

SUCCESSIVE HABIT REVERSAL LEARNING  
BY THE SPECTACLED CAIMAN

By  
JOHN TAYLOR WILLIAMS, JR.

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## CHAPTER 1

### INTRODUCTION

In a successive habit reversal problem a subject is given a series of two-choice discriminations in which the valences of the positive and negative stimuli are reversed periodically. The primary focus of interest is usually the course of improvement, if any, across successive reversals. This problem is viewed by many as a similar, but simpler, type of set learning when compared with the object-quality discrimination set learning studied by Harlow (1949). As Warren (1965a) has pointed out, there is an orderly progression in ability to show interproblem improvement in an object-quality set learning situation when one compares mammals at various stages of phylogenetic development. This progression is most marked when comparisons are made among various primates.

In addition to its apparent similarity to a traditional learning-set situation, the successive habit reversal problem has gained the interest of comparative psychologists since Bitterman announced that fish either showed interproblem improvement that was qualitatively different than rats (Wodinsky & Bitterman, 1957) or that they showed no interreversal improvement whatsoever (Bitterman, Wodinsky, & Candland, 1958). These findings have sparked a number of studies designed to help determine what changes in learning ability are associated with the evolutionary development of more complex nervous systems.

A review of the findings phylogenetically and a discussion of some of the methodological variations may help to evaluate the importance of studies of habit reversals to the comparative psychologist and suggest further experimentation which may be of value.

### Phylogenetic Review

Mammals.--As Warren (1965b) has pointed out, every mammalian species which has been studied has shown progressive improvement across successive reversals. Schusterman (1962) studied chimpanzees and found "extremely efficient" learning, even though the Ss only received three reversals. He trained his Ss to a criterion of 12 consecutive correct responses, using a correction procedure. The most striking aspect of his findings was the great number of errors made on the first reversal ( $\bar{x}=57.8$ ); after this, it would have been most surprising if there had not been a great improvement.

House and Zeaman (1959) studied reversal learning of low-grade retardates on a position discrimination with a correction procedure and candy for a reward. The Ss were trained to a criterion with conditional limits regarding trials per day and reversals during the course of a day's testing. There was negative transfer during the first four reversals, but the Ss had approached single error reversing after six reversals.

Warren and Warren (1962) trained two horses and one raccoon on confounded (visual and spatial) problems for food reward and found rapid improvement. These Ss were trained to a criterion of 11 correct in 12 trials and learned one reversal per day, using a noncorrection procedure. The raccoon learned 20 reversals (four with no errors), one horse learned nine, and the other horse was given only six reversals before testing was terminated.

Kittens of various ages have been tested (Warren & Warren, 1967) for food reward on a confounded problem. A criterion of ten consecutive correct trials was used with a noncorrection procedure. There was no systematic variation based upon age, and the results were consistent with studies of older cats (Cronholm, Warren, & Hara, 1960) in that there was an increase in errors on the first reversal and a rapid decrease on subsequent reversals to an asymptote of about six errors per reversal.

In general, the studies with rats agree with the studies conducted with other mammals. There is usually, but not always, an increase in errors on the first few reversals and then a decrease so that there is a high level of efficiency after a dozen or so reversals. North (1950a, 1950b) performed the first systematic studies of successive habit reversal learning in the rat, partly as a result of Buytendijk's (1930) report that the rat could learn to reverse after a single error. However, North was unable to get single error reversals in a T maze, even after 60 reversals. Procedurally, North reversed his Ss after 6, 18, or 30 trials rather than training his Ss to a criterion. He also used delayed correction and noncorrection rather than a correction procedure. In a widely cited study, Dufort, Guttman, and Kimble (1954) found that rats could quickly develop single error reversing. Their results were very similar to those of House and Zeaman (1959) with retardates. Their Ss were trained on spatial discriminations with food reinforcement. A noncorrection procedure was used, and only four trials per day were given. As in Buytendijk's study, Ss were trained to a criterion. Pubols (1957, 1962) has compared performance when rats are trained to a criterion with performance of rats which are reversed after set numbers of trials. He

found that training to criterion is superior to reversing after a set number of trials and that reversing after a large number of trials is superior to reversing after a small number of trials. Gatling (1952) studied rats on a series of visual discrimination reversals for food reward. The Ss were trained to a performance criterion. The results showed the usual mammalian pattern of a drastic increase in errors on the first couple of reversals and a subsequent improvement to a level of greater efficiency than that demonstrated on the original problem. However, unlike the situation in most studies using rats, the Ss were still making about 40 errors per reversal after a dozen reversals. Gatling did show that the pattern of elimination of errors was basically the same throughout training. That is, errors were reduced at all stages of intrareversal learning throughout all stages of reversal training. Estes and Lauer (1957) reported the only recent rat study in which there was not a clear-cut improvement across successive reversals. Their study differed from most experiments in that their Ss only received one, two, or four trials per day. Also, they only gave their Ss four reversals. Lawrence and Mason (1955) studied reversal learning in rats with varying numbers of relevant cues and noted that with three relevant cues a S is apt to perform on the basis of position and is less efficient than a S which is given only two relevant cues.

Birds.--In the first reversal study using birds, Reid (1958) failed to find the interreversal improvement which is so characteristic of mammals. He used pigeons on a color discrimination with food reward. Bullock and Bitterman (1962) studied pigeons on both visual and spatial discriminations and found progressive improvement. When the discrimination was spatial rather than visual, this improvement was faster.

Instead of a standard correction or noncorrection procedure they used a "guidance" procedure in which an incorrect response is followed by the presentation of the positive stimulus alone. A more recent study (Bitterman, 1965) also showed that pigeons were capable of improving across reversals when given visual discriminations. Warren, Brookshire, Ball, and Reynolds (1960) studied chicks on spatial and confounded problems for food reward and found that older chicks were more efficient at reversing than were younger ones. Successive improvement by chickens on multi-dimensional visual tasks has been reported (Bacon, Warren, & Schein, 1962) in another study using food reward.

