{x}=1.3$

GRAND MEAN ± S.D. = 8.4 ± 7.6   1.6 ± 1.1

ANOVA: F (1.22) = 9.4, p = .006, R^2 = .281

-INSERT FIGURE 2 HERE-

Visual inspection of Figure 2 indicates that chickens made more errors and took more sessions to reach criterion under the Complete Reversal condition. These differences, however, failed to reach statistical significance (see Table 4).

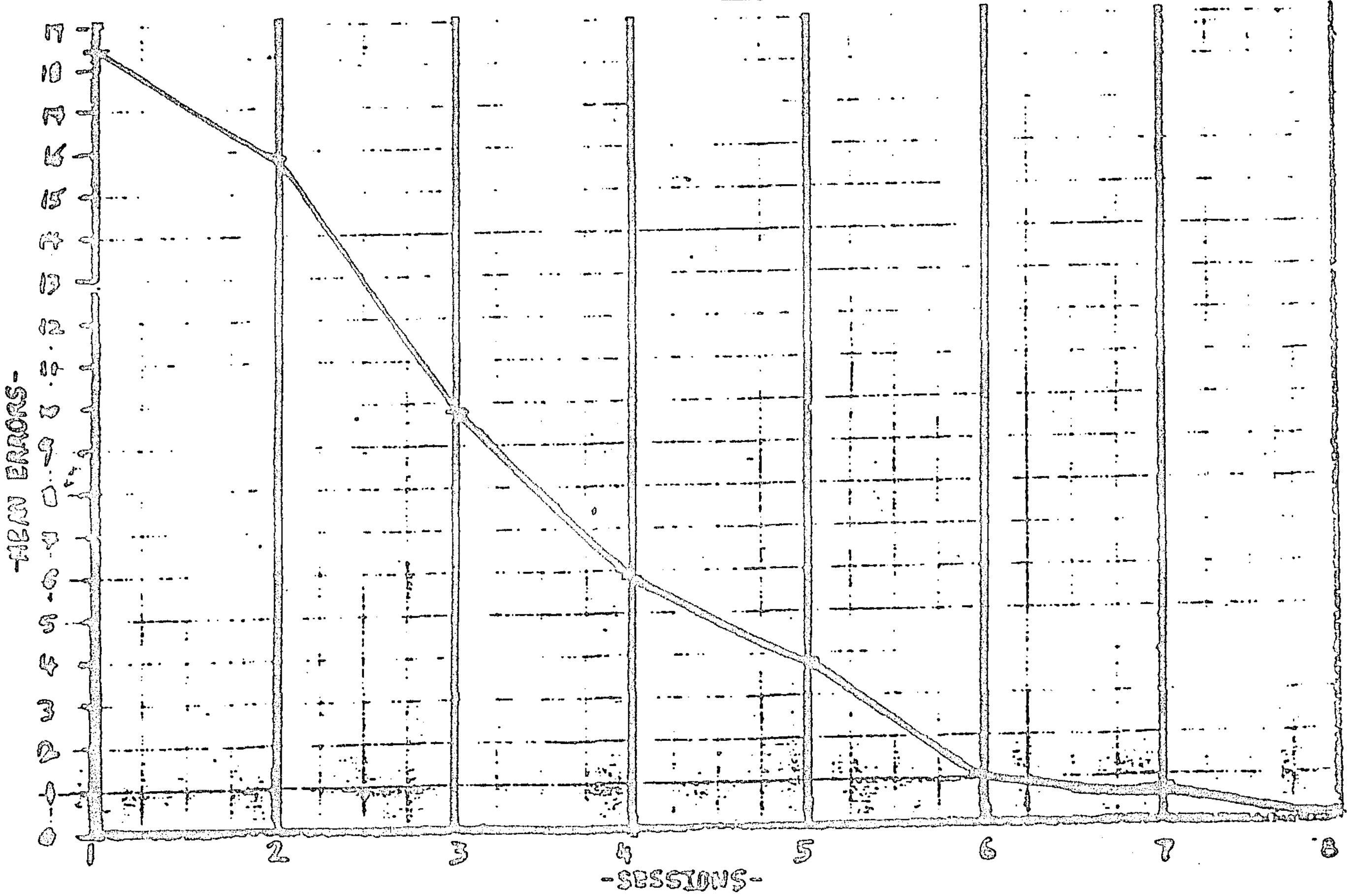
-INSERT TABLE 4 HERE-

Analyses of covariance (ANCOVAs) including corresponding tests of the homogeneity of regression as well as analyses of variance (ANOVAs) were carried out for Total Error Problem II, Total Mean Error per session Problem II, and Total Initial Error Problem II for between and within species comparisons. The Problem I data served as the covariate for the ANCOVAs. ANOVAs only were performed for Percent Error Session One Problem II and Initial Error Session One Problem II as no equivalent Problem I data was included, and for the control comparisons since the control groups only received one problem.

For all F tests the alpha level (the level at which the H_o was accepted or rejected) chosen was .05 (two tailed). Due to the small number of subjects per group (4), for those comparisons that approached significance ($p = .05- .10$) judgement of significance was suspended. All F tests were

FIGURE 2: MEAN ERROR PER SESSION PROBLEM II-COMPLETE REVERSAL

CHICKENS



PIGEONS

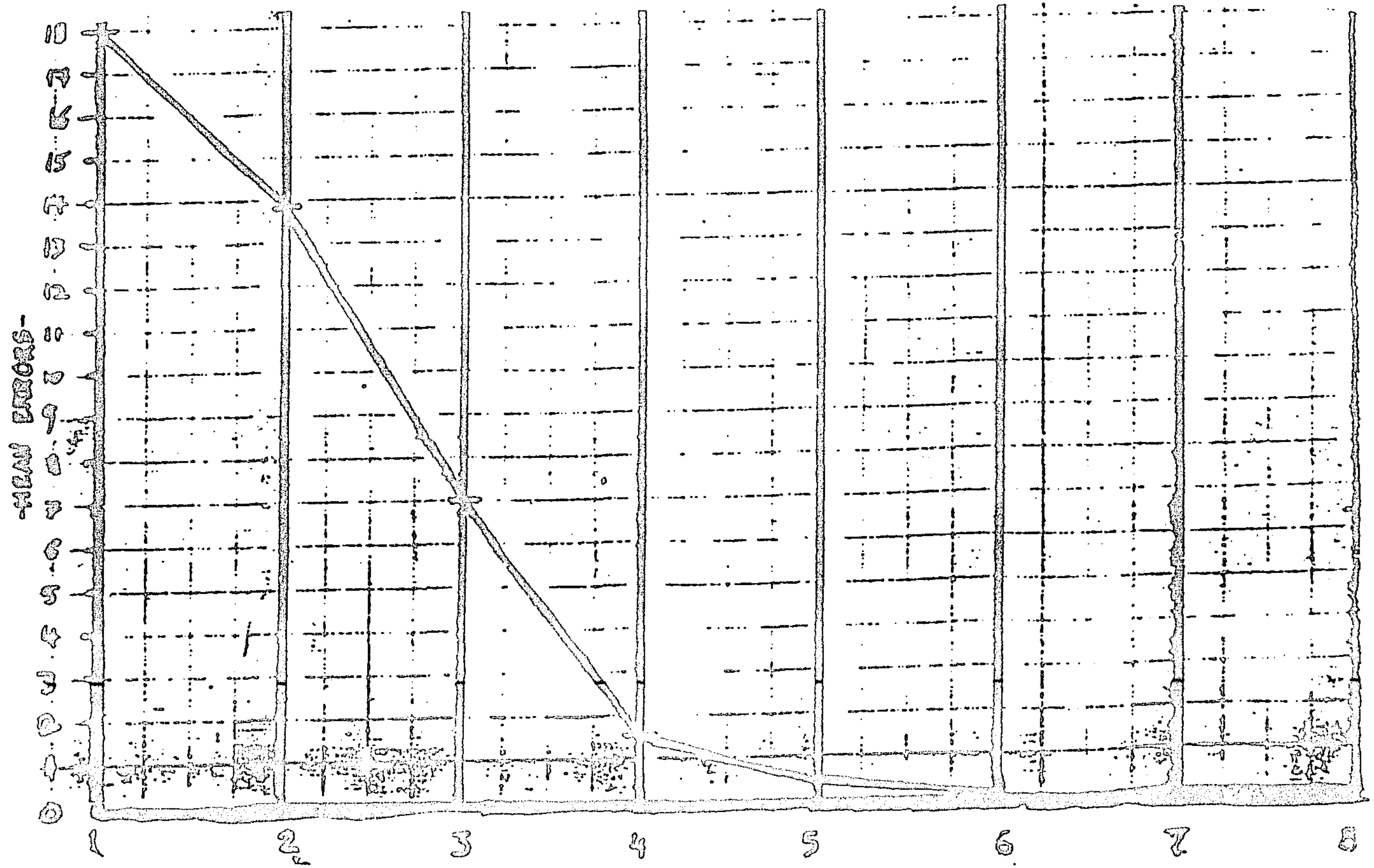


TABLE 4:

STATISTICAL RESULTS OF BETWEEN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

COMPLETE REVERSAL

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
1) Total Error Problem II	55.0	48.4	±15.2	41	41.0	47.6	±8.2	33
				43				37
				65				42
				71				52

ANCOVA: F (1,5) = .002, p = .959, R^2 = .0003

2) Total Mean Error per Session Problem II	10.0	9.7	±1.2	8.2	9.6	9.9	±1.0	8.3
				10.1				9.3
				10.8				10.4
				10.8				10.5

ANCOVA: F (1,5) = .005, p = .942, R^2 = .0008

3) Total Initial Error Problem II	24.0	20.5	±14.4	2	13.5	17.0	±8.9	5
				24				7
				31				19
				37				23

ANCOVA: F (1,5) = .107, p = .756, R^2 = .017

4) Percent Error Session One Problem II	92.3		±8.4	.08	90.1		±4.1	.85
				.95				.90
				.95				.90
				.99				.95

ANOVA: F (1,6) = .23, p = .646, R^2 = .036

TABLE 4: (continued)

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
5) Initial Error Session One Problem II	14.8		±7.3	4 17 18 20	9.0		±8.2	0 4 16 16

ANOVA: F (1,6) = 1.09, p = .336, R^2 = .153

computed using nonpooled error terms as a significant interaction between the covariate and the dependent variable was detected using the homogeneity of regression with pooled error terms. In no case was there a significant interaction using nonpooled error terms. Variance accounted for was calculated using the multiple R^2.

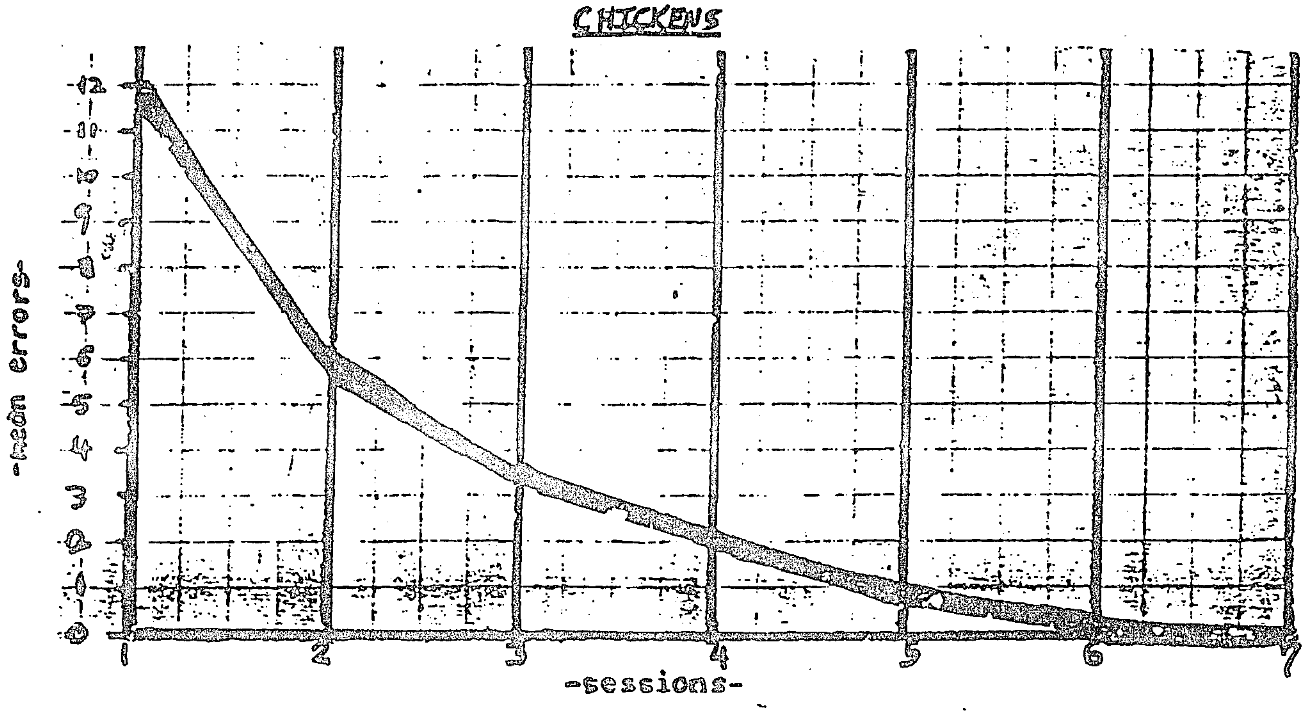
Examination of the observed means in Table 4 reveals that the chickens exceeded the pigeons on all dependent measures as expected but none of these differences approached significance. For the three measures involving the ANCOVA, the adjusted means were much closer than the observed means, reflecting the influence of the covariate. It is possible that differences in performance in Problem I obscured differences in Problem II. The hypothesis that pigeons would show fewer errors than chickens on the Complete Reversal task could therefore not be supported statistically. Differences between observed means, however, were all in the expected direction.

