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THE EFFECT OF AUGMENTED FEEDBACK ON THE ACQUISITION AND TRANSFER OF A TRACKING SKILL

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

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The Ohio State University
1960

Approved by:

[Signature]  
Advisor

Department of Psychology
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INTRODUCTION

A major hindrance to progress in the field of psychology is inadequate description of behavioral events. Description encompasses both the definition, cataloguing or classification of events and statements regarding empirical relationships associated with these events. Although empirical relationships are continually being investigated by experimental and observational procedures, little effective progress can be made without an adequate taxonomy. This is particularly evident in the problem area variously labeled knowledge of performance, or knowledge of results.

Even the specification of the general area is obscure. Miller (1953) regards knowledge of results as any event following a response which S can consider as a consequence of his response. A more restrictive definition holds that knowledge of performance is any information concerning the effectiveness of a response, or set of responses, which is added to the information contained in the task environment. The latter definition is more consistent with general usage than the former. However, even when the more restrictive definition of the problem area is accepted, a considerable amount of tautology concerning classifications within the area remains.

Brown (1949) refers to two types of feedback within the area of knowledge of results: motivational and informational feedback. When S is operating in a task environment, he usually has some opinion
concerning what constitutes "good" or "bad" performance. Also, S usually has some notion, provided by his own background, of how adequately he can perform in a task situation. The S can measure, then, his subjective impressions as to how well he is doing against his level of aspiration while operating in a task situation. When the information which is fed back to S has evaluational or personalized meaning, it is termed motivational feedback. However, the information which is fed back to S usually contains an error signal, or directive component. When the information presents error information, it is termed informational feedback.

Annett and Kay (1957) also take S's subjective impressions into account in their two information-source classification of the area. According to this classification, subjective impressions about the effectiveness of performance are referred to as intrinsic sources of knowledge of results. Extrinsic sources of knowledge of results are either supplied directly by E or through additional feedback-loop circuits. Implied in the definition of an extrinsic source of knowledge of results is the assumption that this information has a directional component. Therefore, the terms intrinsic and extrinsic sources of knowledge of results and the terms motivational and informational feedback essentially refer to the same distinction.

Miller (1953) distinguishes between action feedback and learning feedback. Action feedback consists of information which indicates to S what adjustment to make next. Learning feedback is information concerning what adjustment S should have made. That is,
$S$ may receive immediate information concerning the "correctness" of a response (learning feedback) or $S$ may continue to emit responses until he "hits" upon the correct response (action feedback). The primary basis for the distinction between action feedback and learning feedback depends upon whether the information concerning the effectiveness of responses is utilized by $S$ repetitively or only once. If the initial response is correct, the objective distinction between the two types of feedback breaks down. Although Miller convincingly posits different functions for the two types of feedback during a learning situation (learning feedback functions both as a reward and as a source of information while action feedback functions solely as a source of information), the distinction does not appear to be suitable for classification purposes. The reason for this is that in many instances the only way to ascertain whether the information is being utilized as action or learning feedback is to employ the subjective reports of $S$.

Several other distinctions, while not intended as comprehensive, have been made in this area. Bilodeau (1952), who employed a simulated gunnery tracking task, refers to a change in the color of the target when $S$ is tracking appropriately as supplemental information feedback. Morin and Gagne (1951) refer to the identical operation as psychological feedback. In a simple compensatory tracking task, Smode (1958) refers to auditory clicks when $S$ is "on target" plus a visual display of time on target scores as high achievement information feedback. Obviously, there is no distinction between psychological feedback and supplemental information feedback, since both refer to the
identical operation. Moreover, Houston (1947) has demonstrated that there is no statistical, or apparent difference between giving only an additional "on target" cue and giving both an "on target" cue and a cumulated time "on target" score. Therefore, it appears that there is no real distinction between psychological feedback, supplemental information feedback, or high achievement information feedback.

It follows from the foregoing discussion that the available classification systems are not exhaustive and contain considerable functional overlap. Most of these classifications are based on the assumed function of "additional" information. A classification of the area, based on the employment of the additional information in a particular type of task environment, will be presented below.

Knowledge of performance may serve as a primary source of information in a task environment where all other cues regarding appropriate responding are reduced to a minimum. When knowledge of performance is employed in this manner, it is labeled primary feedback. The usage of primary feedback is illustrated in an experiment by Bilodeau (1952). In this experiment, S's task was to turn a micrometer knob to a target reading when the scale was concealed from his view. After S had responded, E provided knowledge of performance which was derived from the scale. Since S had no other information regarding the consequences of his responses in this environment, he could not adequately modify his behavior without primary feedback. In other words, S would be operating in an open-loop system when primary feedback was unavailable. Other tasks
employing an open-loop situation in which primary feedback variables have been investigated are: line-drawing (Greenspoon and Foremand, 1956), ball-tossing (Lorge and Thorndike, 1935), and dart-throwing (Alexander, 1950). In each of these task environments, absence of fundamental feedback prohibited accurate responding.