Reptiles and Amphibians.--An early study (Kirk & Bitterman, 1963) tested turtles in a T maze with confounded cues for food reward. The Ss given five trials per day and reversed after errorless days showed no improvement, but Ss given ten trials per day with daily reversals showed some improvement over the course of 70 days (but no statistical tests were reported). Bitterman (1965) reported some work done with Holmes in which turtles were tested on spatial and visual discriminations. His conclusions (again without reporting statistical significance) were that turtles improved on the spatial task but not on the visual task. The data in his graph of the errors by the visual group could have been generated by Ss which were operating strictly on a position basis. Since Ss were reversed every four days, this could have easily happened with position preference responses being reinforced about half of the time. Recently this work has been published in greater detail with additional experimentation (Holmes & Bitterman, 1966). It was learned that turtles improved substantially on a visual task when they were trained to a criterion before being reversed. Iguana lizards showed improvement in a T maze with confounded cues (Alkov & Crawford, 1966). Davidson, (1966a,

1966b) studied alligators, but only three of his Ss learned the second reversal. He used escape from drying heat for reinforcement, and could only give his Ss a single trial per day.

One study (Seidman, 1949) cited frequently in early reversal learning studies, reported that terrapins were more efficient than newts at reversing a direction habit in a T maze. A block, visible from the choice point, was used to convert the incorrect arm into a cul-de-sac, and Seidman's criterion for learning was only three consecutive correct trials. Perhaps he showed that newts cannot see as well as terrapins, but we still have no information regarding reversal learning by amphibians.

Fish.--When fish (African mouthbreeders) were first tested in a habit reversal paradigm (Wodinsky & Bitterman, 1957), they showed improvement over the first six reversals and then a leveling off in performance. The Ss were tested on a visual discrimination to a criterion of 17 correct of 20 daily trials. A correction procedure, in which a trial was terminated by a correct choice or by five incorrect choices, produced greater improvement than did a noncorrection procedure. It was noted that the improvement occurred only in the later stages of training on each reversal, and thus it was qualitatively different from the improvement reported by Gatling (1952). Further studies inspired by this qualitative difference were reported in a paper the next year (Bitterman, Wodinsky, & Candland, 1958). However, no improvement was found on either visual or spatial tasks using either correction or guidance procedures and training to criteria. Further experimentation with fish has failed to demonstrate improvement on confounded problems (Warren, 1960; Bitterman, 1965), and Warren even found a progressive

increase in errors while testing paradise fish. Behrend, Domesick, and Bitterman (1965) tried even more methodological variations and reported typical negative results. However, they mentioned that two or three of the individual Ss showed a pattern similar to that shown by typical mammals in which there was an increase in errors on the first reversal, followed by a decrease across reversals.

Invertebrates.--The results have been quite difficult to interpret at the invertebrate level. Thompson (1957) tested sow bug on a spatial problem for eight reversals. There was no significant improvement, but the data clearly indicated a trend toward improvement. Significant findings were probably very unlikely because of a small number of Ss and very strong position preferences. The Bermuda land crab was tested (Datta, Milstein, & Bitterman, 1960) on a confounded problem, with escape from fresh water used for reinforcement. Ss were reversed either daily or every four days, and no improvement was found. On the other hand, Mackintosh (1964) has reported clear-cut improvement across a dozen reversals in octopuses. They were performing at the level of the original problem when it became necessary to terminate the study because the Ss became unhealthy. Datta (1962) has found a decline in errors by earthworms given five trials per day and reversed every four days. However, control Ss quickly reached the efficiency of reversed Ss when they were given reversals. Therefore, Datta concluded that the improvement was not due to learning to reverse but was due to a greater familiarity with and adaptation to the maze. Longo (1964) reports similar results and conclusions using cockroaches. He used control Ss, Ss reversed daily, and Ss reversed every four days. The errors for the Ss reversed daily declined significantly, but those with reversals every four days did not.

After 44 days, the four-day reversal and control Ss were switched to daily reversals and reached the level of the daily reversal group in six days. Therefore, Longo concluded that the improvement by the daily group was a result of better adjustment to the maze situation. Crawford and Henton (1965) reported that when tarantulas were given three reversals, the third was the easiest and the second was the hardest.

In summary, mammals usually, but not always, made more errors on the first few reversals than they did on their original problems and then improved across successive reversals to asymptotic performances which were superior to the performances on the original problems. Frequently mammals approached single error reversing, but sometimes they did not do so even after extended training. Birds usually showed a pattern like that shown by mammals, but they have not attained single error reversal learning. Interreversal improvement has been demonstrated in reptiles, but it has been found less frequently than in higher forms. Fish have failed to improve across reversals in all but one of the studies using them as Ss, and that was the first study in which relatively crude techniques were used. The data collected using invertebrates as Ss were rather contradictory, and interpretations of interreversal improvement by invertebrates are open to controversy.

#### Methodological and Interpretive Considerations

If animals form learning sets for habit reversals, these sets should increase the efficiency of the animal in solving a problem. In the phylogenetic review, it was frequently mentioned that many animals significantly improved across a series of reversals. However, little was said about comparisons between the performance on the original discrimination and the performance at the end of reversal training. Although the

graphs presented by several authors indicated that there may have been some gains over the original levels of efficiency, there have been no reports of submammals reaching a level of proficiency that significantly surpassed their ability to solve the first problem. It is very hard to be convinced that an animal has formed a set to reverse if all it does is eliminate negative transfer effects. However, when a mammal can consistently reverse after single errors when it had made three or four errors on the first problem, it seems reasonably safe to assume that it has formed such a set.

Bitterman (1965) has stressed the differences which are often evident when results from visual discriminations are compared with those from spatial discriminations, and Mackintosh (1965) has discussed the role which attention may play in the overtraining reversal effect. If a S is performing on the basis of position when visual cues are relevant, it will receive about fifty per cent reinforcement for its preferred position response. Therefore, if the S receives a series of reversals after some set number of trials, it could easily keep performing on the basis of its position preference. The resulting fifty per cent reinforcement should make its position response fairly resistant to extinction, and it would perform at a level of fifty per cent errors to the relevant cue with no improvement across reversals. Therefore, failure to improve may not always result from an inability to improve, but rather from the S's lack of attention to the relevant cues. Training to a performance criterion assures that the S attends to the relevant cue and effectively eliminates this problem; this training to criterion has been shown to be more effective in producing interreversal improvement in rats.