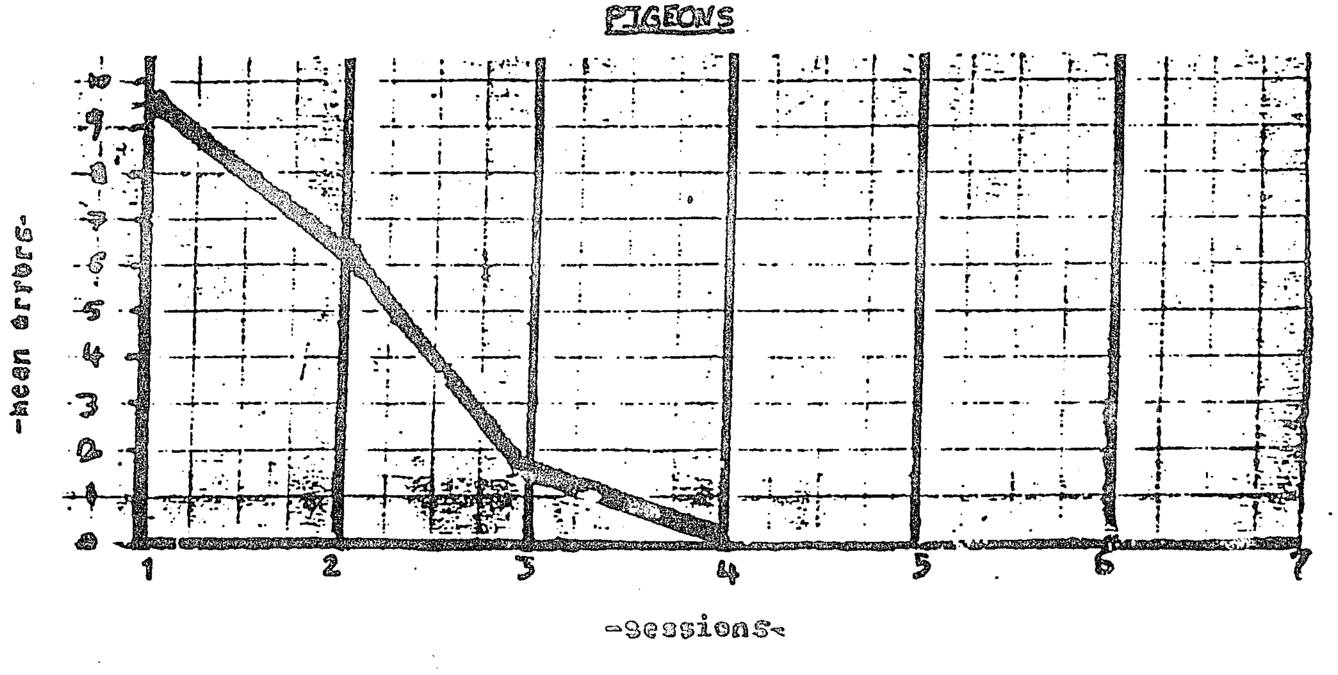
B. S+ Partial Reversal: Chickens vs. Pigeons

This comparison was included as a direct test of Hypothesis #2 which stated that fewer errors were expected for the pigeons on this task than for the chickens. Results appear graphically in Figure 3.

-INSERT FIGURE 3 HERE-

FIGURE 3:
MEAN ERROR PER SESSION PROBLEM II
S+ PARTIAL REVERSAL


CHICKENS


PIGEONS

Examination of Figure 3 indicates that pigeons made fewer errors under the S+ Partial Reversal condition. Chickens appeared to begin at a higher level of error and to take longer to reach criterion.

-INSERT TABLE 5 HERE-

Inspection of the means in Table 5 reveals that all differnces between observed means and between adjusted means were in the expected direction, with pigeons outperforming chickens. The ANCOVA for Total Mean Error per Session Problem II very closely approached significance with a p value of .055, accounting for 50.8% of the variance. None of the other comparisons reached significance but they did account for between 16.5% and 26.8% of the variance.

While mean differences conformed to expectation based on Hypothesis #2, four out of five of the statistical comparisons failed to reach significance. The close approach to significance of Mean Error per Session Problem II permits the suspension of judgement of whether to accept or reject this null hypothesis.

C. S- Partial Reversal: Chickens vs. Pigeons

The between species comparison of performance on the S- Partial Reversal was included to assess species differences in magnitude of transfer as a result of experience with

TABLE 5:

STATISTICAL RESULTS OF BETWEEN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

S+ PARTIAL REVERSAL

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
1) Total Error Problem II	24.8	26.3	±12.2	18 19 19 42	17.3	15.7	±3.4	14 16 17 22

ANCOVA: F (1,5) = 1.2, p = .315, R^2 = .166

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
2) Total Mean Error per Session Problem II	6.1	6.5	±1.1	4.5 6.3 6.3 7.1	5.7	5.3	±1.0	4.6 5.3 5.6 7.3

ANCOVA: F (1,5) = 6.2, p = .055, R^2 = .508*

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
3) Total Initial Error Problem II	5.0	5.5	±4.7	0 3 6 11	2.3	1.7	±1.0	1 2 3 3

ANCOVA: F (1,5) = 1.5, p = .277, R^2 = .20

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
4) Percent Error Session One Problem II	60.0		±14.7	.45 .55 .60 .80	47.5		±6.5	.40 .45 .50 .55

ANOVA: F (1,6) = 2.4, p = .171, R^2 = .285

TABLE 5 (continued)

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
5) Initial Error Session One Problem II	5.0		±4.7	0	1.5		±0.6	1
				3				1
				6				2
				11				2

ANOVA: F (1,6) = 2.2, p = .189, R^2 = .268

---

* = Approaches significance: p = .05 - .10.

the Problem I S-. In the graphical depiction of this comparison (see Figure 4), it appears that the chickens began Problem II at a much higher level or errors, and took longer than the pigeons to eventually meet criterion. Mean differences and data analyses supported this contention as 3 out of 5 comparisons of this task reached statistical significance (see Table 6).

-INSERT FIGURE 4 HERE-

-INSERT TABLE 6 HERE-

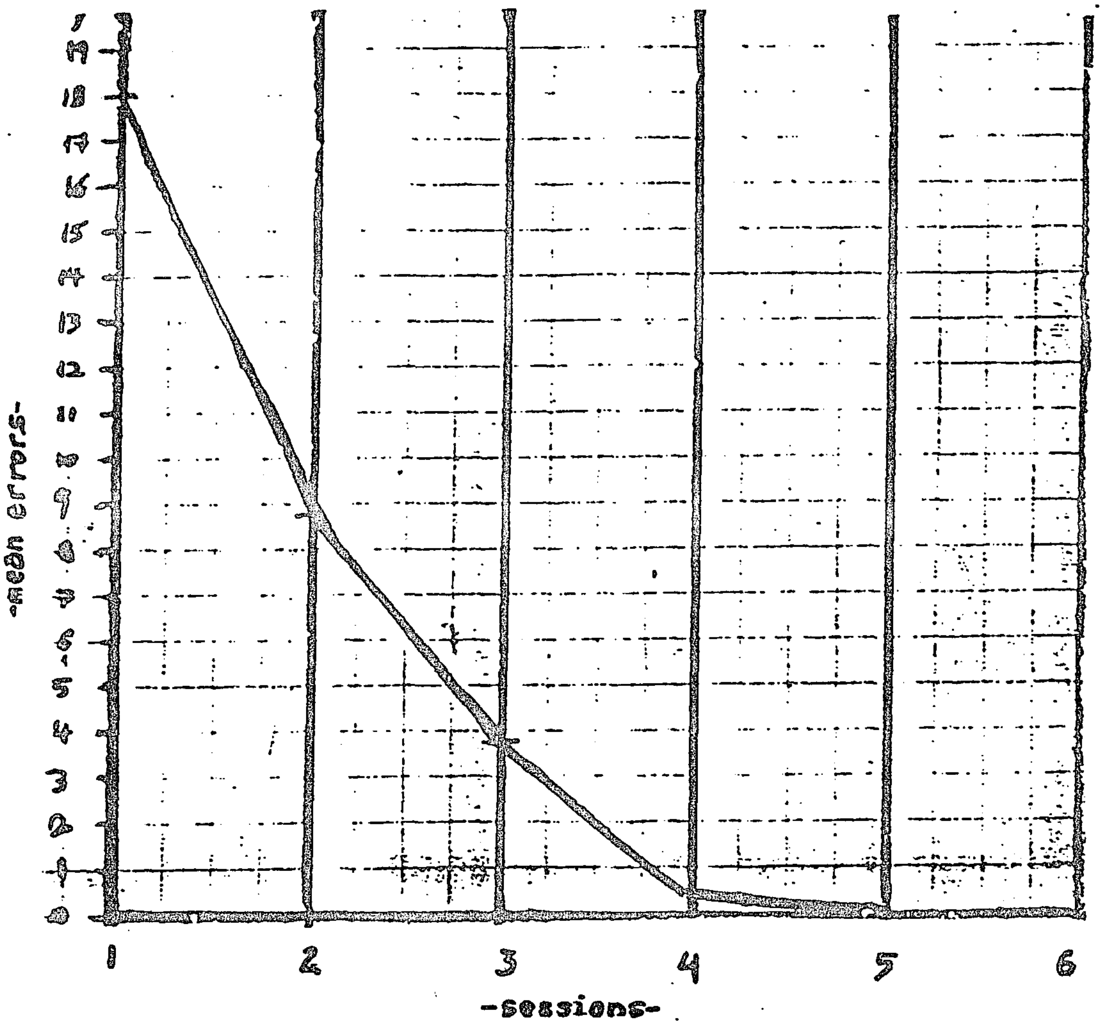
Examination of Table 6 indicated that chickens exceeded pigeons on all error variables for the S- Partial Reversal comparison. Observed as well as adjusted means reveal superior performance by the pigeons. The F tests for Total Mean Error per Session Problem II, Percent Error Session One Problem II, and Initial Error Session One Problem II were significant and accounted for between 62% and 85% of the variance. The ANCOVA for Total Initial Error Problem II approached significance. The ANCOVA for Total Error Problem II failed to reach significance. Apparently, the S- Partial Reversal was more difficult for the chickens.

