THE EFFECT OF OVERTRAINING ON HUMAN
REVERSAL LEARNING

by

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STATEMENT BY AUTHOR

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ABSTRACT

An examination of the overtraining reversal effect (ORE) in humans was made in a successive discrimination task. It has been found with humans and with rats, that in a simple discrimination task, fewer errors occur in reversal of the original task under conditions of overtraining than when the Ss have learned the task to a criterion.

In this study, 54 college students were presented with pairs of digits, either odd (11, 33, 13, 31) or even (22, 44, 24, 42). In original acquisition the verbal response "right" was reinforced for the even pairs and "left" for the odd pairs.

There were two reinforcement groups: NB (n = 36), which had a green light presented for correct responses only; and B (n = 18) with a green light presented for correct responses and a buzzer presented for incorrect responses. Each group was divided into 3 equal sub-groups of levels of original training: Criterion (C) with 8 out of 10 responses correct, Overtraining A (OTA) with 13 out of 15 responses correct, and Overtraining B (OTB) with 18 out of 20 responses correct. Upon completion of original acquisition, the task was reversed and the number of trials to correct consistent reversal (first correct response in a series of 18 out of 20 correct) was recorded.
The overtraining reversal effect was found to occur in a human successive discrimination task. It appears to begin at the first overtraining level and the effect is practically asymptotic from that point on. Under conditions of overtraining there was no effect due to the reinforcement conditions, but the buzzer condition (Group B) suffered a decrement at the criterion level of training. A possible explanation of the ORE is that the selected cue dimension is more strong in the overtraining conditions thus permitting a faster reversal. The unexpected decrement for Group B at the criterion level was explained in terms of level of drive.
INTRODUCTION

In general, theories of learning have assumed that response strength, and consequently resistance to extinction, is an increasing function of the number of reinforcements. North and Stimmel (1960), the first of a recent series of studies, report results which may seriously question this assumption. They conducted two experiments (one a replication) using rats in a straight alley runway with a differential number of reinforced trials (45, 90, or 135) before the onset of the extinction trials. Their findings suggest that resistance to extinction is not a monotonically increasing function of reinforcement, but that resistance to extinction first increases with overlearning and then decreases.

Similarly, perhaps, studies of habit reversal in simple discrimination tasks have often found fewer errors during reversal when the original task is overtrained. The basic paradigm for habit reversal tasks requires that the subject first be trained to make a discrimination and then to reverse the discrimination. For example, in a black-white discrimination, an approach toward white would be reinforced while a response toward black would not. At some point (often referred to as "criterion") the reinforcement contingencies are reversed and the response toward black is reinforced while the response
A recent review of the effect of overlearning on habit reversals in rats (Paul, 1965), reports 13 published experiments showing a facilitative effect of overtraining on reversal, and 19 published experiments which fail to show facilitation. Paul reports that the weight of evidence suggests that the overlearning reversal effect (ORE) is more likely to be found for visual discrimination tasks than for spatial or position discrimination tasks.

An early study of the ORE was reported by Reid (1953) in a simultaneous discrimination. He trained rats in a Y maze on a black-white discrimination with three levels of learning (criterion - with 9 out of 10 responses correct, 50 reinforced overlearning trials, or 150 reinforced overlearning trials) and found that the rats given the 150 overlearning trials learned the reversal more quickly than did the animals trained to criterion or criterion plus 50 trials. Reid interpreted the results in terms of a discrimination response hypothesis. During overlearning, the rat learns a response of discrimination (learning to respond to a set of stimuli of which the specific stimulus is a member) which was not present at the outset of learning. Reid assumes that the response of discriminating transfers to the reversal problem with a facilitatory effect and because this response has greater resistance to extinction in Ss receiving overlearning than in Ss at criterion, the ORE is explained. Reid's findings and interpretation
were corroborated by Pubols (1956).

The above findings have been also confirmed by Birch, Ison, and Sperling (1960) who trained rats in a successive situation. The rats traversed a straight alley runway. The approach to a white platform was reinforced while approach to a black platform was not reinforced. The criterion group was trained until all responses to white were faster than the fastest response to black (in one day of training), and then was reversed; the overtraining group received 12 additional days of training before reversal.