One factor which may greatly influence the situation just described is the consequence of an error. If the S is poorly motivated, the consequences resulting from an error are minimal. Reid's pigeons (1958) apparently were poorly motivated as were the crabs studied by Datta, Milstein, and Bitterman (1960). Bullock and Bitterman (1962) made the suggestion that Reid's birds lacked proper motivation, but the lack of improvement in their birds with a guidance procedure with a time out of zero seconds seems to be quite parallel. They stated that this lack of improvement was a function of delay of reinforcement, but perhaps it is more useful to think of it in terms of elimination of the consequences of an error. This could offer a possible explanation for the reason that sometimes invertebrates seem to improve while fish do not. The fish have all been tested with food reward, and may not have been "punished" sufficiently for their errors. Typically, invertebrates have been studied in situations where they were escaping aversive stimuli.

Another obstacle to one who is trying to determine whether animals can form sets to reverse is the fact that Ss are typically reversed at the beginning of a new day. This creates a special problem with lower forms which may have trouble remembering from one day to the next. It is quite conceivable that a S may gradually learn something about how to perform in the situation, e.g., to repeat a correct response, without being able to remember which way it went the day before. Thus, if a S is being reversed on a daily basis, it may reach the point where the first trial each day is performed on a chance basis, and the rest of the trials that day are performed correctly. This could result in interreversal improvement without anything being learned about reversing. This could possibly explain how the raccoon studied by Warren and Warren

(1962) learned four of its 20 reversals without any errors. Another explanation is that being reversed each day could serve as another cue for the S to reverse.

The effects of using correction, noncorrection, or guidance procedures are hard to separate from other factors; for example, a correction procedure is necessary in an escape situation. Perhaps further experimentation may show that these procedures have some effects above and beyond the effects due to interactions between them and other aspects of the procedure.

Most of the comparative studies of habit reversals have been performed by M. E. Bitterman, J. M. Warren, and their students. In making comparisons, Bitterman looks for different functional relationships at different levels, and Warren looks for qualitative differences or for quantitative differences in which there is little or no overlap between distributions.

The following study was performed to try to determine whether a reptile, in this case Caiman sclerops, could improve across reversals in a way comparable to that of mammals. Caimans were chosen to supplement the rather sparse information regarding reptilian habit reversal learning because they have not been studied previously; they have a slight amount of neocortical tissue, and they are hardy animals which can be maintained in good health for extended periods. They are of interest phylogenetically in that they are more closely related to the ancestral stock of birds than to that of mammals. The results will be compared with mammalian data to determine whether the functional relationships are the same at the two levels and whether the caimans can attain performance which falls in the range of efficiency usually reported in studies using mammals. In

order to make these comparisons in some way meaningful, a situation was designed which, hopefully, produced optimal opportunity for inter-reversal improvement. Therefore, Ss were first tested to see whether they normally attended to spatial or visual cues; the chosen cue was then made relevant for a study of reversal learning. Shock escape was chosen so that a sufficiently high level of motivation could be achieved with definitely noxious consequences following an error. Ss were trained to one of two criteria on each problem and reversals took place during the day's testing so that the first trial of a day would not serve as a cue to reverse.

## CHAPTER 2

### EXPERIMENT 1--CUE DOMINANCE

By training a S on a confounded task with both visual and spatial cues relevant and then giving a test trial on which the cues give contradictory information it should be easy to determine which cue is normally used by the S. A group of caimans was tested in this way to determine whether they would consistently choose one cue in a situation in which both types of cues were available and relevant.

#### Method

Subjects and Housing.--Eight spectacled caimans (Caiman sclerops) purchased commercially about 18 in. in length served as Ss. They were housed in a 2- by 4-ft. tank in which the water temperature was maintained at about 90° F. Each morning the water was changed, and a sun lamp was turned on for about 9 hr. The diet consisted of ground chicken parts (including bones) with cod liver oil added periodically. Identification of individual Ss was made possible by the use of varicolored neckbands.

Apparatus.--The apparatus was a modified T maze with galvanized metal sides and a floor made of 1 in. wide stainless steel plates running diagonally and spaced 1/8 in. apart. It is illustrated in Fig. 1, and the dimensions are given in Fig. 2. The goal box was a specially built pan which was 18 in. long and held up to 7 in. of water. A metal guillotine door converted the incorrect arm into a cul-de-sac. The wall of the arms opposite the stem was made either black on the left and



Fig. 1. Maze with interchangeable black-white panel and with goal box at left. The meter was to monitor the current across two grid plates.

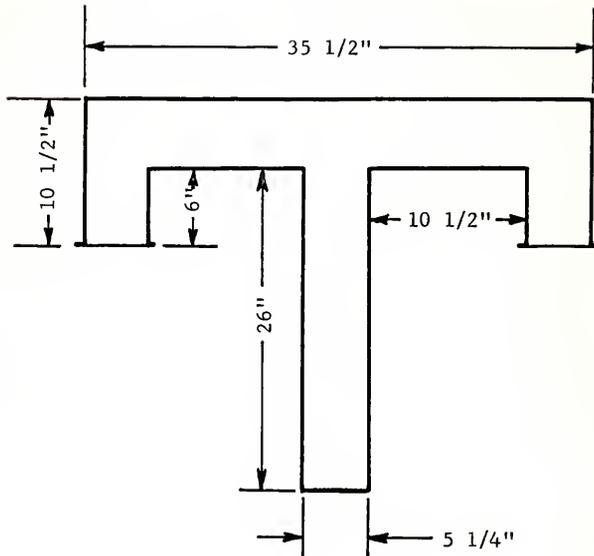


Fig. 2. Top view of maze and major dimensions. All walls were 14 in. high, and the maze was elevated 7 in. above the floor.

white on the right, or vice versa, by the use of interchangeable sheet metal panels. A variable voltage transformer delivered a shock through a scrambler to the floor and sides of the maze. A short-circuit current of 6 to 8 ma. was used, depending upon the behavioral reactions of the individual Ss. Observations were made by using a mirror mounted at an angle over the maze.