III. Within Species Ordering of Reversal Difficulty

For chickens and pigeons it was of interest to determine within species differences between experimental conditions,

FIGURE 4:
MEAN ERROR PER SESSION PROBLEM II
S- PARTIAL REVERSAL

CHICKENS



PIGEONS

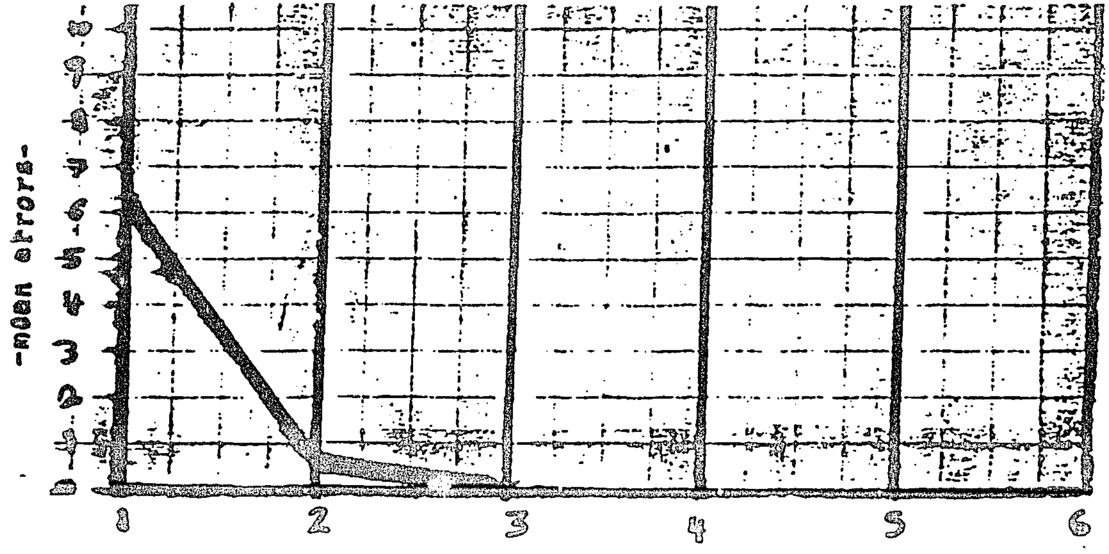


TABLE 6

STATISTICAL RESULTS OF BETWEEN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

S- PARTIAL REVERSAL

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
1) Total Error Problem II	30.8	27.6	±14.2	12	7.0	10.2	±2.9	4
				28				5
				35				9
				14				10
ANCOVA: F (1,5) = 1.9, p .224, R^2 = .240								
2) Total Mean Error per Session Problem II	9.1	9.2	±2.2	6.5	3.5	3.4	±1.5	2.0
				8.8				2.5
				9.3				4.5
				11.8				5.0
ANCOVA: F (1,5) = 9.8, p = .026, R^2 = .620*								
3) Total Initial Error Problem II	17.3	14.8	±10.2	5	1.3	3.7	±.5	1
				17				1
				23				1
				26				2
ANCOVA: F (1,5) = 5.1, p = .074, R^2 = .459**								
4) Percent Error Session One Problem II	89.5		±16.4	.65	31.3		±13.3	.15
				.95				.25
				.99				.40
				.99				.45
ANOVA: F (1,6) = 29.5, p = .002, R^2 = .831*								

TABLE 6: (continued)

	Means: Chickens				Means: Pigeons			
	Observed	Adjusted	S.D.	Raw Data	Observed	Adjusted	S.D.	Raw Data
5) Initial Error Session One Problem II	15.8		±5.1	10 13 20 20	1.0		±0.0	1 1 1 1

ANOVA: F (1,6) = 34.0, p = .001, R^2 = .85*

* = Significant: $p < .05$.

** = Approaches significance: p = .05-.10

as a first step in analyzing Hypothesis #3 which predicted greater negative transfer for both species in the S+ Partial Reversal than in the S- Partial Reversal. The ordering of difficulty of the experimental conditions within species might reflect the relative presence of negative transfer in Problem II. The existence of negative transfer will later be determined in the control comparisons. In order to arrange the experimental conditions in order of relative difficulty the following planned comparisons were calculated for each species individually: Complete Reversal vs. S+ Partial Reversal, Complete Reversal vs. S- Partial Reversal, S+ Partial Reversal vs. S- Partial Reversal.

A. Chickens

Inspection of Figure 5 reveals that the Complete Reversal seemed most difficult for the chickens followed by the S- Partial Reversal, with the S+ Partial Reversal seeming to be easiest. The data and data analysis generally supported this observation (see Tables 7, 8, and 9).

-INSERT FIGURE 5 HERE-

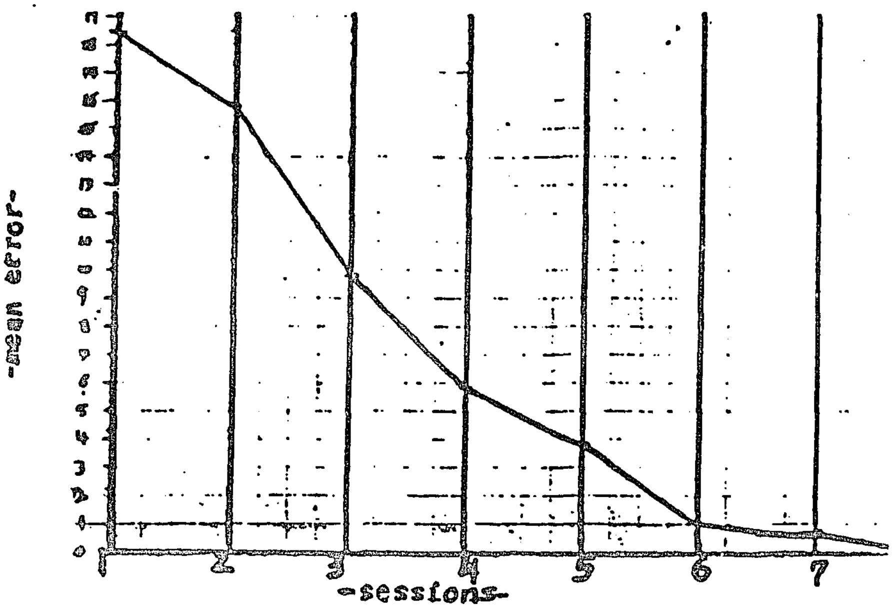
-INSERT TABLE 7 HERE-

-INSERT TABLE 8 HERE-

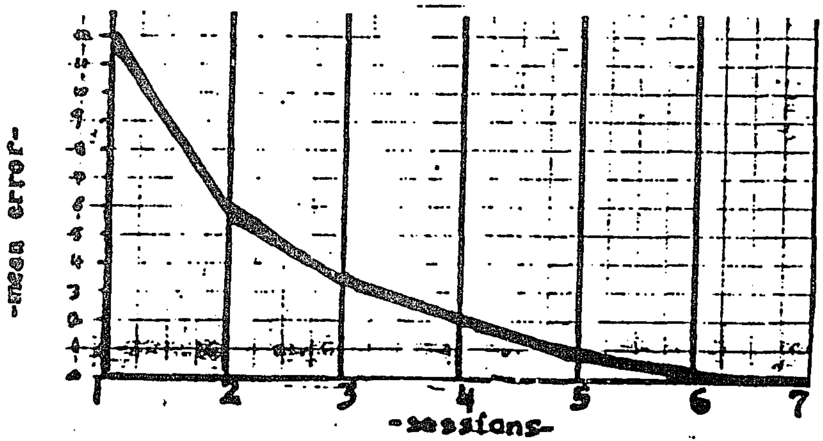
-INSERT TABLE 9 HERE-

FIGURE 5: MEAN ERROR PER SESSION PROBLEM II ACROSS EXPERIMENTAL GROUPS
CHICKENS

Complete Reversal:



S+ Partial Reversal:



S- Partial Reversal:

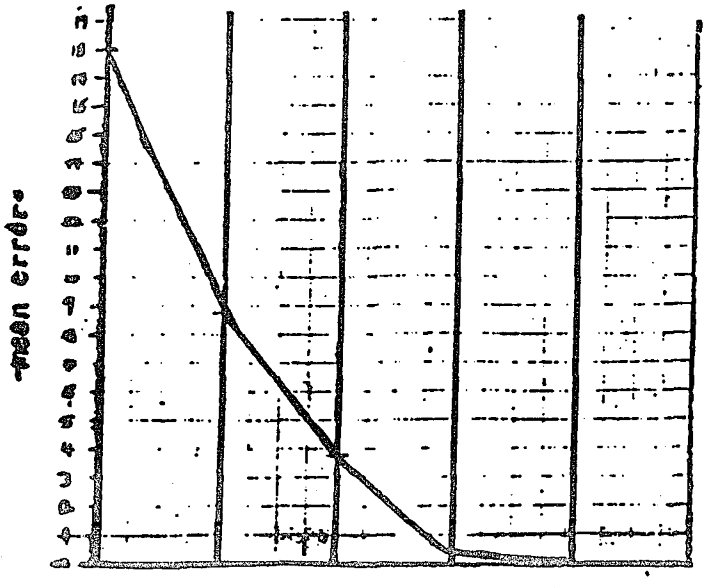


TABLE 7:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

CHICKENS: COMPLETE REVERSAL vs. S+ PARTIAL REVERSAL

	Complete Reversal			S+ Complete Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total	55.0	±15.2	14	24.8	±12.2	18
Error			43			19
Problem			65			19
II			71			43

ANOVA: F (1,6) = 9.6, p = .021, R^2 = .615*

	Complete Reversal			S+ Complete Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
2) Total	10.0	±1.2	8.2	6.1	±1.1	4.5
Mean			10.1			6.3
Error			10.8			6.3
per			10.8			7.1
Session						
Problem						
II						

ANOVA: F (1,6) = 22.7, p = .003, R^2 = .791*

	Complete Reversal			S+ Complete Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
3) Total	24.0	±14.4	4	5.0	±4.7	0
Initial			24			3
Error			31			6
Problem			37			11
II						

ANOVA: F (1,6) = 6.3, p = .045, R^2 = .512*

	Complete Reversal			S+ Complete Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
4) Percent	92.3	±8.4	.80	60.0	±14.7	.45
Error			.95			.55
Session			.95			160
One			.99			.80
Problem						
II						

ANOVA: F (1,6) = 14.5, p = .009, R^2 = .707*

TABLE 7: (continued)

	Complete Reversal			S+ Complete Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	14.8	±7.3	4 17 18 20	5.0	±4.7	0 7 6 11

ANOVA: F (1,6) = 5.1, $p = .065$, $R^2 = .459$**

---

* = Significant: $p < .05$.

** = Approached significance: p = .05-.10.

TABLE 8:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

CHICKENS: COMPLETE REVERSAL vs. S- PARTIAL REVERSAL

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	55.0	±15.2	41	30.8	±14.2	13
			43			28
			65			35
			71			47
ANOVA: F (1,6) = 5.4, p = .059, R^2 = .473**						
2) Total Mean Error per Session Problem II	10.0	±1.2	8.2	9.1	± 2.2	6.5
			10.1			8.8
			10.8			9.3
			10.8			11.8
ANOVA: F (1,6) = 6.8, p = .016, R^2 = .531*						
3) Total Initial Error Problem II	24.0	±14.4	4	17.3	±10.2	5
			24			17
			31			23
			37			26
ANOVA: F (1,6) = .587, p = .472, R^2 = .089						
4) Per-cent Error Session One Problem II	92.3	± 8.4	.80	89.5	±16.4	.65
			.95			.95
			.95			.99
			.99			.99
ANOVA: F (1,6) = 6.8, p = .015, R^2 = .531*						

TABLE 8: (continued)

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	14.8	±7.3	4 17 18 20	15.8	±5.1	10 13 20 20

ANOVA: F (1,6) = .05, $p = .826$, $R^2 = .008$

* = Significant: $p < .05$.

** = Approaches significance: $p = .05-.10$.

TABLE 9:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

CHICKENS: S+ PARTIAL REVERSAL vs. S- PARTIAL REVERSAL

	S+ Partial Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	24.2	±12.2	18	30.8	±14.2	13
			19			28
			19			35
			43			47
	ANOVA: F (1,6) = .410, p = .545, R^2 = .064					
2) Total Mean Error per Problem II	6.1	±1.1	4.5	9.1	± 2.2	6.5
			6.3			8.8
			6.3			9.3
			7.1			11.8
	ANOVA: F (1,6) = 6.3, p = .046, R^2 = .512*					
3) Total Initial Error Problem II	5.0	±4.7	0	17.3	±10.2	5
			3			17
			6			23
			11			26
	ANOVA: F (1,6) = 4.8, p = .072, R^2 = .444**					
4) Percent Error Session One Problem II	60.0	±14.7	.45	89.0	±16.4	.65
			.55			.95
			.60			.99
			.80			.99
	ANOVA: F (1,6) = 7.1, p = .037, R^2 = .542*					

TABLE 9: (continued

	S+ Partial Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	5.0	±4.7	0 3 6 11	15.8	±5.1	10 13 20 20

ANOVA: $F(1,6) = 9.7$, $p = .021$, $R^2 = .618$*

* = Significant: $p < .05$.

** = Approaches significance: $p = .05-.10$.

Examination of Table 7 reveals that for chickens, the means were greater in the Complete Reversal than in the S+ Partial Reversal groups over all five error variables. These differences were significant for the first four dependent variables listed and approached significance for the fifth. Between 45.9% and 79.1% of the variance was accounted for by these group differences. For chickens,then, the Complete Reversal was more difficult than the S+ Partial Reversal.

Examination of Table 8 reveals that the means for the Complete Reversal exceeded the means for the S- Partial Reversal with the exception of Initial Error Session One Problem II (which was a small insignificant difference). Two of these differences were significant and a third approached significance. In these three comparisons, the group differences accounted for between 47.3% and 53.1% of the variance. The Complete Reversal was also more difficult than the S- Partial Reversal for chickens.

Examination of Table 9 indicates that for chickens the S- Partial Reversal was more difficult than the S+ Partial Reversal. For each dependent variable, the mean was greater in the S- Partial Reversal group. These differences were statistically significant in three of the comparisons and approached significance in another accounting for between 44.4% and 61.8% of the variance. Only Total Error per Problem failed to approach significance.