Birch et al., suggest that conditions imposed by single stimulus presentation in a successive discrimination effectively rules out Reid's interpretation because a "response of discriminating" requires a simultaneous discrimination task. They feel that this is true because all stimuli in a single stimulus presentation are not present on each trial, thus the subject does not have the opportunity to make a direct comparison for discrimination and the importance of complex receptor orientating acts is minimized. Birch et al., do not refute the fact that this factor may be in operation in the simultaneous discrimination, but they do suggest that it is not a sufficient explanation of the ORE in the successive situation.

Capaldi and Stevenson (1957), using a T maze, trained rats on a black-white discrimination to a criterion of 7 out of 8 trials correct (Group I). Two levels of overlearning were used; Group II was trained
until 8 additional correct responses were made and Group III was trained for 43 additional correct responses. Each group was reversed upon reaching their criterion. An inverse relation was found between the degree of training and the errors during the reversal: Group III learned the reversal significantly faster and with fewer errors than did Groups I or II. The results were interpreted in terms of the hypothesis that the rate of extinction of the original stimulus-response relationship is a function of the degree to which the pattern of reinforcement is changed upon reversal of the training problem. In other words, the criterion group has a history of partial reinforcement while the overtrained group has a longer period of reinforcement before reversal; therefore, a change in problem is more readily discriminated and extinction of the formerly correct response is faster following overtraining than it is during earlier stages of learning.

Mackintosh (1963) examined the effect of irrelevant cues and overtraining on reversal learning. He used 24 rats which were trained on a brightness discrimination with either zero or 150 overtraining trials and then immediately reversed. For one group, only one irrelevant cue (position) was present throughout the experiment. The other group learned the reversal with orientation (horizontal or vertical) as the second irrelevant cue. Greater facilitative effect of overtraining on reversal learning was found when two irrelevant cues were present than when only one irrelevant cue was present. Mackintosh interpreted
the results as suggesting that the effect of overtraining is to increase
the probability that responses will be controlled during reversal by the
relevant stimulus dimension. He reports that the interpretation of this
and the results of two previous experiments, are consistent with the
two-stage model suggested to him by Sutherland:

"First an analyzer specific to the relevant stimulus
dimension is switched in, and secondly, approach and
avoidance responses are attached to the outputs of the
analyzer representing the positive and negative stimuli.
Overtraining is assumed to have the effect of strengthen-
ing the first process so that the analyzer remains
switched in after the overt choice responses have been
extinguished, thus insuring that the problem will still
be solved in terms of the relevant dimension."

In 1959, Stevenson and Weir examined the effect of overtraining
and delay on the learning of a reversal in humans. They used 90 sub-
jects (6 to 8 years of age) in a 3 choice discrimination problem in which
colors (red, yellow, or blue) were presented on a milk glass screen.
The color indicated which one of 3 drawers would contain a wooden peg
which would lead to reward. The Ss were trained to 6 consecutively
correct responses within a maximum of 72 trials. There were 3 im-
mediate reversal groups: 1-I, which was reversed upon reaching
criterion; 2-I, which was reversed after 36 overtraining trials; and
3-I, which was reversed after 72 overtraining trials. There were 3
additional groups, with corresponding training, which received a 24
hour delay before reversal. They found that increased training had no
facilitatory effect on reversals. However, the delay did facilitate
reversal (measured by number of trials to criterion of 6 correct). The authors hypothesize that overtraining has the greatest effect when motivation is low, and that throughout their experiment, the children enjoyed the task and were highly motivated to please the experimenter.

Youniss and Furth (1964) report an experiment designed to replicate, in part, the study by Stevenson and Weir. Instead of spatial responses, they used one-digit numbers as the response to colored stimuli cards. The Ss were third grade students (7 to 9 years of age). The criterion for original acquisition was again 6 consecutive correct responses with a maximum of 72 trials. In the reversal conditions, Group CR-IM reversed immediately after criterion, Group OT-IM was given 18 overtraining trials before reversal, Group CR-DE trained to criterion with reversal delayed 24 hours, and Group OT-DE received overtraining with the reversal delayed 24 hours. The results showed that both the overtraining and the delay facilitated reversal of the original task. The authors interpret the facilitation of overtraining according to the discriminable change hypothesis (Capaldi and Stevenson, 1957), that is, with overtraining, the reinforcement change following reversal was more clearly discriminable for the overtrained groups than when reversal followed criterial training.