Procedure.--On each trial the S was removed from the home tank by hand and dropped onto the start area of the grid facing the choice point. When a S entered the goal pan, it was lifted to the home tank, and the S was allowed to swim out. This prevented handling (which was obviously noxious) in the goal area. The goal pan was then refilled with water from the home tank for the next trial. An intertrial interval of 15 min. was used to prevent cumulative effects of shock. An error was defined as an entrance into the wrong arm as far as the S's hind legs, and the criterion for learning used was eight consecutive correct trials. Four Ss were trained with right and white positive, and four were trained to go to black on the left. After a S reached criterion, it received a single test trial with the positions of the black and white reversed. A goal pan was at each arm of the T during the test trial.

#### Results and Discussion

Of the eight Ss, seven reached criterion in 8, 9, 10, 10, 11, 12, and 16 trials, and the eighth was discarded when it had shown no indications of learning after 30 training trials. On their test trials, all seven Ss made a turn to the side to which they had been trained. Even if the eighth S had made a choice on the basis of brightness, the results would have been significant ( $p < .05$ ) in favor of the use of spatial cues.

Thus, it is readily apparent that caimans tend to use spatial cues rather than visual cues in a maze situation such as this. This lends

some support to the usually untested assumption that most animals attend more to spatial than to visual cues.

Incidentally, three of these Ss were then trained on a black-white discrimination with their positive color unchanged and with the position cues made irrelevant. Two of the Ss reached criterion in 51 and 57 trials, and the third had shown some indications of learning after 60 trials. Two of these Ss took over 40 trials to abandon an almost absolute preference for the position to which they had been trained on the confounded problem. Therefore, caimans can learn a visual discrimination, but it is a much more difficult problem for them than is a spatial discrimination.

## CHAPTER 3

### EXPERIMENT 2--REVERSAL LEARNING

After it had been determined that position was the primary cue used by caimans in this situation, a study of habit reversal learning was made using position as the relevant cue.

#### Method

Subjects and Housing.--Sixteen spectacled caimans (Caiman sclerops) ranging from 16 to 19 in. in length served as Ss. They were housed and fed as in Experiment 1, except that prior to use as Ss they were housed in a 2- by 5- ft. colony tank. On the days when data were being collected from an individual S, it was housed in a 2- by 4- ft. tank with about five other Ss.

Apparatus.--The apparatus was that used in Experiment 1, except that the black and white sheet metal panels were not used. Thus, the entire inside of the maze was unfinished, galvanized metal.

Procedure.--The procedure on any given trial was identical to that in Experiment 1. However, each S received 20 trials per day throughout training on the original problem and on 20 reversals. As before, half of the Ss were trained to go to the right on the first problem and half were trained to go to the left.

The Ss were divided into two groups of eight Ss, matched on the basis of length. One group was reversed after having reached a criterion of six consecutive correct trials, and the criterion for learning for the other group was twelve consecutive correct. The next problem was

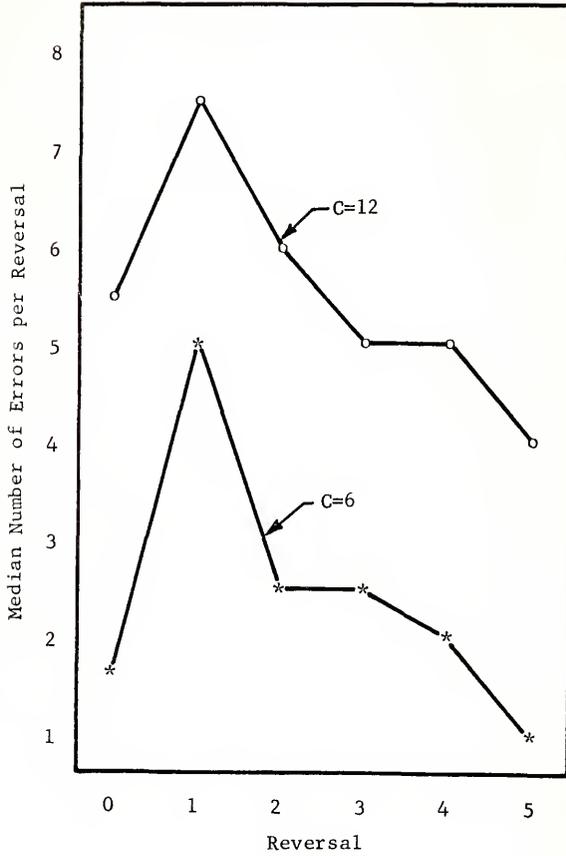


Fig. 3. Median number of errors per reversal for the first five reversals. (Reversal 0 represents the original problem.)