In summary, then, for chickens, the order of relative difficulty of the reversal tasks from most to least was: Complete Reversal, S- Partial Reversal, S+ Partial Reversal. This is in contrast to Hypothesis #3 which would place the S+ Partial Reversal before the S- Partial Reversal.

B. Pigeons

Figure 6 shows that for pigeons the Complete Reversal is most difficult, followed by the S+ Partial Reversal and finally the S- Partial Reversal. Across groups it seems that there is a general decrease in initial level of errors and sessions to criterion. Data and data analyses support this observation (see Tables 10, 11, and 12).

-INSERT FIGURE 6 HERE-

-INSERT TABLE 10 HERE-

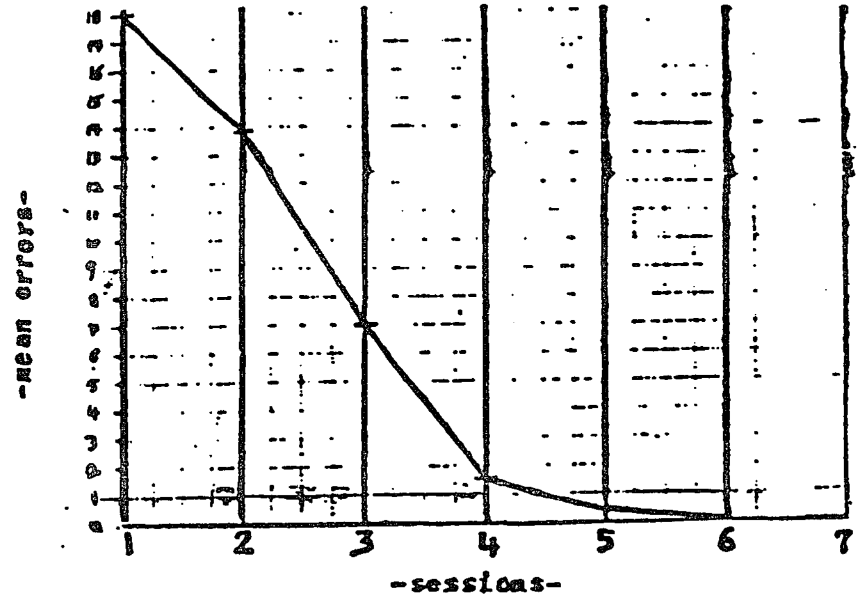
-INSERT TABLE 11 HERE-

-INSERT TABLE 12 HERE-

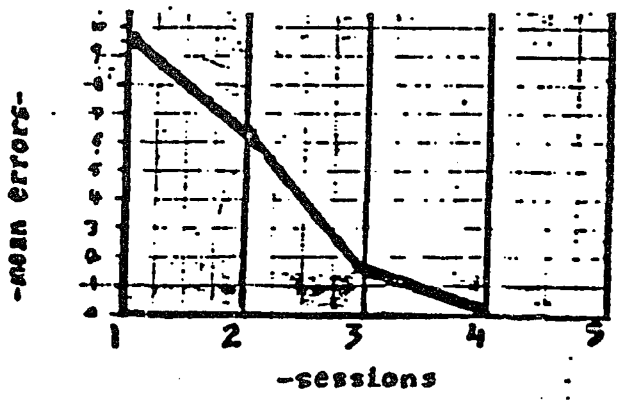
Examination of Table 10 reveals that means for pigeons in the Complete Reversal group exceed means for pigeons in the S+ Partial Reversal group over all five dependent variables. These differences are statistically significant for the first four of the dependent variables listed, and

FIGURE 6: MEAN ERROR PER SESSION PROBLEM II ACROSS EXPERIMENTAL GROUPS
PIGEONS

Complete Reversal:



S+ Partial Reversal:



S- Partial Reversal:

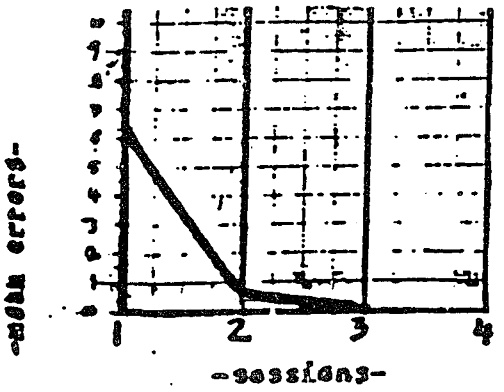


TABLE 10:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISON OVER FIVE DEPENDENT VARIABLES

PIGEONS: COMPLETE REVERSAL vs. S+ PARTIAL REVERSAL

	Complete Reversal			S+ Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	41.0	±8.2	33	17.3	±3.3	14
			37			16
			42			17
			52			22
	ANOVA: F (1,6) = 28.6, p = .002, R^2 = .781*					
2) Total Mean Error per Session Problem II	9.6	±1.0	8.3	4.7	±1.1	4.6
			9.3			5.3
			10.4			5.6
			10.5			7.3
	ANOVA: F (1,6) = 25.8, p = .002, R^2 = .811*					
3) Total Initial Error Problem II	13.5	±8.9	5	2.3	±1.0	1
			7			2
			19			3
			23			3
	ANOVA: F (1,6) = 6.4, p = .045, R^2 = .516*					
4) Percent Error Session One Problem II	90.0	±4.1	.85	47.5	±6.5	.40
			.90			.45
			.90			.50
			.95			.55
	ANOVA: F (1,6) = 23.8, p = .004, R^2 = .798*					

TABLE 10: (continued)

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	9.0	±8.2	0	1.5	±.60	1
			4			1
			16			2
			16			2

ANOVA: $F(1,6) = 3.3$, $p = .120$, $R^2 = .355$

* = Significant: $p < .05$.

TABLE 11:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

PIGEONS: COMPLETE REVERSAL vs. S- PARTIAL REVERSAL

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	41.0	±8.2	33	7.0	±2.9	4
			37			5
			42			9
			52			10

ANOVA: F (1,6) = 30.8, p = .001, R^2 = .837*

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
2) Total Mean Error per Session Problem II	9.6	±1.0	8.3	3.5	±1.5	2.0
			9.3			2.5
			10.4			4.5
			10.5			5.0

ANOVA: F (1,6) = 25.4, p = .002, R^2 = .809*

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
3) Total Initial Error Problem II	13.5	±8.9	5	1.3	±.5	1
			7			1
			19			1
			23			2

ANOVA: F (1,6) = 7.6, p = .033, R^2 = .559*

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
4) Percent Error Session One Problem II	90.0	±4.1	.85	31.3	±13.8	.15
			.90			.25
			.90			.40
			.95			.45

ANOVA: F (1,6) = 26.9, p = .002, R^2 = .817*

TABLE 11: (continued)

	Complete Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	9.0	±8.2	0 4 16 16	1.0	±0.0	1 1 1 1

ANOVA: F (1,6) = 3.8, $p = .10$, $R^2 = .388$**

---

* = Significant: $p < .05$.

** = Approaches significance: $p = .05-.10$.

TABLE 12:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

PIGEONS: S+ PARTIAL REVERSAL vs. S- PARTIAL REVERSAL

	S+ Partial Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	17.3	±3.4	14	7.0	±2.9	4
			16			5
			17			9
			22			10
ANOVA: F (1,6) = 20.8, p = .004, R^2 = .776*						
2) Total Mean Error per Session Problem II	5.7	±1.1	4.6	3.5	±1.5	2.0
			5.3			2.5
			5.6			4.5
			7.3			5.0
ANOVA: F (1,6) = 5.6, p = .056, R^2 = .482**						
3) Total Initial Error Problem II	2.3	±1.0	1	1.3	±.5	1
			2			1
			3			1
			3			2
ANOVA: F (1,6) = 3.4, p = .114, R^2 = .363						
4) Percent Error Session One Problem II	47.5	±6.5	.40	31.3	±13.8	.15
			.45			.25
			.50			.40
			.55			.45
ANOVA: F (1,6) = 4.5, p = .076, R^2 = .428*						

TABLE 12: (continued)

	S+ Partial Reversal			S- Partial Reversal		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	1.5	±.6	1 1 2 2	1.0	±0.0	1 1 1 1

ANOVA: F (1,6) = 3.0, $p = .134$, $R^2 = .333$

---

* = Significant: $p < .05$.

** = Approaches significance: $p = .05-.10$.

account for between 51.6% and 81.1% of the variance. The Complete Reversal is more difficult than the S+ Partial Reversal for pigeons.

Examination of Table 11 reveals that means for pigeons in the Complete Reversal group exceed means for pigeons in the S- Partial Reversal group. These differences are significant for the first four of the dependent variables listed, and account for between 55.9% and 83.7% of the variance. The fifth variable, Initial Error Session One Problem II, approaches significance, and accounts for 38.8% of the variance. For pigeons, then, the Complete Reversal is also more difficult than the S- Partial Reversal.

Examination of Table 12 reveals that means for pigeons in the S+ Partial Reversal group exceeded means for pigeons in the S- Partial Reversal group over all five dependent variables. This difference was significant for Total Error Problem II, and accounted for 77.6% of the variance. Total Mean Error per Session Problem II and Percent Error Session One Problem II approached significance, accounting for respectively, 48.2% and 42.8% of the variance. For pigeons, the S+ Partial Reversal was more difficult than the S- Partial Reversal.

In summary, then, for pigeons the order of relative difficulty from most to least was: Complete Reversal, S+ Partial

Reversal, S- Partial Reversal. This conforms to Hypothesis #3.

IV. The Question of Negative Transfer: Control Comparisons

In order to infer the presence of negative transfer in Problem II as a result of training with Problem I stimuli for the S+ and S- Partial conditions, for chickens and for pigeons, control groups were run. These control groups only received training on one Problem. The S+ Partial Controls received training on the Problem II contingency for the S+ Partial Reversal condition (S+ = horizontal line, S- = green), while the S- Partial Controls received training on the Problem II contingency for the S- Partial Reversal condition (S+ = red, S- = horizontal line). Planned comparisons were therefore: S+ Partial Reversal (Problem II data) vs. S+ Partial Control (Problem I data), and S- Partial Reversal (Problem II data) vs. S- Partial Control (Problem I data) for each species. In addition to the ordering of relative difficulty of experimental conditions, these results were relevant to Hypothesis #3 which stated that for both species, greater negative transfer was expected for the S+ Partial Reversal condition than for the S- Partial Reversal condition.

A. Chickens: S+ Partial Reversal vs. S+ Partial Control

The chickens in the S+ Partial Control group reached criterion in the first session, finding the discrimination

S+ = horizontal line, S- = green quite easy. Consequently, graphical depiction of error reduction for this group was not possible. Examination of Table 13, however, indicates that the means for chickens in the S+ Partial Reversal exceed the means for the chickens in the S+ Partial Control over all five dependent variables. These differences are significant for three of the comparisons, accounting for between 71.1% and 84.7% of the variance. The values for Total Initial Error Problem II and Initial Error Session One Problem II are identical as in both groups all initial errors occurred in the first session. For these two error variables, differences approached significance and accounted for 42.8% of the variance.

-INSERT TABLE 13 HERE-

It can be concluded, therefore, that the prereversal S+ is a source of negative transfer for the chickens.

B. Chickens: S- Partial Reversal vs. S- Partial Control

Figure 7 shows greater difficulty for the chickens in the S- Partial Reversal than those in the S- Partial Control group. In general, experimental animals started at a higher level of errors, and made more errors than control animals. The data and statistical analyses supported this observation. (see Table 14).