Some doubt remains concerning the validity of the ORE. It appears that the nature of the task and the type of species examined are factors which may influence the presence of a facilitory effect of
overtraining on reversal. The purpose of the present study was to
determine if overtraining could be found to facilitate reversal of a
successive discrimination task in adult humans. From a pilot study,
two important considerations became apparent. First, if the task is
made too simple, adults will learn in very few trials and reverse
almost immediately, thus precluding the appearance of the ORE.
Second, if the task is too difficult, acquisition will require more
time, for many Ss, than practical considerations will allow. In order
to control for the first problem, a task of discriminating the oddness
or evenness of digit pairs was chosen. The oddness or evenness of
the digit pairs was embedded in a number of irrelevant cues (reported
by Ss to be: actual digit number, position, alternation, and a combina-
tion of these) which tend to make the task more difficult. A selection
of reinforcement parameters attempted to overcome the second problem.
Two conditions of reinforcement were utilized, one with only a positive
reinforcer and a second with both positive and negative reinforcer, in
hopes that the number of subjects failing to learn the original task
would be reduced by the second condition.
METHOD

Subjects

The Ss were 79 students enrolled at the University of Arizona. Of the total, 25 did not reach the acquisition criterion within 100 trials and were eliminated for failure to learn the original task. The remaining 54 Ss were divided by sex at a ratio of 7 females to 5 males, with a mean age of 20.2 years (range 17 to 37 years). None of the Ss had previous experience with experimental learning tasks and were totally naive to the task under examination.

Apparatus

The Bisensory Unilateral Response Processor (BURP), described by Chambers and Bartlett (1962), is an electronic logic device capable of presenting a series of paired stimuli in a pre-programmed sequence of order and interval. Connected to the BURP was an aluminum subject display panel 10 1/2 inches wide by 17 inches high, through which shone two miniature Nixie tubes (1/2 inch diameter, Model 7009), horizontally separated by 1 3/4 inches (Figure 1). These Nixie tubes presented a randomized series of digits, either odd (11, 33, 13, 31) or even (22, 44, 24, 42) and were controlled in stepping rate by E. A 1 inch diameter green jewel reward light, controlled
Figure 1. Subject display panel.
by $E_s$ was flush mounted on the face of a 4 inch by 4 1/2 inch by 2 inch aluminum box affixed to the top of the display panel. A Kiho electric horn, No. 1390, of presumed noxious tone, also controlled by $E$, was mounted behind the display panel.

The $S_s$ isolated from $E_s$ was seated in a small air conditioned sound proof room (Figure 2). A one way, triple plate window in one side of the room allowed $E$ to continually observe $S_s$ and an intercommunication system in $S_s$'s display panel allowed $E$ to monitor $S$ while allowing "pushing-to-talk" capability for $E$.

**Procedure**

There were two reinforcement groups: Group No-Buzzer (NB) ($n = 36$), which had a green light presented following a correct response only; and Group Buzzer (B) ($n = 18$) which had a green light presented following a correct response and a buzzer presented following an incorrect response. Each group was divided into three equal treatment groups corresponding to the levels of acquisition training of the original task: Criterion (C) requiring 8 out of 10 responses correct, Overtraining A (OTa) requiring 13 out of 15 responses correct, and Overtraining B (OTb) requiring 18 out of 20 responses correct. In effect, the data indicated that the overtraining groups could be considered as $C$ plus 5 correct responses and $C$ plus 10 correct responses.
Figure 2. Floor plan for subject's chamber and experimenter's room.
In original acquisition, the verbal response "right" was positively reinforced for the even pairs and "left" for the odd pairs. Upon completion of the original acquisition phase, the task was reversed (response "right" was reinforced for the odd pairs and "left" for the even pairs) and the number of trials to correct consistent reversal (first correct response in a series of 18 out of 20 correct responses) was recorded.

At the beginning of the experimental session, which lasted approximately 30 minutes, the subjects were read a standard set of instructions. These instructions were as follows:

You will see a series of paired numbers. There is something about the numbers that will tell you a side to choose, either the right side or the left side. Each pair of numbers will be presented for a short duration; as soon as you have decided if the numbers are "right" numbers or "left" numbers, you must immediately say either "right" or "left." It is possible to make a correct choice for every pair. If your choice is correct, you will see a green light. If your choice is incorrect... you will see no light (reinforcement Group Nb) ... a buzzer will sound (reinforcement Group B). Your task is to make as many correct choices as you possibly can. Are there any questions?
If any questions occurred, they were answered by paraphrasing the original instructions.