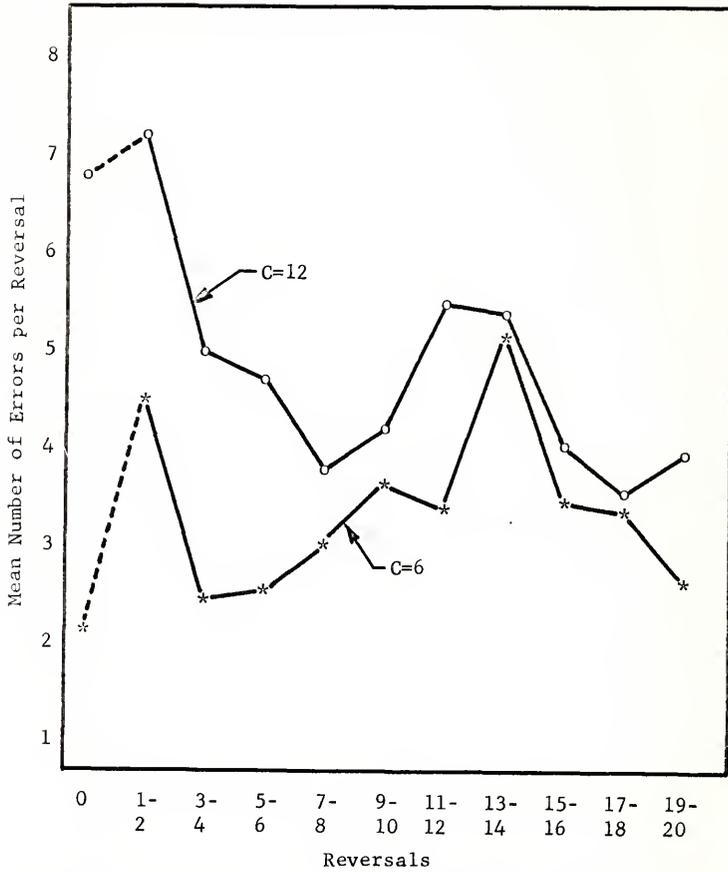


Fig. 4. Mean number of errors per reversal averaged across pairs of reversals.

begun on the trial after criterion was reached, rather than beginning each new problem on the first trial of a new day as is typically done in reversal learning experiments.

### Results

The median number of errors for each of the first five reversals is given in Fig. 3. (Medians were used here because the averages were based upon only eight scores.) It is of interest that the pattern is for an increase in errors on the first reversal, followed by a consistent drop in errors thereafter. It is interesting that the average S with a criterion of six consecutive correct (group C=6) performs perfectly on the fifth reversal. The group with a criterion of twelve consecutive correct (group C=12) also shows impressive improvement. However, the study was not terminated at this point, and the picture changed somewhat with additional testing. The mean number of errors for each pair of reversals is given in Fig. 4. Pairs of reversals are used for this and for statistical purposes to eliminate any effects which position preferences could have introduced. It may be noted that the original decline in number of errors in each group was followed by an increase in errors and then another decrease. Also, both groups are almost identical for the last eight reversals. Numbers of errors and trials to criterion for individual Ss on each reversal are given in the Appendix.

An analysis of variance of errors per pair of reversals for group C=6 is summarized in Table 1. As is indicated in the table, there was a significant reversals effect. Orthogonal tests for trend showed that the cubic trend component was significant as was the quartic. An analysis of trials to criterion data yielded almost identical results except that the quartic component in the trend analysis was not significant.

Table 1

Analysis of Variance of Errors to Criterion for C=6

Source	SS	df	MS	F
Between <u>Ss</u>	141.2	7		
Within <u>Ss</u>	[678.6]	[72]		
Reversals (pairs)	(234.6)	(9)	26.06	3.73**
Linear component	.01	1	.01	.001
Quadratic component	3.29	1	3.29	.47
Cubic component	139.37	1	139.37	19.99**
Quartic component	28.27	1	28.27	4.05*
Quintic component	.04	1	.04	.005
Residual	444.0	63	6.98	

\* $p < .05$ \*\* $p < .01$ 

As was evident in Fig. 4, the final level of proficiency was no better than on the original problem.

An analysis of variance of errors per pair of reversals for group C=12 is summarized in Table 2. As in group C=6, there was a significant reversals effect. However, in this group the linear trend component was significant as was the cubic component. There were no significant differences in an analysis of trials to criterion data because of great variability (a single error after eight or nine correct trials has a drastic effect on number of trials to criterion). A comparison between the original problem and the last pair of reversals showed that the final level of efficiency surpassed the performance on the original discrimination problem ( $t=1.67$ ,  $df=22$ ,  $p < .06$ ). (If the last four reversals are compared with the first problem,  $t$  becomes 2.37,  $df=38$ , and the level of significance becomes .02.)

Table 2

Analysis of Variance of Errors to Criterion for C=12

Source	SS	df	MS	F
Between <u>Ss</u>	243.9	7		
Within <u>Ss</u>	[1362.4]	[72]		
Reversals (pairs)	(363.8)	(9)	40.42	2.55*
Linear component	131.85	1	131.85	8.31**
Quadratic component	26.72	1	26.72	1.68
Cubic component	98.48	1	98.48	6.21*
Quartic component	53.65	1	53.65	3.38
Quintic component	25.64	1	25.64	1.62
Residual	998.6	63	15.85	

\* $p < .05$ \*\* $p < .01$ 

The within-problem learning of group C=12 is illustrated in Fig. 5. The mean errors per trial are plotted for five-trial blocks, as averaged across blocks of four reversals. It may be noted that the shapes of the curves are very similar. Data for group C=6 are plotted by blocks of three trials in Fig. 6.

The percentage of correct choices on the first trial of each day as a function of the number of consecutive correct trials at the end of the previous day is shown in Fig. 7. As indicated in Fig. 7, Ss which finished a day with two or fewer correct trials performed at a chance level at the beginning of the next day. However, binomial tests indicated that a significant majority of those Ss which finished the day with three or more correct made a correct choice on the first trial of the following day (for 3-5 correct,  $z=2.12$ ,  $p=.03$ ; for 6-11 correct,  $z=2.97$ ,  $p=.003$ ).