-INSERT FIGURE 7 HERE-

TABLE 13:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

CHICKENS: S+ PARTIAL REVERSAL vs. S+ PARTIAL CONTROL

	S+ Partial Reversal			S+ Partial Control		
	Mean	S.D.	Raw Data		S.D.	Raw Data
1. Total Error Problem II	24.8	±12.2	18	1.3	±1.0	0
			19			1
			19			2
			43			2
	ANOVA:	F (1,6) = 14.8, p = .008, R^2 = .711*				
2) Total Mean Error per Session Problem II	6.1	±1.0	4.5	1.3	±1.0	0
			6.3			1
			6.3			2
			7.1			2
	ANOVA:	F (1,6) = 33.3, p = .001, R^2 = .847*				
3) Total Initial Error Problem II	5.0	±4.7	0	0.0	±0.0	0
			3			0
			6			0
			11			0
	ANOVA:	F (1,6) = 4.5, p = .077, R^2 = .428**				
4) Percent Error Session One Problem II	60.0	±14.7	.45	6.3	±4.8	.0
			.55			.5
			.60			.10
			.80			.10
	ANOVA:	F (1,6) = 28.2, p = .002, R^2 = .824*				

TABLE 13: (continued)

	S+ Partial Reversal			S+ Partial Control		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial	5.0	±4.7	0	0.0	±0.0	0
Error			3			0
Session			6			0
One			11			0
Problem						
II						

ANOVA: F (1,6) = 4.5, $p = .077$, $R^2 = .428$**

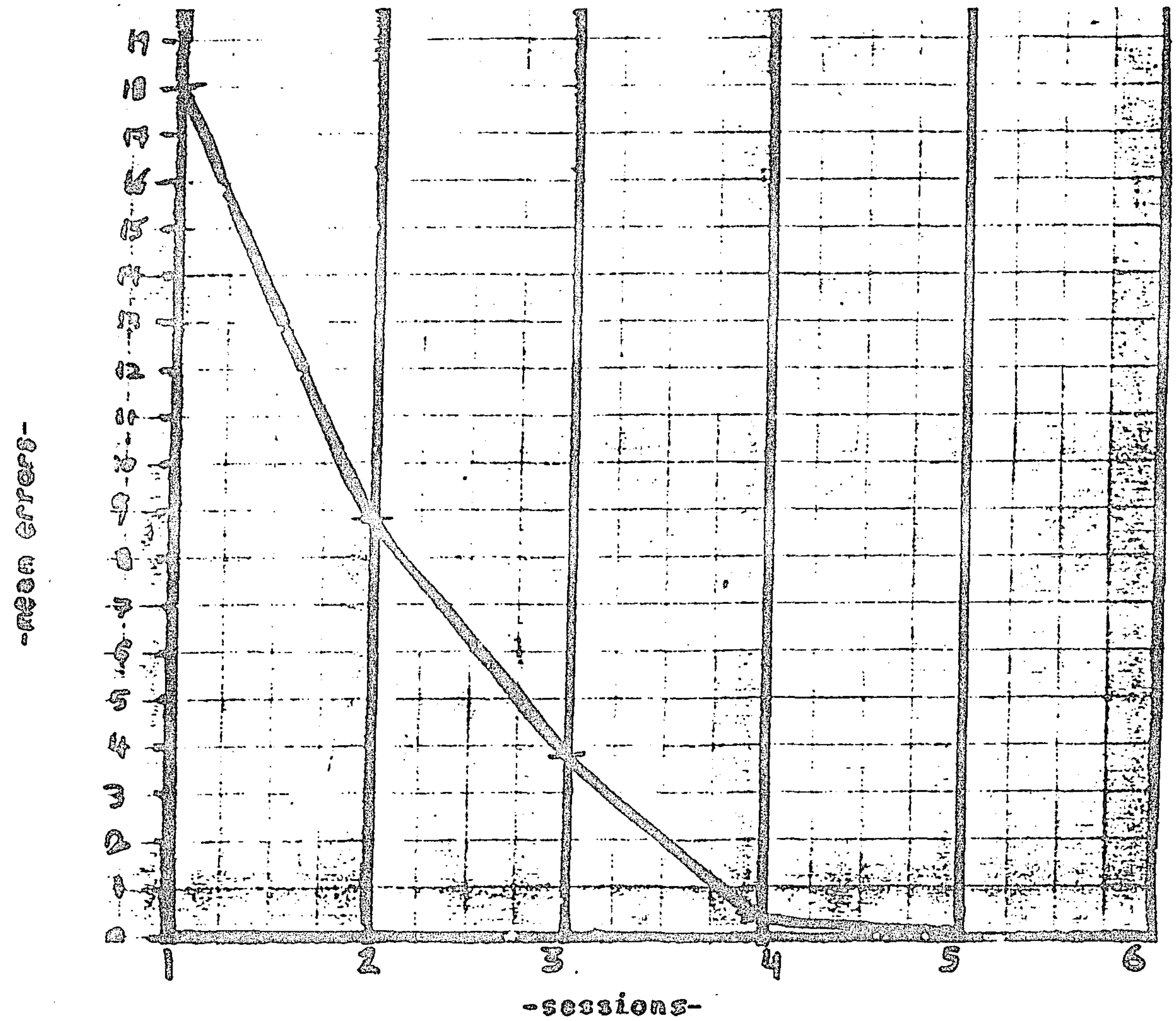
---

* = Significant: $p < .05$.

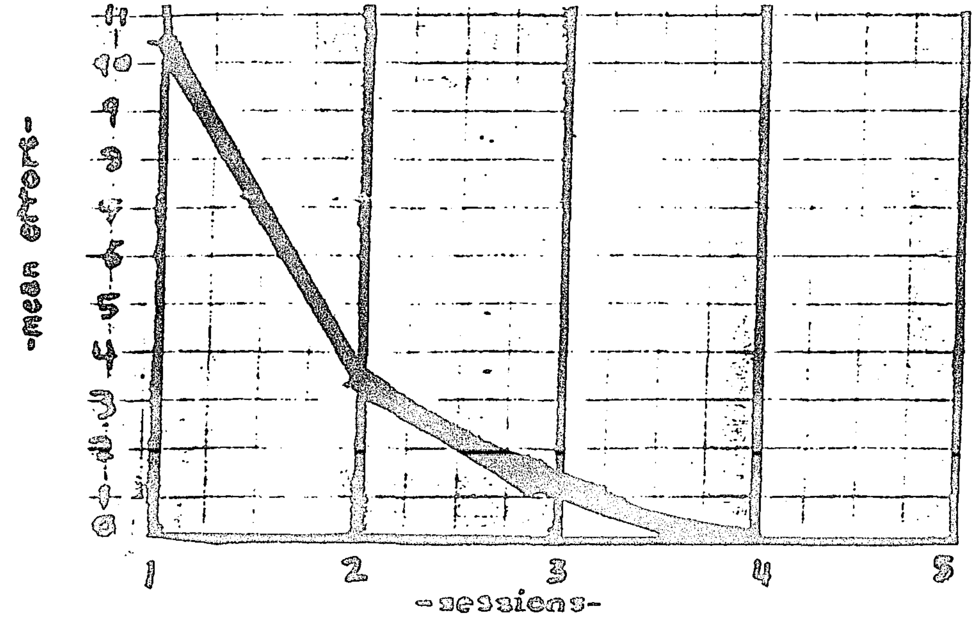
** = Approaches significance: $p = .05-.10$.

FIGURE 7:
MEAN ERROR PER SESSION PROBLEM II
CHICKENS: S- PARTIAL REVERSAL VS. S- PARTIAL CONTROL

S- Partial Reversal



S- Partial Control



-INSERT TABLE 14 HERE-

Examination of Table 14 indicates that the means for chickens in the S- Partial Reversal group exceeded the means for the chickens in the S- Partial Control group over all error variables. These differences were significant for the last four of the five dependent variables listed, and accounted for between 60.8% and 85.7% of the variance. The ANOVA for the first variable, Total Error Problem II, approached significance, and accounted for 42.8% of the variance. Apparently, the prereversal S- is also a source of negative transfer for the chickens.

C. Pigeons: S+ Partial Reversal vs. S+ Partial Control

Figure 8 shows that for pigeons, the S+ Partial Reversal may be more difficult than the S+ Partial Control as it generally takes longer for the experimental subjects to reach criterion, and more errors are apparent for the experimental group in the second and third sessions.

-INSERT FIGURE 8 HERE-

-INSERT TABLE 15 HERE-

Examination of Table 15 indicates that the means for the first three variables listed are greater for the experimental group. The means for the last two variables listed

TABLE 14:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

CHICKENS: S- PARTIAL REVERSAL vs. S- PARTIAL CONTROL

	S- Partial Reversal			S- Partial Control		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	30.8	±14.2	13	14.8	±5.1	9
			28			13
			35			16
			47			21
ANOVA:	F (1,6) = 4.5, p = .077, R^2 = .428**					
2) Total Mean Error per Session Problem II	9.1	±2.2	6.5	4.9	±1.7	3.0
			8.8			4.3
			9.3			5.3
			11.8			7.0
ANOVA:	F (1,6) = 9.3, p = .022, R^2 = .608*					
3) Total Initial Error Problem II	17.3	±10.2	5	.50	±.60	0
			17			0
			23			1
			26			1
ANOVA:	F (1,6) = 10.7, p = .017, R^2 = .641*					
4) Percent Error Session One Problem II	89,.5	±16.4	.65	51.3	±16.5	.35
			.95			.40
			.99			.60
			.99			.70
ANOVA:	F (1,6) = 10.8, p = .017, R^2 = .643*					

TABLE 14: (continued)

	S- Partial Reversal			S- Partial Control		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	15.8	±5.1	10 13 20 20	.50	±.60	0 0 1 1

ANOVA: F (1,6) = 35.9, $p = .001$, $R^2 = .857$*

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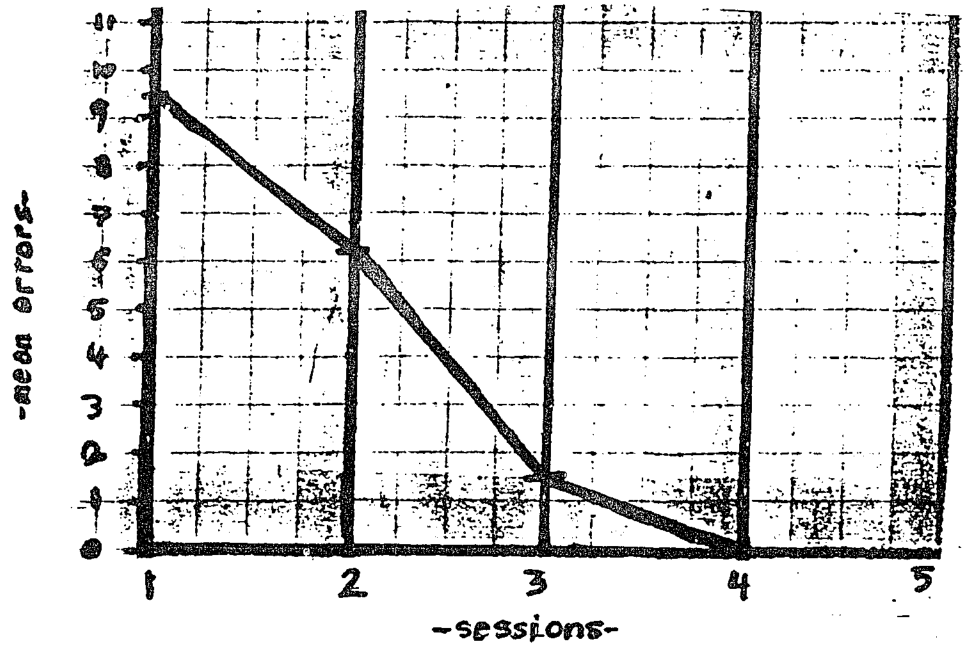
* = Significant: $p < .05$.

** = Approaches significance: $p = .05-.10$.

FIGURE 8:
MEAN ERROR PER SESSION PROBLEM II
PIGEONS: S+ PARTIAL REVERSAL VS. S+ PARTIAL CONTROL

S+ Partial Reversal



S+ Partial Control

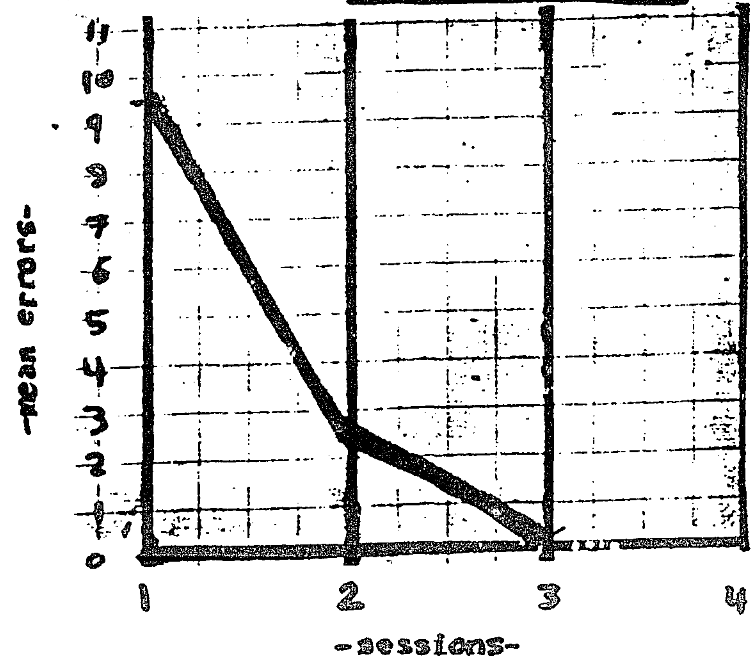


TABLE 15:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

PIGEONS: S+ PARTIAL REVERSAL vs. S+ PARTIAL CONTROL

	S+ Partial Reversal			S+ Partial Control		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	17.3	±3.4	14	12.0	±5.5	5
			16			11
			17			14
			22			18
	ANOVA: F (1,6) = 2.7, p = .155, R^2 = .310					
2) Total Mean Error per Session Problem II	5.7	±1.1	4.6	4.7	±1.4	2.5
			5.3			4.6
			5.6			5.5
			7.3			6.0
	ANOVA: F (1,6) = 1.2, p = .317, R^2 = .166					
3) Total Initial Error Problem II	2.3	±1.0	1	2.0	±2.2	0
			2			1
			3			2
			3			5
	ANOVA: F (1,6) = .044, p = .839, R^2 = .007					
4) Percent Error Session One Problem II	47.5	±6.5	.40	47.5	±18.5	.25
			.45			.45
			.50			.50
			.55			.70
	ANOVA: F (1,6) = 0.0, p = .99					

TABLE 15: (continued)

	S+ Partial Reversal			S+ Partial Control		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	1.5	±.6	1 1 2 2	2.0	±2.2	0 1 2 5

ANOVA: F (1,6) = .2, p = .670, R^2 = .032

hardly differ. None of these differences, however, are statistically significant, and little variance is accounted for. While a trend exists that suggest that the experimental condition was somewhat more difficult than the control condition, the failure to obtain significant results does not permit the conclusion that the prereversal S+ was a source of negative transfer for the pigeons.