Reinforcement immediately followed a response with the green light remaining "on" after a correct response until the next stimulus pair was presented. For Group B, the buzzer remained "on" after an incorrect response for 3 seconds. The stimuli remained "on" until the subject made a response and there were approximately 12 seconds between stimuli during which time the E recorded the response on preprinted data sheets.
RESULTS

To evaluate training performance, a 2 x 3 analysis of variance of the original task was calculated. The main effects and interaction were not significant, showing equivalence between the groups during original acquisition.

The primary data were the number of trials to reversal as a function of the type of reinforcement and the three levels of training. The mean trials to reversal for Group NB were: C, 10.33; OTa, 5.25; and OTb, 3.91. For Group B the means were: C, 25.83; OTa, 4.83; and OTb, 4.83. Figure 3 graphically shows the mean number of trials to correct reversal as a function of the level of training and the presence or absence of the buzzer. Table 1 summarizes a 2 x 3 analysis of variance which shows that the effect of the levels of training was significant (P < .001), as was the reinforcement group effect and the level of training x group interaction (P < .05).

Table 2 summarizes the two orthogonal comparisons which were used to independently test the effect of the levels of training on each of the reinforcement groups. The criterion vs. the overtrained groups comparison was significant for both Group NB (P < .005) and Group B (P < .01). The Overtraining A vs. Overtraining B comparison was not significant for either reinforcement group.
Figure 3. Mean number of trials to correct reversal as a function of level of training and type of reinforcement.
LEVELS OF TRAINING

MEAN TRIALS TO REVERSAL

- NO BUZZER
- BUZZER

C (8/10)  OTa (13/15)  OTb (18/20)
### TABLE 1. Summary of Analysis of Variance for Reversal.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of training (A)</td>
<td>1415.45</td>
<td>2</td>
<td>707.72</td>
<td>9.41</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Type of reinforcement (B)</td>
<td>341.34</td>
<td>1</td>
<td>341.34</td>
<td>5.53</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>A x B</td>
<td>623.69</td>
<td>2</td>
<td>311.84</td>
<td>4.15</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Within cells</td>
<td>3610.36</td>
<td>48</td>
<td>75.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5990.84</td>
<td>53</td>
<td></td>
<td></td>
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</table>

### TABLE 2. Summary of Orthogonal Comparisons for Reversal.

<table>
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<tr>
<th>Source</th>
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<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Buzzer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>275.16</td>
<td>2</td>
<td>137.58</td>
<td>7.16</td>
<td>&lt;.005</td>
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<tr>
<td>C vs. OTa-OTb</td>
<td>264.50</td>
<td>1</td>
<td>264.50</td>
<td>13.78</td>
<td>&lt;.005</td>
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<tr>
<td>OTa vs. OTb</td>
<td>10.67</td>
<td>1</td>
<td>10.67</td>
<td>.56</td>
<td>NS</td>
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<tr>
<td>Within Groups</td>
<td>633.84</td>
<td>33</td>
<td>19.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>909.00</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Buzzer</td>
<td></td>
<td></td>
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<tr>
<td>Between Groups</td>
<td>1764.01</td>
<td>2</td>
<td>882.00</td>
<td>4.44</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>C vs. OTa-OTb</td>
<td>1764.01</td>
<td>1</td>
<td>1764.01</td>
<td>8.89</td>
<td>&lt;.01</td>
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<tr>
<td>OTa vs. OTb</td>
<td>0.00</td>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>NS</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2976.52</td>
<td>15</td>
<td>198.43</td>
<td></td>
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<tr>
<td>Total</td>
<td>4740.50</td>
<td>17</td>
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DISCUSSION AND CONCLUSIONS

The results showed that fewer trials were required to learn the reversal with overtraining than with criterion training. No increased facilitation occurred with increased overtraining within the overtraining limits examined. It may then be concluded, that for this study, utilizing a successive discrimination, overtraining did facilitate reversal learning up to a point. Beyond this point, however, further overtraining has no facilitative effects upon reversal.

Although the type of reinforcement was a significant variable, this appears mainly to be due to an unanticipated decrement in reversal performance for the buzzer group at the criterion level of training. The presence or absence of the buzzer had little or no effect on the overtrained groups (Figure 3). This interpretation was borne out by the significant interaction of the reinforcement and training variables. That is, the interaction indicated that the effect of the buzzer depended upon the level of training.