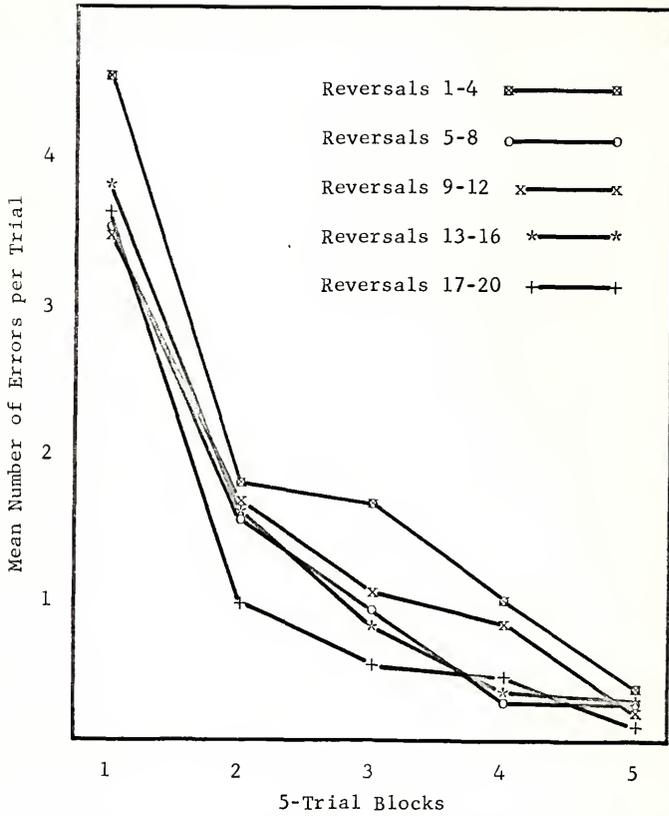


Fig. 5. Within-problem learning averaged across sets of four consecutive reversals for group C=12.

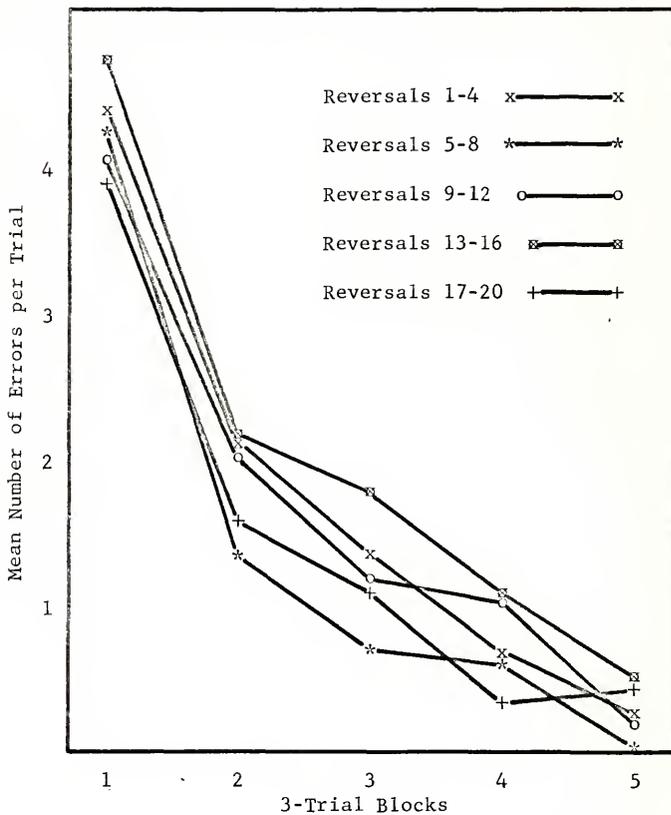


Fig. 6. Within-problem learning averaged across sets of four reversals for group C=6.

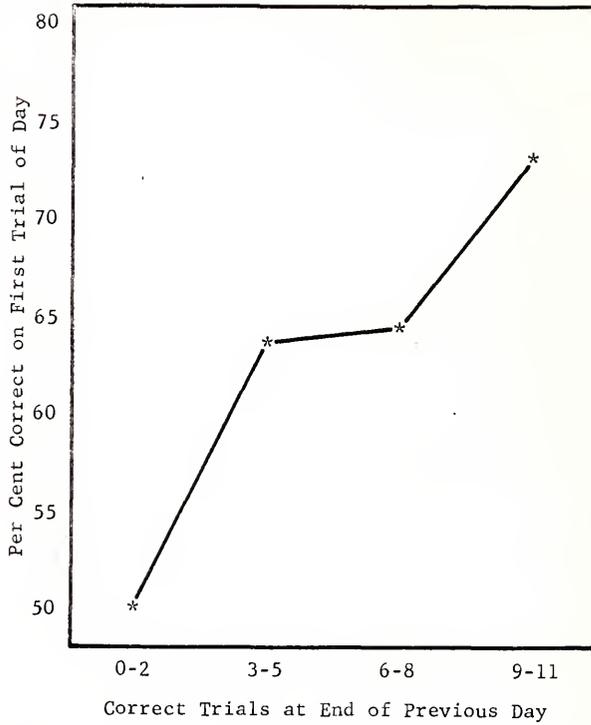


Fig. 7. Per cent of first trials of each day correct as a function of the number of consecutive correct trials at the end of the previous day.

## CHAPTER 4

### DISCUSSION

The results clearly answered several questions, but they raised still others. The data presented with Fig. 7 made it quite clear that the caiman is capable of remembering from day to day which way it had learned to turn the day before. Since many of the Ss were averaging a reversal each day near the end of training, they had to remember not only which way they were turning the day before, but they had to remember which way they were turning at the end of the day rather than at the beginning. Knowing that the Ss were able to remember from day to day relieves one of concern about a possible disruption of reversal learning as a result of the daily break in testing.

From a phylogenetic standpoint, the pattern of within-problem learning is more like that of the rat (Gatling, 1952) than that reported for the fish (Wodinsky & Bitterman, 1957). The similarity of the curves presented in Fig. 5 indicates that errors were eliminated in the same way across the series of reversals. Improvement took part at all stages of learning within each problem.