Knowledge of performance can serve also as a secondary source of information when it is employed in a task environment which contains sufficient information for high-level performance. Knowledge of performance in the form of quantitative scores may be employed to summarize the effectiveness of a series of responses. When knowledge of performance is utilized in this manner, it is labeled summary feedback. An example of the use of summary feedback is provided in an experiment by Book and Norvelle (1922). School children were required to, among other tasks, write a series of legible a's as rapidly as possible. Obviously, all the information for performing the task at a high-level was present in the task situation. However, when summary feedback in the form of the number of appropriate responses was available, Ss performed at a higher level than when it was not available. In other words, Ss were performing in a closed-loop system, and summary feedback information facilitated this performance.

An additional use of knowledge of performance as a secondary source of information occurs when non-quantitative information is presented during performance in a task environment which contains sufficient information for high-level performance. Knowledge of performance, when utilized in this manner, is labeled augmented
feedback. The usage of augmented feedback is illustrated in an experiment by Reynolds and Adams (1953). The task required S to track the metal disc on a pursuit-rotor with a pointer. In this situation, both the target and the pointer were clearly visible to S. Augmented feedback consisted of auditory clicks when S's pointer was on the target. It is clear that this task environment is a closed-loop system, even when the augmented feedback (auditory) signal is absent: in this task, S could clearly see when the pointer was on the target and the information contained in the auditory clicks merely augmented that contained in the visual display. Even though high-level performance was possible in the absence of augmented feedback, the presence of the additional signal facilitated performance. This facilitory effect of augmented feedback on performance has been obtained in other closed-feedback-loop systems, such as The Pedestal Sight Manipulation Test (Houston, 1947), The Rudder Control Test (Gagne and Bilodeau, 1954), and the OSU Simple Electronic Tracking Apparatus (Smode, 1958).

Since performance is facilitated when knowledge of performance is available in both an open-loop system and a closed-loop system, it has been generally accepted that the function of knowledge of performance is similar in both systems. The fact that accurate responding without primary feedback in an open-loop system is impossible has been ignored. Also, it has been demonstrated (Houston, 1947) that summary feedback and augmented feedback have a different effect on performance during the acquisition of a tracking skill. The presentation of augmented feedback enhanced tracking performance more
than presentation of summary feedback (as mentioned earlier, however, there is no difference between augmented feedback alone and augmented feedback plus summary feedback). These considerations have led to the belief that the three types of feedback differ as to their function and their relevance to certain problems. Findings regarding primary feedback are related to display design problems. That is, primary feedback is analogous to Brown's informational feedback, and components of motivational feedback are reduced to a minimum. This extrinsic source of knowledge of performance is typically utilized as learning feedback. Knowledge of the variables related to primary feedback is essential for the determination of what information is necessary before a task can be performed satisfactorily. Findings regarding summary feedback are primarily related to incentive or motivational problems. Since the information contained in summary feedback has a minimum error component, it is analogous to Brown's motivational feedback. The value of summary feedback is that it influences performance where skill level is near an asymptotic level. Augmented feedback has direct implications for training problems. Although the function of the additional feedback is not explicit, it is probable that this extrinsic source of feedback contains both motivational and informational components. It may be utilized by $S$ either as action feedback or learning feedback in a training situation. It should be noted that the specification of the type of feedback is contingent upon defining the task environment as being either an open-loop, or a closed-loop environment. In certain task environments, this may be difficult to do and the function
of knowledge of results in this environment may have to be established empirically.

The function of an additional signal indicating an appropriate set of responses during the acquisition of a continuous tracking skill (augmented feedback) has been explained by such concepts as motivation (Smode, 1958), reinforcement (Minor, 1958), and as a source of information or a "psychological crutch" (Bilodeau, 1952). While there is considerable theoretical speculation in the area regarding the function of augmented feedback, there is little empirical knowledge concerning the relation between augmented feedback variables and changes in performance during training. Further, although augmented feedback has generally been shown to have a facilitory effect on performance, there have been a few exceptions (Archer and Namikas, 1958) (Archer, Kent and Mote, 1956). These two factors, limited empirical knowledge and exceptions to the usual findings, indicate that the application of specific concepts regarding the function of augmented feedback are probably premature.

A more general interpretation of augmented feedback is that it serves as an instructor surrogate during training. The instructor provides information and commendation in a training situation. In addition to other functions, the instructor also programs the complexity of the input and evaluates performance. Augmented feedback serves as an instructor surrogate in that it provides information and commendation. As a source of information, augmented feedback may clarify the specific goals of a task. Although these goals may be stated
explicitly in the instructions, S probably has a clearer conceptualization of them after he has received information which tells him when he is approaching these goals while participating in the task. Moreover, augmented feedback may expedite the separation of relevant and irrelevant cues in the task environment by emphasizing the responses which produce the additional signal. It can be assumed also that where there is some ambiguity regarding the exact location of the target, S will utilize the augmented feedback signal in order to reduce this ambiguity. As a source of commendation, augmented feedback may increase the effort which S makes in order to obtain the signal. Part of this greater effort may be due to an influence on S's morale. That is, the task becomes intrinsically more interesting when augmented feedback is available in much the same way that the flashing lights and clanging bells on a pinball machine induce people to continue playing and paying even though no monetary rewards are offered.