D. Pigeons: S- Partial Reversal vs. S- Partial Control

Inspection of Figure 9 reveals that for pigeons, the S- Partial Reversal may have been easier than the S- Partial Control. The control group seems to have made more errors in session two and to generally take longer to reach criterion. Examination of the data, however, indicates very small differences between means (see Table 16).

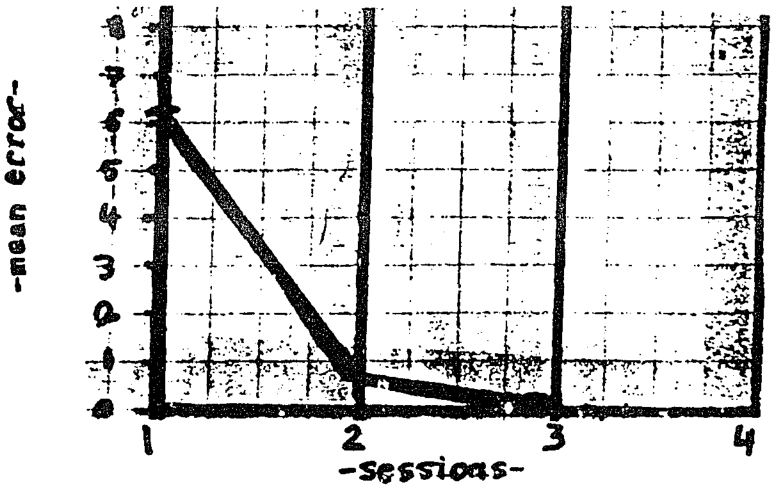
-INSERT FIGURE 9 HERE-

-INSERT TABLE 16 HERE-

Table 16 shows that for the first two error variables listed, the means for the control group slightly exceed the means for the experimental group. The reverse occurs for the last three variables listed. None of these differences approach statistical significance, and very little variance is explained. It cannot be concluded therefore that the prereversal S- is a source of negative transfer for the pigeons.

FIGURE 9:
MEAN ERROR PER SESSION PROBLEM II
PIGEONS: S- PARTIAL REVERSAL VS. S- PARTIAL CONTROL

S- Partial Reversal



S- Partial Control

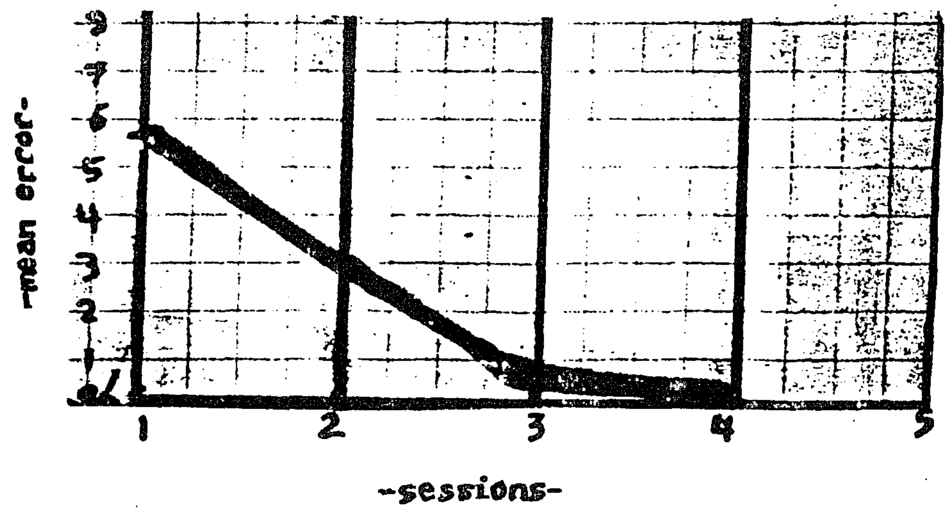


TABLE 16:

STATISTICAL RESULTS OF WITHIN SPECIES COMPARISONS OVER FIVE DEPENDENT VARIABLES

PIGEONS: S- PARTIAL REVERSAL vs. S- PARTIAL CONTROL

	S- Partial Reversal			S- Partial Control		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
1) Total Error Problem II	7.0	±3.0	4	9.3	±3.8	6
			5			6
			9			12
			10			13
	ANOVA: F (1,6) = .883, p = .383, R^2 = .128					
2) Total Mean Error per Session Problem II	3.5	±1.5	2.0	3.7	±.6	3.0
			2.5			3.3
			4.5			4.0
			5.0			4.3
	ANOVA: F (1,6) = .035, p = .857, R^2 = .006					
3) Total Initial Error Problem II	1.3	±.5	1	.8	±.10	0
			1			0
			1			1
			2			2
	ANOVA: F (1,6) = .857, p = .390, R^2 = .25					
4) Per-cent Error Session One Problem II	31.3	±13.8	.15	28.8	±10.3	.20
			.25			.20
			.40			.35
			.45			.40
	ANOVA: F (1,6) = .084, p = .781, R^2 = .014					

TABLE 16: (continued)

	S- Partial Reversal			S- Partial Control		
	Mean	S.D.	Raw Data	Mean	S.D.	Raw Data
5) Initial Error Session One Problem II	1.0	±0.0	1 1 1 1	0.8	±1.0	0 0 1 2

ANOVA: F (1,6) = .272, p = .620, R^2 = .043

Hypothesis #3 predicted that for both species, there would be greater negative transfer in the S+ Partial Reversal condition than in the S- Partial Reversal condition. For chickens, both the prereversal S+ and S- were found to be sources of negative transfer, but the S- Partial Reversal was more difficult than the S+ Partial Reversal. For the pigeons, while the within species ordering of relative difficulty of reversal conditions conformed to expectation, neither the prereversal S+ or S- could be adequately demonstrated to be a source of negative transfer. Hypothesis #3 could therefore not be supported.

DISCUSSION

The major purpose of the present investigation was to attempt to gather evidence to begin to answer the question of whether previously established differences between chickens and pigeons in SDR performance could be accounted for by variation in the ease with which previously conditioned control by the S+ or S- can be eliminated. Implicit in this question is a test for the validity of the differential extinction hypothesis (Gossette, 1970) which posits that differences in abilty level (either within species as with mental age, or between species according to traditional phylogenetic assumptions) can be explained in terms of resistance to extinction to the prereversal S+, with organisms of lower ability levels generally demonstrating stronger resistance to extinction than organisms of higher ability levels.

I. Differences Between Chickens and Pigeons: Problem I

The difference between chickens and pigeons in Problem I performance found in the present study with chickens finding Problem I significantly more difficult was not expected based on previous research by Gossette (1967, 1968), and Levine (1972). Gossette (1968) reporting data on the successive spatial discrimination reversal performances of 7 species of mammals and 10 species of birds noted: "Interestingly, despite the greater interspecies differences in total error scores, there are relatively small differences in error scores on both final and original problems (pp. 1148-1149)." Specifically, the data presented indicated that White Leghorn chickens made 18.4 mean errors on Problem I while pigeons made 14.8 means errors on Problem I.

Levine (1972) as the present study employed simultaneous red/green discriminations. Levine (1972) did not address the question of Problem I differences directly, but on page 35, he presented Figure 1: "Mean Errors Across All Levels of D and K for Pigeons and Chickens, Over Blocks of 3 Problems." In this figure, it can be seen that chickens and pigeons performed the original discrimination at an almost identical level of mean error approximating a value of 24.

The Problem I difference found in the present study may be attributed to a problem with the methodology. When the first eight chickens were run (the Complete and S+ Partial Reversal groups), counterbalancing for color was initially attempted. Two chickens in each group therefore received red as the S+ while green was the S+ for the other chickens. The chickens who received red as the S+ unexpectedly demonstrated a preference for that stimulus represented by 95% correct responding in session one of Problem I, therefore immediately reaching criterion.

At that point, counterbalancing was abandoned, and it was decided that for all subjects, the S+ would be green and the S- red. Unfortunately, this meant that 2 chickens in the Complete Reversal group, and 2 chickens in the S+ Partial Reversal group received one extra reversal problem as their stimulus contingencies were reversed on the second day of training. This unanticipated methodological difficulty may therefore have contaminated their subsequent reversal performance. The preference for red may have increased the number of Problem I errors for these chickens and interfered with performance of Problem II.

II. Differences Between Chickens and Pigeons: Problem II

Hypothesis #1 stated that pigeons should show fewer errors than chickens on the Complete Reversal task. While all means were in the expected direction, and the depiction of error reduction in Figure 2 conformed to expectation, none of the dependent measures of error were able to significantly differentiate species on the Complete Reversal task. Hypothesis #1 could therefore not be fully supported.

The most relevant previous research on which this hypothesis was based was carried out by Levine (1972) who used 32 chickens and 32 pigeons at 4 levels of deprivation and 2 levels of incentive. In his analysis, a significant difference between chickens and pigeons was reported for performance on the Complete Reversal, with pigeons making fewer errors and taking less sessions to reach criterion than chickens. Birnbaum (1974) replicated these results, however, his results are less relevant to the present study because successive presentation of stimuli was used. Also, in earlier studies by Gossette (1967, 1968), pigeons outperformed chickens on spatial discriminations.

Three essential differences exist between the present study and Levine (1972) which may account for the failure to fully support Hypothesis #1. The most obvious difference is in the number of subjects per group. Levine's study contained 32 subjects per group for the species comparison whereas in the present study only 4 subjects were in each group. Importantly, even with this low N the means in the present study were in the expected direction. Secondly, Levine's birds experienced 19 successive reversals of the red/green discrimination, whereas in the present study only one reversal occurred. The differences found in Levine's study were therefore based on many more observations and opportunities for error (especially for the Total Error variable) than in the present study. Thirdly, and most importantly, in the present study, Problem I was found to be significantly easier for the pigeons. No such difference was reported by Levine, but as previously noted, the difference in Problem I found in the present study may have been the result of extra pre-reversal experience for four of the chickens. This added experience which was manifest as a preference for red may also have served to lessen Problem II species differences under this condition.

Since the usefulness of inferential statistics in evaluating differences between small numbers of subjects can be questioned, it is important to note that differences between means for all error variables of the Complete Reversal comparison conformed to expectation. Also Figure 2 reveals that pigeons performance was superior to that of the chickens for this task. Some support for Hypothesis #1 was therefore obtained.

Hypothesis #2 stated that pigeons should make fewer errors on the S+ Partial Reversal task than chickens. In the present study, the depiction of error reduction in Figure 3 conformed to expectation. Also, differences between means were all in the expected direction, and in one instance this difference closely approached significance, thus providing partial support for the hypothesis. This hypothesis was based on Newman's (1976), and Berger's (1975) studies which analyzed respectively, the complete and partial reversal performance of mentally retarded children at two levels of mental age (MA) and intellectually average children at two levels of MA. Both studies used simultaneous presentation of stimuli. In both studies, the results indicated that performance on the Complete and S+ Partial Reversals were directly related to MA but that the S- Partial condition failed to differentiate between MA levels. This implied that the prereversal S+ was a more potent source of negative transfer than the prereversal S-, and lent support to Gossette's differential extinction hypothesis.

In the present study, the S+ Partial Reversal almost successfully differentiated ability level if the assumption that pigeons are phyletically superior to chickens is accepted. While only one comparison approached statistical significance (Mean Error per Session Problem II), all differences between means for chickens and pigeons conformed to expectation as did the depiction of error reduction in Figure 3 with pigeons outperforming chickens, suggesting greater difficulty for the chickens on this task. Since increased difficulty in solving the S+ Partial Reversal should imply greater resistance to extinction to the prereversal S+ in Problem II, positive results would lend support to the differential extinction hypothesis. Future research may therefore extend the applicability of the differential extinction hypothesis from within species comparisons of SDR performance involving humans at different mental age levels to between species comparisons involving chickens and pigeons.