There are some very difficult questions to answer regarding inter-reversal improvement. Why did one group improve while the other group did not, and why did the Ss in each group improve initially, regress, and then improve again? Perhaps an attempt to design an ideal experimental situation resulted in a problem which was too easy, at least for the Ss with the less stringent criterion. In fact, the median

number of errors for group C=6 on the original discrimination problem was 1.5. This does not leave much room for improvement. The increase in errors on the first reversal was expected and typical, as was the rapid decline over the next few reversals. However, when it appeared that the Ss had completely mastered the situation, some of them regressed severely. The pattern of regression was not uniform enough to be easily analyzed. About 5 Ss appeared to have developed position habits which had not been evident in early training. The shock level which was used was moderately severe, and an error sometimes led to trials of lengthy duration, which caused some temporary impairment of locomotion. It is possible that trauma suffered on one of these trials could have caused an avoidance of one side and, thus, created the position preferences noted late in training. Several Ss appeared to anticipate the reversals and would make errors just before they would have reached criterion; for example, the scores by trials for one S on one problem were - - + + + + - + + + + - + + + + +. Perhaps some of the Ss had learned a temporal discrimination and were trying to eliminate all errors. Performing on a position basis, while fairly effective, produced periodic errors, so some of the Ss may have deserted this to try other "hypotheses." Since any system of responding other than a win-stay, lose-shift strategy based upon position would result in more punishment, a S which had deserted this system would eventually return to it. This return could account for the final decline in errors seen in both groups. The author has studied data collected by Jack Sandler in which monkeys in a shock avoidance situation will sometimes cease to respond for periods of time for no apparent reason; perhaps this phenomenon is related to the regression shown by the caimans.

While part of the preceding discussion applies to both groups, it is certainly not a complete explanation for group C=12. The more rigorous criterion made their original problem much harder than that for group C=6, so that there was ample room for improvement. Indeed, their performance at the end of the series of reversals is markedly similar to group C=6's performance. One very important difference, however, is that in the trend analysis there was a highly significant linear component for group C=12. This, coupled with the fact that there was a significant difference between their performance on the last few reversals and on the original problem, makes their overall performance quite similar to that usually found in mammals. True, they did not, as a group, attain single error reversing, but neither did the mammals in a number of studies.

Behrend, et al. (1965) have mentioned the great individual differences among their fish. The abilities of caimans in this situation also varied greatly. One S in group C=6 is especially noteworthy. It learned the original problem and all 20 reversals with a total of 36 errors, of which five were on the first reversal. This S, which learned 13 problems with single errors and had one errorless reversal, is certainly as efficient as most mammals when it comes to performing in this reversal learning situation. Given the data from this experiment, Warren would probably have to concede that there is no basis for stating categorically that mammals have a greater ability to form habit reversal sets than do reptiles. The data agree very well quantitatively with typical data from experiments using birds.

Some may argue that the significant cubic trend components indicate a different functional relationship between reversals and efficiency

in caimans than that found in mammals. One answer would be to ask what would have happened if the mammals had been tested beyond the time when they reached their asymptotic performance. After all, the curves in Fig. 3 look like ideal mammalian results. Further experimentation is necessary to clarify this point, but the linear trend in group C=12 indicates that they probably did improve in the same way as higher forms.

On several occasions, individual Ss made unusually great numbers of errors before learning a problem. With only eight Ss per group, this raised the question of whether the means were excessively influenced by the behavior of one or two individual Ss. However, when the median numbers of errors per trial were plotted, the general shape of the curve was the same as the shape of the curve when the means were plotted.

While these data were being collected, one study was published (Settingington & Bishop, 1967) which may alter some thinking regarding phylogenetic trends in ability to form reversal sets. In this experiment, seven African mouthbreeder fish did improve progressively across a series of 80 reversals. They also improved at all stages of training within problems. Settingington and Bishop used what they called an "unlimited correction" method (actually a noncorrection procedure with a variable number of trials per day), daily reversals with 20 "trials" per day, and a spatial discrimination problem with the targets almost twice as far apart as those used in previous studies. Greater separation of goal boxes has been shown to improve delay of response performance by chimpanzees (Carpenter & Nissen, 1934), so it is not unlikely that separating the targets improved the discriminability of the situation for the fish. The unlimited correction would also make

it possible for an incorrect response to be repeated indefinitely, thereby increasing the consequences of an error by delaying a reinforcement for a considerable length of time.

Perhaps comparative psychologists are unable to see the forest for the trees when they study habit reversal learning. Maybe we will eventually learn that there is not some point at which animals higher on the phylogenetic scale have the ability to improve on successive reversals and those below that point do not. There may not even be a point which will discriminate between those which can reverse after single errors and those which cannot. What we might eventually learn is that those animals which are at the top of the phylogenetic scale have greater plasticity and can benefit from reversal training in a variety of situations, while it is necessary to set up an ideal experimental situation to demonstrate improvement across reversals in lower forms. Questions such as these can only be answered by testing a greater variety of organisms in a greater variety of situations.

There are some insurmountable problems for one who is interested in the evolutionary aspects of comparative psychology. Foremost among these problems is the fact that one cannot study the behavior of extinct forms of life. Although both mammals and birds evolved from reptiles, the mammal-like reptiles are now extinct, and there are no living reptiles which are very closely related to mammals.

## CHAPTER 5

### SUMMARY

Successive habit reversal tasks have shown some promise as a tool with which to study the differences in learning abilities at various phylogenetic levels. There is some evidence that there is a trend toward greater ability to benefit from reversal training at progressively higher levels, at least within vertebrates. A study was conducted using spectacled caimans as Ss in order to add to the rather sparse information available regarding reversal learning in reptiles.

Since there are sometimes differences between the results when the Ss are given a spatial discrimination as compared with those when the Ss are given a visual discrimination, Experiment 1 was conducted to determine whether caimans would normally attend to visual or to spatial cues. Eight caimans about 18 in. long were trained to escape shock in a T maze in which both visual and spatial cues were relevant. After a S made a correct choice on eight consecutive trials, a single test trial was given with the positions of the visual cues reversed. Therefore, the visual and spatial cues were giving contradictory information on the test trial. Seven Ss quickly learned the problem, and all of them performed on the basis of the spatial cue on the test trial. It was thus clear that caimans attended to spatial cues in this type of maze situation.

Experiment 2 was a habit reversal study using the dominant cue of position as the basis for the two-choice discrimination problems.