Observation of the Ss during the experimental session and the Ss' subjective reports upon completion of the session indicates that during acquisition of the original problem, stimulus dimensions (cues) are sampled until the correct dimension is selected and the correct response is associated with it. It was noted from Ss reports, that the
selection of the correct dimension and response was tentative at first, due to the chance reinforcement of responses to irrelevant cues previously selected. With continued utilization of the relevant dimension, the S's association of the relevant dimension with reinforcement becomes stronger as does the correct response. Subjects at Level C report that during original acquisition they became relatively confident that the relevant dimension was oddness-evenness. However, upon reversal and a subsequent number of unreinforced responses, they again sampled other dimensions before returning to the relevant dimension. This occurred because the non-reinforcement upon reversal made the relevant dimension more difficult to distinguish from previously incorrect choices of cue dimensions. Unlike Ss in Level C, Ss in both overtraining groups were more "confident" in their choice of the relevant dimension. Upon reversal and subsequent non-reinforcement, they retained the odd-even dimension and only resampled their response repertoire. During the first few reversal trials, after making the new correct response, the Ss tended to sporadically revert back to the originally correct response for a few trials; but, with continued reinforcement of the reversal response, the reversal was learned rapidly.

This somewhat subjective indication of the learning process supports Sutherland's two stage model of discrimination learning (Mackintosh, 1963). With overtraining, the analyzer is more strongly switched in so that upon reversal, the analyzer remains switched in and
only the response is changed. The discriminable change hypothesis (Capaldi and Stevenson, 1957; Youniss and Furth, 1964) appears to be a necessary adjunct to explain why resampling of analyzers occurs at Level C and not at the overtrained levels. At Level C, the Ss cannot easily distinguish the chance reinforcement of an incorrect analyzer selection that occurred prior to the selection of the correct analyzer, from the selection of the correct analyzer and the subsequent non-reinforcement upon reversal. Thus, a new analyzer is switched in.

The overtraining groups are better able to discriminate between correct and incorrect analyzers and thus retain the relevant analyzer with only a response change during reversal.

Although the ORE was observed for both reinforcement groups, it is of interest that Group B had such difficulty in learning the reversal at the criterion level of training. As previously noted, this result was quite unexpected. However, if it is assumed that the buzzer (Group B) produced a state of higher drive than the absence of the buzzer (Group NB), then a basis for the decrement of Group B at the criterion level of training may be given by Spence's (1958) theory of emotionally based drive. He predicts that when the habit strength of a correct response is weaker at the beginning of learning than the habit strength of an incorrect response, performance under conditions of high drive will then be poorer than under conditions of low drive. As training proceeds, however, the habit strength of the correct
reinforced response will increase and become greater than the strength of the incorrect unreinforced response. From this point on, as learning progresses, Spence predicts that there should be more correct responses under conditions of high drive than under conditions of low drive.

Since there is only one relevant dimension and numerous irrelevant dimensions, the response tendencies toward the irrelevant dimension taken collectively will be stronger than the response tendency toward the single, relevant dimension at the outset of learning. Following Spence's argument, Group B should make more incorrect responses, during original acquisition, at the criterion level than Group NB, while with further training the number of incorrect responses should be approximately equal for the two reinforcement groups. Although the overall differences in errors during original acquisition were not significant, at the criterion level the Ss in Group B did indeed make significantly more errors than the Ss in Group NB (t = 2.274, d.f. = 16, P < .05).

In terms of Sutherland's theory, at the criterion level of training, the analyzer for Group B, weakly switched in to begin with, will be even less strongly switched in for Group NB. With overtraining the analyzer for both groups should be switched in to approximately the same degree. In the reversal condition, Group B should reverse more slowly than Group NB at the criterion level of training because of
greater resampling of analyzers, caused, perhaps, by the higher level of drive. With overtraining Group $B$ should equal to or better than Group $NB$. The results were consistent with this interpretation.

Also consistent with these findings is the discriminable change in reinforcement hypothesis. Group $B$, with a greater number of incorrect responses at the criterion level would reverse more slowly than Group $NB$ because there would be an even less discriminable difference between original training and reversal.

In general, the results of this experiment indicated that overtraining facilitated reversal of a successive discrimination problem under two types of reinforcement conditions. The findings are in agreement with previous studies which found evidence for a facilitative effect of overtraining on reversal in humans (Youniss and Furth, 1964) and in rats (Paul, 1965).
REFERENCES