The between species comparison of the S- Partial Reversal groups revealed higher means on all error variables for chickens with significant results for three of the five variables and were not expected based on previous research. As already noted, both in Berger (1975) and Newman (1976), the S- Partial Reversal failed to differentiate ability level in humans. In the present study, however, the S- Partial Reversal was significantly more difficult for the chickens than the pigeons. At first glance, it might be concluded that this observed difference implies that the prereversal S- is an important source of negative transfer (at least for the chickens), and also serves to differentiate between species ability levels. While this possibility cannot be completely ruled out, a closer examination of the within species results for chickens serves to contradict this conclusion. There is a possibility that stimulus preferences could have been influencing the performance of the chickens in the S- Partial Reversal group in a manner that would have made the task to appear more difficult as will be discussed below.

III. Within Species Comparisons: The Question of Negative Transfer

A. Chickens

For chickens, the Complete Reversal was generally more difficult than both Partial Reversal conditions, and the S- Partial Reversal was generally more difficult than the S+ Partial Reversal. This was in contrast with Hypothesis #3 which predicted greater negative transfer for both species on the S+ than on the S- Partial Reversal. The chickens in both Partial Reversal conditions made significantly more errors than their corresponding controls as predicted, indicating the possibility of substantial negative transfer. Contrary to prediction and previous work by Berger (1975),and Newman (1976) with humans,and Reich (1976) with goldfish, the negative transfer was greater in the S- condition than in the S+ condition.

One possible source of this discrepancy may have been unanticipated and thus uncontrolled stimulus preferences arising from the problem constructed for the S- Partial Reversal comparison. A comparison of the control groups suggested a strong preference for responding to the horizontal line. This conclusion is based upon comparison of errors made by the S+ and S- control groups. That is, greater errors were made when the horizontal line was the S- than when it was the S+. If in fact such a preference existed it would have enhanced the negative transfer in the S- Partial Reversal condition. On the other hand, the same preference would have reduced the negative transfer in the S+ Partial condition. Therefore the finding of significant differences for the chickens with more errors in the experimental than control group for the S+ comparison indicates that the prereversal S+ is most certainly a source of negative transfer, while the role of the prereversal S- remains obscured.

B. Pigeons

As predicted from previous studies, the ordering of relative difficulty of the reversal conditions for the pigeons was as follows. The Complete Reversal was generally more difficult than both Partial Reversal conditions, with the S+ Partial Reversal exceeding the S- Partial Reversal in difficulty. While these results seemed to lend some support to Hypothesis #3, closer examination of the control comparisons was necessary before reaching this conclusion .

If negative transfer is to be detected, the solution of a discrimination should be more difficult after Problem I training than in its' absence. The comparison of the S+ Partial Reversal with the S+ Partial Control revealed that differences between means suggested more difficulty in the experimental condition, but this was not supported statistically. Thus, there was only a suggestion that the prereversal S+ was a source of negative transfer for pigeons.

Results obtained by Williams (1974), however, indicated that for pigeons, extinction to the prereversal S+ may be an important determinant of reversal performance and conformed to the differential extinction hypothesis. Williams found that the performance of pigeons on simultaneous color reversals (blue/green) was facilitated by randomly interspersed extinction to the previous S+,and uneffected by exposure to randomly interspersed reward to the previous S- in a series of reversals. The failure to find such an effect in the present study may have been a result of the low number of subjects as a trend was suggested by the comparison of the pigeon S+ Partial Reversal and S+ Partial Control groups. This contention was supported by post hoc power analyses (Cohen, 1977). For this comparison, analyses revealed only a moderate power value of.48 for Total Error, .26 for Total Mean Error per Session, and less than .10 for the remaining three dependent measures of error. This meant that at best, there was a 48% chance of finding a difference that approached significance with the stated alpha level and observed effect size.

The performances of the pigeons in the S- Partial Reversal and S- Partial Control groups were very similar as there were small insignificant differences between means and plots of error reduction revealed similar functions. This meant that these pigeons found the discrimination S+ = red, S- = horizontal line no more difficult after learning the original discrimination S+ = green , S- = red. This implied that very little negative transfer developed as a result of experience with the prereversal S- for pigeons.

In summary,Hypothesis #3 could not be supported as the data indicated that for the chickens, greater negative transfer may have occurred in the S- Partial Reversal than the S+ Partial Reversal, and the existence of negative transfer could not be adequately demonstrated for the pigeons.

A possible explanation for the difference in negative transfer effects found between chickens and pigeons involves amount of exposure to stimuli in Problem I. Recalling the data for Problem I, chickens made significantly more errors than pigeons: means = 31.1 vs. 16.3, F (1,22) = 16.4, p = .001. Chickens therefore had more prereversal experience with both the S+ and the S- than pigeons including the four chickens who initially received red as the S+. Consequently, it is possible that the chickens were relatively more conditioned to each respective stimulus in Problem I; the S+ excitatively through reinforcement (CRF) and the S- inhibitively through nonreinforcement (extinction). Their performance in Problem II, therefore may have been more likely to have been influenced by both prereversal stimuli which would be demonstrated by greater negative transfer effects than for the pigeons from both prereversal stimuli.

IV. Conclusions

In summary, the following conclusions can be drawn:

1) In the present study, Hypothesis #1 which predicted more errors by chickens on the Complete Reversal task could not be fully supported. While plots of error reduction showed superior pigeon performance, and differences between all measures of error were in the expected direction, none of these differences approached statistical significance. This species comparison could have been obscured by differences in Problem I performance which may have arisen from a methodological difficulty with four of the chickens.

2) While comparison of chickens and pigeons performance on the S+ Partial Reversal suggested greater difficulty for chickens, this performance difference could not be supported or disconfirmed statistically. This suggested that future research may be able to extend the applicability of Gossette's differential extinction hypothesis from within species between level SDR differences involving humans at different mental ages to between species comparisons involving

chickens and pigeons.

3) While the S- Partial Reversal was significantly more difficult for the chickens, this difference was suspected to have been caused by a stimulus preference for the chickens which would have exaggerated the difficulty of this discrimination for the chickens.

4) In support of the differential extinction hypothesis, for chickens the prereversal S+ was shown to be a potent source of negative transfer.

5) For chickens, the role of the prereversal S- was obscured due to the possibility of a stimulus preference effect. Whether the prereversal S- was truly a source of negative transfer could therefore not be concluded.

6) For pigeons, the ordering of the relative difficulty of the reversal conditions conformed to previous results, however, neither the prereversal S+ or S- could be adequately demonstrated to be a source of negative transfer.

7) Hypothesis #3 which predicted greater negative transfer for both species on the S+ Partial Reversal than on the S- Partial Reversal could not be supported as transfer effects were obscured for chickens and minimal for the pigeons.

While the results of the present study lent some support to the differential extinction hypothesis in addition to the previously discussed convergent evidence involving DRL, SAE, partial reversals, extradimensional shifts, and the extinction of a simple operant, the possibility raised by the Bitterman (1976, 1979) group that the prereversal S- also exerts significant control over reversal performance could not be discounted, especially in light of the ambiguous results for the chicken S- Partial Reversal group.

It is suggested that future research continue to explore this possibility. Future studies may attempt nondifferential pretraining to all experimental stimuli in order to avoid stimulus preference effects, while presenting the risk of contaminating reversal performance. This procedure was used successfully by Berger (1975), Newman (1976), and Reich (1976).

More importantly, a larger number of subjects per group is recommended for future studies. In addition, a battery of tasks that measure inhibitory capacities may be given. For example, the subject could be switched to a DRL task after experiencing a complete or partial reversal, and then exposed to simple extinction. In this manner, individual as well as group differences in inhibitory capacity as a result of reinforcement and nonreinforcement could be observed and tested with respect to the differential extinction hypothesis to help further understand the role of response inhibition in explaining differences in ability level.

REFERENCES

Ansheutz, R.A. (1973). Variations in performance on serial discrimination reversal (SDR) as a function of the level of mental retardation. Unpublished doctoral dissertation, Hofstra University, New York.

Behrend, E.R., and Bitterman, M.E. (1961). Probability matching in the fish. American Journal of Psychology, 74, 542-511.

Berger, G.H. (1975). Discrimination reversal learning as a function of mental age and type of reversal shift among children of intermediate intellectual ability. Unpublished doctoral dissertation, Hofstra University, New York.

Birnbaum, S. (1974). Inter-species serial discrimination reversal performances as a function of motivational and incentive level under conditions of successive stimulus presentation. Unpublished doctoral dissertation, Hofstra University, New York.

Bitterman, M.E. (1960). Toward a comparative psychology of learning. American Psychologist, 15, 704-712.

Bitterman, M.E. (1965). The evolution of intelligence. Scientific American, 23, 169-170.

Bitterman, M.E. (1965). Phyletic differences in learning. American Psychologist, 20, 396-410.

Bitterman, M.E. (1968). A reply to Weiner and Huppert. Science, 160, 100.

Bitterman, M.E. (1972). Comparative studies of the role of inhibition in reversal learning. In R.A. Boakes and M.S. Halliday (Eds.). Inhibition and Learning. New York: Academic Press.

Bitterman, M.E. (1975). The comparative analysis of learning. Science, 188, 699-709.

Bitterman, M.E. (1976). Issues in the comparative psychology of learning. In R.B. Masterson, W. Hodos, and H.Jerison (Eds.). Evolution of Brain and Behavior: Persistent Problems. New Jersey: Lawrence Erlbaum Associates.

Bitterman, M.E. (1979). Discrimination. In M.E. Bitterman, Lolordo, Overmeier, and Rashotte (Eds.). Animal Learning: Survey and Analysis, New York: Plenum Press.

Bitterman, M.E. (1980). Brain development and learning. In M. Spatz, B.B. Mrusulija, L.M. Rakie, & W.D. Lust (Eds.). Circulatory and Developmental Aspects of Brain Metabolism, New York: Plenum Press.

Bitterman, M.E., Woodinsky, J., & Candland, D.K. (1958). Some comparative psychology. American Journal of Psychology, 71, 94-110.

Brookshire, K.H. (1976). Vertebrate learning: Evolutionary divergences. In R.B. Masterson, W. Hodos, H. Jerison, (Eds.). Evolution of Brain and Behavior. New Jersey: Lawrence Erlbaum Associates.

Buchman, O.L., & Rhodes, J. (1979). Instrumental discrimination: Reversal Learning in the monotreme-Tachyglossus aculeatus setosus. Animal Behavior, 27, 1048-1053.

Bullock, D.H. & Bitterman, M.E. (1962). Habit reversal in the pigeon. Journal of Comparative and Physiological Psychology, 75, 634-639.

Clark, F.C. (1961). Avoidance conditioning the chimpanzee. Journal of the Expermental Analysis of Behavior, 4, 393.

Cohen, J. (1977). Statistical Power Analysis for the Behavioral Sciences. New York: Academic Press.

Davenport, J.W. (1969). Successive acquisition and extinction of discrete bar-pressing in monkeys and rats. Psychonomic Science, 16, 242-244.

Davis, R.R., & Markowitz, H. (1978). Orangutan performance on a light-dark reversal discrimination in the zoo. Primates, 19, 755-759.

Demarest,J. (1983). The ideas of change progress and continuity in the comparative psychology of learning. In D.W. Rajecki (Ed.). Comparing Behavior: Studying Man Studying Animals, New Jersey: Lawrence Erlbaum Publishers.

Denny,M.R. & Ratner, S.C. (1970). Comparative Psychology: Research in Animal Behavior, IL.: Dorsey.

Doty, B.A., Jones, C.N.,&Doty, L.A. (1967). Learning set formation by monkeys, ferrets, skunks, and cats. Science, 155, 1579-1580.

Ellins, S.R., Cramer, R.E., & Martin, G.C. (1982). Discrimination reversal learning in newts. Animal Learning and Behavior, 10, 301-304.

Ferster, C.B. & Skinner, B.F. (1957). Schedules of Reinforcement, New York: Appelton-Century Crofts.

Gellerman, L.W. (1933). Chance orders of alternating stimuli in visual discrimination experiments. Journal of Genetic Psychology, 42, 206-208.

Gonzales, R.V., Behrend, E.R., & Bitterman, M.E. (1967). Reversal Learning and forgetting in birds and fish. Science, 158, 519-521.

Gossette, R.L. (1966). Comparison of successive discrimination reversal performance across 14 different avian and mammalian species. Paper presented at the 133rd Annual Meeting of the American Association for the Advancement of Science, Washington, D.C.

Gossette, R.L. (1967). Successive discrimination reversal (SDR) performance of four avian species on a brightness discrimination task. Psychonomic Science, 8, 17-18.

Gossette, R.L. (1968). Examination of retention decrement explanation of comparative successive discrimination reversal learning by birds and mammals. Perceptual and Motor Skills, 27, 1147-1152.