Sixteen Ss were divided into two matched groups and trained on a total of 21 problems, with one side correct on odd-numbered problems and the other side correct on even-numbered problems. Eight of the Ss were reversed every time they made six consecutive correct choices, and the other eight were reversed after 12 consecutive correct.

There was a substantial increase in errors on the first reversal, as compared with the original problem, followed by a rapid decline in errors over the next few reversals. However, as testing continued, there was an increase in errors followed by a second decrease. The group with a criterion of six correct (C=6) showed no overall improvement across reversals. This was probably because the original problem was so easy that there was almost no room for improvement. The group with the criterion of 12 correct (C=12) did show significant overall improvement and made significantly fewer errors on the last few reversals than it had made on the original discrimination. The pattern shown by this group was very much like that usually displayed by birds and mammals, and the number of errors per reversal was within the range of errors made by mammals. One of the individual Ss in group C=6 learned 13 of the 21 problems with a single error. It was certainly as efficient as most mammals on this type of task. It was concluded that under some circumstances reptiles can perform with an efficiency equal to that of many mammals on a successive habit reversal problem. An attempt was made to explain possible causes for the increase in errors midway in testing, but further experimentation is necessary before a definitive explanation can be made.

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## APPENDIX

Performance of Individual Ss in Group C-12 on each Reversal

(Errors/Trials to Criterion)

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
R-0	5/25	8/28	21/69	2/16	4/21	6/34	6/28	2/17
R-1	8/29	10/33	19/39	2/15	3/17	7/39	8/26	6/31
R-2	6/30	3/20	8/33	6/36	5/19	5/23	7/30	10/45
R-3	7/23	5/23	3/20	8/29	2/14	5/18	5/29	3/20
R-4	7/27	3/26	5/30	5/24	5/31	3/19	5/24	5/22
R-5	4/19	4/29	7/25	3/34	1/13	3/21	7/36	9/44
R-6	5/20	4/19	4/26	6/33	4/23	4/26	3/24	2/14
R-7	4/18	2/19	3/21	3/21	1/13	2/23	6/40	9/34
R-8	4/18	3/28	5/26	2/14	3/22	1/13	3/26	5/26
R-9	2/25	7/43	3/26	5/31	4/20	1/13	5/28	5/22
R-10	5/23	4/27	1/13	6/27	3/20	3/19	4/26	5/26
R-11	4/17	6/33	8/38	2/14	2/14	4/25	6/30	14/73
R-12	3/19	4/25	5/27	7/32	5/31	5/29	2/14	6/22
R-13	2/19	23/82	6/22	8/28	3/16	1/13	2/16	4/17
R-14	4/17	4/18	2/18	7/38	5/24	5/20	4/20	2/20
R-15	4/33	3/20	4/24	1/13	4/25	2/18	3/19	4/18
R-16	8/28	3/20	3/17	6/43	5/30	4/20	3/17	3/22
R-17	2/16	9/30	2/22	4/25	1/13	1/13	3/24	6/33
R-18	4/19	3/15	4/25	2/16	5/25	3/27	1/13	3/28
R-19	4/28	13/67	3/24	2/16	1/13	3/20	1/13	3/21
R-20	5/19	6/29	2/15	4/28	4/19	4/20	2/20	3/18

Performance of Individual Ss in Group C-6 on each Reversal

(Errors/Trials to Criterion)

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
R-0	2/10	4/13	6/16	0/6	1/7	2/8	0/6	1/11
R-1	2/9	8/14	2/8	10/20	5/17	4/12	7/15	5/16
R-2	2/9	3/10	4/12	2/8	1/7	8/27	1/7	6/16
R-3	2/12	3/13	3/15	1/7	1/7	5/19	3/11	2/13
R-4	0/6	0/6	7/16	2/11	2/11	2/9	1/7	2/8
R-5	2/9	1/7	1/7	3/10	1/7	2/8	1/7	1/8
R-6	3/13	2/10	3/9	3/10	2/8	8/25	2/10	2/8
R-7	3/12	5/17	2/12	1/7	1/7	3/10	4/15	3/10
R-8	6/16	2/12	3/13	0/6	4/14	5/16	2/9	1/7
R-9	5/13	4/12	4/16	7/24	0/6	5/15	4/11	2/8
R-10	1/7	2/13	5/21	3/11	1/7	7/30	4/10	1/7
R-11	4/17	4/16	3/13	2/13	1/7	1/10	4/14	4/15
R-12	3/16	3/10	2/10	5/17	3/12	4/18	4/22	3/11
R-13	10/18	2/13	7/19	5/19	1/7	9/26	12/35	6/17
R-14	3/12	5/15	3/16	2/9	5/13	4/13	4/15	3/12
R-15	8/25	3/14	4/15	2/9	1/7	1/7	11/23	6/13
R-16	4/17	3/12	2/8	1/7	1/7	3/14	2/10	0/6
R-17	4/22	4/15	4/14	4/20	1/7	1/7	9/20	5/21
R-18	1/7	2/11	2/12	3/11	2/12	5/23	2/12	2/11
R-19	4/10	3/14	3/13	3/15	1/7	7/15	2/11	2/8
R-20	2/13	3/13	3/12	1/9	1/7	2/14	1/7	1/9

#### BIOGRAPHICAL SKETCH

The author, John Taylor Williams, Jr., was born in St. Charles, Missouri on January 31, 1941. He was graduated from Sunset High School in Dallas, Texas in 1959. After having attended Southern Methodist University for two years, he transferred to Arlington State College where he received his Bachelor of Arts degree in 1963. He enrolled as a psychology student in the Graduate School of the University of Florida in 1963 and received his Master of Arts degree in 1965. Since that time he has been working toward the degree of Doctor of Philosophy. During his enrollment at the University of Florida, he has spent a total of eighteen months at the Veterans Administration Hospital in Augusta, Georgia as a psychology trainee and as a research technician.

John Taylor Williams, Jr., is married to the former Linda Carol Gratt. He is a member of the University of Florida chapter of Psi Chi, Phi Kappa Theta, and the Southeastern Psychological Association.





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