Gossette, R.L. (1969). Variation in magnitude of negative transfer on successive discrimination reversal (SDR) tasks across species. Perceptual and Motor Skills, 29, 803-811.

Gossette, R.L. (1970). Note on the calibration of interspecies SDR performance differences: qualitative vs. quantitative variation. Perceptual and Motor Skills, 31, 95-104.

Gossette, R.L. (1970). Comparisons of SDR performances of Gibbons and three species of New World Monkeys on a spatial task. Psychonomic Science, 19, 301-303.

Gossette, R.L. (1972). Comparative avian and mammal DRL performance. Unpublished research proposal, New York: Hofstra University.

Gossette, R.L. (1972). Comparison of pigeons and chickens on successive acquisition and extinction. Talk given at 7th Annual Conference of the Australian Psychological Society, Canberra, Australia.

Gossette, R.L. (1974). Note on methodology in comparative behavioral analysis: systematic variation vs. control by equation. Perceptual and Motor Skills, 39, 155-162.

Gossette, R.L., Birnbaum, S. & Ramsey, P. (1970). The role of motivational and incentive levels in the determination of successive discrimination reversal (SDR) performance of chukar partridge. Psychonomic Science, 20, 291-292.

Gossette, R.L., Gossette, M.F., & Riddell, W. (1966). Comparisons of successive discrimination reversal performances among closely and remotely related species. Animal Behavior, 14, 560-564.

Gossette, R.L. & Hombach, A. (1969). Successive discrimination reversal (SDR) performance of the American crocodile and American alligator on a spatial task. Perceptual and Motor Skills, 28, 63-68.

Gossette, R.L., & Inman, N. (1966). Comparison of spatial successive discrimination reversal performance of two groups of New World monkeys. Perceptual and Motor Skills, 23, 169-170.

Gossette, R.L., & Slonim, P. (1969). Spatial SDR performance across three species of New World Monkeys. Psychonomic Science, 14, 222-223.

Guirintano, L.P., Schadler, M., & Thomas, D.R. (1972). Angularity preference and stimulus orthogonality in pigeons. Psychonomic Science, 26, 273-275.

Harlow,H.F. (1949). The formation of learning sets. Psychological Review, 43, 231-239.

Harlow, H.F. (1950). Performance of monkeys on a series of SDR problems. Journal of Comparative and Physiological Psychology, 43, 231-239.

Hilgard, E.R. & Marquis, D.G. (1936). Conditioned eyelid responses in monkeys, with a comparison of dog, monkey, and man. Psychological Monographs, 47, (2), 186-198.

Jensen, C. & Fuller, J.C. (1978). Learning performance varies with brain weight in heterogeneous mouse lines. Journal of Comparative and Physiological Psychlogy, 29, 830-836.

Jerison, H.J. (1973). Evolution of the Brain and Intelligence, New York: Academic Press.

Karn, H.W. & Munn, N.L. (1932). Visual pattern discrimination in the dog. Journal of Genetic Psychology, 40, 363-374.

Kaufman, M.E., & Peterson, W.H. (1958). Acquisition of a learning set by normal and retarded children. *Journal of Comparative and Physiological Psychology*, *51*, 619-621.

Kelleher, R.T., & Cook, L. (1959). An analysis of the behavior of rats and monkeys on concurrent fixed-ratio reinforcement schedules. *Journal of the Experimental Analysis of Behavior*, *2*, 203.

Kirkby, R.J., & Williams, G. (1979). Behavior of marsupials: Successive reversal learning in the bushtail possum (Trichosurus vulpecula). *Australian Journal of Psychology*, *31*, 185-191.

Kirkish, P.M., Fobes, J.L. , & Richardson, A.M. (1979). Spatial reversal learning in the lizard coleonyx variegatus. *Bulletin of the Psychonomic Society*, *13*, 265-267.

Levine,B.A.(1972)The calibration of the control ranges of drive and incentive variables in the serial discrimination reversal learning of two avian species. Unpublished doctoral dissertation, Hofstra University, New York.

Levine, B.A. (1975). Effects of drive and incentive magnitude on serial discrimination reversal learning in pigeons and chickens. *Journal of Comparative and Physiological Psychology*, *86*, 730-735.

Levine, B.A. (1975). Resistance to extinction as a function of IQ and reinforcement ratio among retarded children. *Journal of Mental Deficiency Research*, *20*, 25-30.

Longo, N. (1964). Probability learning and habit reversal in the cockroach. *American Journal of Psychology*, *77*, 29-47.

Mackintosh, N.J. (1969). Comparative studies of reversal and probability learning: rats, birds, and fish. In R.M. Gilbert, and N.S. Sutherland (Eds.), *Animal Discrimination Learning*, New York: Academic Press.

Mackintosh, J.J., & Mackintosh, J. (1964). Performance of octopus over a series of reversals of a simultaneous discrimination. *Animal Behavior*, *12*, 321-324.

MacPhail, E.M. (1970). Serial reversal performance in pigeons: Role of inhibition. *Learning and Motivation*, *1*, 401-410.

MacPhail, E.M. (1971). Hyperstriatial lesions in pigeons: Effects on response inhibition, behavioral contrast, and reversal learning. Journal of Comparative and Physiological Psychology, 75, 500-507.

MacPhail, E.M. (1972). Inhibition in simultaneous discrimination reversals. In R.A. Boakes and M.S. Halliday (Eds.). Inhibition and Learning. New York: Academic Press.

MacPhail, E.M. (1975). Hyperstriatial function in pigeon: Response inhibition or response shift? Journal of Comparative and Physiological Psychology, 89, 607-618.

MacPhail, E.M. (1976). Evidence against the response-shift account of hyperstriatial function in the pigeon. Journal of Comparative and Physiological Psychology, 90, 547-549.

MacPhail, E.M. (1982). Hyperstriatial lesions in pigeons (Columbia livia): Effects on retention and preservation. Journal of Comparative and Physiological Psychology, 96, 725-741.

Marx, M.H. (1970). Learning: Interactions, Toronto: MacMillan.

Meyer, D.R. (1960). The effects of different probabilities of reinforcement on discrimination learning in monkeys. Journal of Comparative and Physiological Psychology, 53, 173.

Meyer, D.R., & Harlow, H.F. (1949). The development of transfer of response to patterning by monkeys. Journal of Comparative Physiological Psychology, 42, 545.

Miles, R.C. (1957). Learning set formation in the squirrel monkey. Journal of Comparative and Physiological Psychology, 50, 356-357.

Miles, R.C., & Meyer, D.R. (1955). Learning sets in marmosets, Journal of Comparative and Physiological Psychology, 49, 219.

Munn, N.J. (1964). Discrimination reversal learning in the kangaroo. Australian Journal of Psychology, 16, 1-8.

Newman, K. (1976). Discrimination reversal learning as a functional mental age, dimensional redundancy and type of reversal shift among mental retardates. Unpublished doctoral dissertation, Hofstra University, New York.

Nissen, H.W., Blum, J., & Blum, R. (1949). Conditional matching behavior in the chimpanzee: Implications for the comparative study of intelligence. Journal of Comparative and Physiological Psychology, 42, 339-356.

Plotnick, R.J., & Tallario, R.B. (1966). Object quality learning set formation in the young chicken. Psychonomic Science, 5, 145-196.

Powell, R. (1972). Responding under basic schedules of reinforcement in the crow. Journal of Comparative and Physiological Psychology, 79, 156-164.

Pubols, B. H. (1957). The acquisition and reversal of a position habit as a function of incentive magnitude. Journal of Comparative and Physiological Psychology, 54, 94-97.

Reich, B.A. (1976). Analysis of complete and partial reversal learning in the goldfish (Carassinius auratus). Unpublished doctoral dissertation, Hofstra University, New York.

Riddell, W., Corl, K., Bennett, V.D., & Reimers, R. (1974). Discrimination learning differences as a function of brain index. Physiology and Behavior, 13, 201-205.

Riddell, W., Gravetter, F., & Rogers, W. (1976). Further investigation of the relationship between cerebral indeces and learning abilities. Physiology and Behavior, 17, 231-234.

Riddell, W., & Corl, K. (1977). Comparative investigations of the relationship between cerebral indeces and learning abilities. Brain, Behavior, and Evolution, 14, 385-398.

Rilling, M. (1977). Stimulus control and inhibitory processes. In W.K. Honig and J.E.R. Staddon, (Ed.). Handbook of Operant Behavior, N.J.: Prentice Hall.

Riopelle, A.J. (1958). Progressive discrimination learning in platyrhine monkeys. Journal of Comparative and Physiological Psychology, 51, 47-470.

Scher, G.A. (1970). Allometric and factor analysis of brain structure and insectivores and primates. In Noback and Monague (Eds.). The Primate Brain: Advances in Primatology, New York: Appleton Century Croft (Cited from Riddell & Corl, 1977).

Saunders, J.C., Chia-Song, C ., & Pridmore, P. (1971). Successive habit reversal in monotreme. Animal Behavior, 19, 552-555.

Schoel, W.M., & Bitterman, M.E. (1971). Further studies of reversal learning with singly presented stimuli in pigeons and goldfish. Journal of Comparative and Physiological Psychology, 28, 170-172.

Seigel, A.I. (1953). Deprivation of visual form discrimination in the ring dove. Journal of Comparative and Physiological Psychology, 46, 115-119.

Sekelman, W. (1973). Behavioral contrast and inhibitory stimulus control as related to extended training. Journal of the Experimental Analysis of Behavior, 20, 245-252.

Setterington, R.G. & Bishop, H.E. (1967). Habit reversal improvement in the fish. Psychonomic Science, 7, 41-42.

Skinner, B.F. (1956). A case history in scientific method. American Psychologist, 11, 221-233.

Squire, L. (1965). Reversal learning improvement in the fish, Astronotus ocellatus (Oscar). Psychonomic Science, 14, 143-144.

Stettner, L.J., & Matyniak, K. (1968). The brain of birds. Scientific American, 218, 64-76.

Strong, P.N., & Hedges, M. (1966). Comparative studies in simple oddity learning: 1. Cats, racoons, monkeys, and chimpanzees. Psychonomic Science, 5, 13-14.

Sutherland, N.S., & Mackintosh, N.J. (1971). Mechanisms of Animal Discrimination Learning, New York: Academic Press.

Thorndike, E.L. (1911). Animal Intelligence. New York: MacMillan.

Voronin , L.G. (1962). Some results of comparative physiological investigations of higher nervous activity. Psychological Bulletin, 44, 80-87.

Warren, J.M. (1965). The comparative psychology of learning. Annual Review of Psychology, 16, 95-118.

Warren, J.M. (1966). Reversal learning and the formation of learning sets by cats and rhesus monkeys. Journal of Comparative and Physiological Psychology, 61, 421-428.

Warren, J.M. (1973). Learning in vertebrates. In D.A. Dewsbury and D.A. Rethlingshafer (Eds.). Comparative Psycholog: A Modern Survey, New York: McGraw Hill.

Warren, J.M. (1980). Spatial probability learning by experimentally naive cats and monkeys. Bulletin of Psychonomic Society. 16, 76-77.

Warren, J.M. & Baron, A. (1956). The formation of learning sets by cats. Journal of Comparative and Physiological Psychology, 49, 227.

Waters, R.H., Rethingshafer, D.A., & Caldwell, W.E. (1960). Principles of Comparative Psychology. New York: McGraw Hill.

Weiner, N., & Huppert, F. (1968). Reversal learning and forgetting. Science, 160, 99.

Wells, M.C., & Lehner, P.N. (1979). Serial reversal learning in the Mallard duck (Anas platyrhyehos). Bulletin of Psychonomic Society, 10, 235-239.

Williams, B.A. (1974). Reward vs. extinction in discrimination reversal learning. Bulletin of the Psychonomic Society, 3, 454-456.

Wilson, W.A., Oscar, M., & Bitterman, M.E. (1964). Probability learning in the monkey. Quarterly Journal of Experimental Psychology, 16, 163.

Woodward, W.T., & Bitterman, M.E. (1972). Further studies of reversal learning with singly presented stimuli with pigeons and goldfish. Psychonomic Science, 28, 170-172.

Woodward, W.T., & Bitterman, M.E. (1976). Asymptotic reversal learning in pigeons: mechanisms for reducing inhibition. Journal of Experimental Psychology: Animal Behavior Processes, 2, 57-66.

Woodward, W.T., Schoel, W., & Bitterman, M.E. (1971). Reversal learning with singly presented stimuli in pigeons and goldfish. Journal of Comparative and Physiological Psychology, 76, 460-467.

Woodinsky, J., & Bitterman, M.E. (1953). Solution of oddity problems by the rat. American Journal of Psychology, 66, 137-146.

Zeigler, H.P. (1961). Learning set formation in pigeons. Journal of Comparative and Physiological Psychology, 54, 252-254.