The present research was intended to contribute empirical data to this problem area. The research was accomplished in a series of four interrelated experiments. The first experiment concerned the effect of different fixed target sizes for the activation of augmented feedback on the acquisition of a simple compensatory tracking skill. The second experiment concerned a comparison of performance during training under a fixed quantity of augmented feedback and under conditions in which the quantity of augmented feedback was proportional to skill level. The third experiment concerned transfer performance level when the target tolerance for the activation of augmented
feedback was changed after a period of training from one fixed error tolerance to different fixed error tolerances. The fourth and final experiment concerned transfer performance when augmented feedback was withdrawn after training. The latter experiment is an attempt to account for a performance decrement which can occur following removal of augmented feedback. Although the primary purpose of the research was to contribute empirical information, the particular variables investigated were related to the assumption that augmented feedback functions as an instructor surrogate.
EXPERIMENT I

ACQUISITION OF A TRACKING TASK WHEN DIFFERENT TARGET SIZES
ARE EMPLOYED FOR PRESENTING AUGMENTED FEEDBACK

Introduction

This experiment concerns the effect of different fixed target sizes on the acquisition of a simple compensatory tracking task. The size of the "on target" area is defined as an error tolerance within which augmented feedback, in the form of auditory clicks, is presented. It is predicted that, when the error tolerance is very broad, augmented feedback will be so easy to obtain that performance will approach an asymptote at a lower level of proficiency than when augmented feedback is less accessible. That is, although the augmented feedback will initially contribute a relatively large amount of information and commendation, as skill progresses the augmented feedback signal will be obtained so frequently as to become relatively ineffective, both as a source of information and as a source of commendation. On the other hand, when the error tolerance is narrow, it is predicted that during the initial trials augmented feedback will not be particularly effective, since it will be obtained so infrequently that it will provide little information and commendation. However, as skill progressively improves, S is expected to continue to increase the amount of augmented feedback he receives under a narrow error tolerance condition, and his proficiency will also continue to improve. That is, a narrow error
tolerance represents a stringent criterion for the commendation and $S$ is expected to strive to increase this commendation. It was further predicted that augmented feedback will have a facilitory effect, regardless of the size of the error tolerance. That is, it is expected that the presence of augmented feedback will produce a higher level of proficiency than the absence of augmented feedback.

**Method**

**Apparatus**

A one-dimensional electronic compensatory tracking instrument (SETA) was utilized in the experiment. This device has been described in detail by Gain and Fitts (1959). The tracking input problem was generated by a cam, driven by a constant-speed motor. Rotation of the cam activated a rocker arm to change a potentiometer which caused deflections of a cursor from a null position on the tracking display. The tracking display was a zero-centered voltmeter $2-1/4 \times 4$ in. in size and located approximately 18 in. in front of $S$ at a 45-degree angle below $S$'s horizontal line of sight. Positional control of the excursions in the tracking task was provided by a control knob 1 in. in diameter, located below and to the right of the compensatory tracking display.

The waveform of the cam-generated tracking input corresponded to a fundamental with a 6-cpm frequency and a harmonic with a 12-cpm frequency in phase with the fundamental, and the amplitude ratio of these two components was 10:8. The tracking input can be specified
as \( E = 10 \sin wt + 8 \sin wt \), where \( E \) is angular degrees of cursor deflection on the display, \( w \) is \( 0.6283 \) radians/sec., and \( t \) is the time in seconds. A constant-speed motor was used in a timing circuit which automatically stopped each problem at the end of 30 sec. In order to eliminate the usual transients in tracking performance which occur at the beginning of each trial, the measurement of tracking error was initiated 5 sec. after the start of each trial.

Augmented feedback was presented to \( S \) through a loudspeaker. A sensing device, which could be adjusted for any desired bandwidth, operated a relay when the error voltage fell within the tolerance level set by \( E \). Operation of the relay closed the loudspeaker circuit, which amplified a click caused by the action of a micro-switch. The micro-switch was operated throughout each tracking trial every 0.5 sec. by the cam of a constant-speed motor.

The measure of performance was integrated absolute error. The error voltage was fed into a conventional DC amplifier which translated error into absolute values which were then integrated by a second operational amplifier. The number of augmented feedback signals presented during each trial, usually termed time on target (TOT), was recorded also.

Subjects

Sixty paid volunteer female undergraduate students were randomly assigned to one control and three experimental groups. Females were used for several reasons, principally because females are
more naive concerning motor skills than males, and therefore, should produce better indications of trends during the initial acquisition of skilled behavior.

**Experimental procedure**

The specific purpose of the first experiment was to determine the influence of different fixed error tolerances (for the activation of augmented feedback) on the acquisition of a perceptual-motor skill. From a pilot study, it was possible to determine the error amplitude distribution for female Ss on the initial training trials. Given this information, it was possible to select, via a table of the normal probability integral, error tolerances to provide the average S with augmented feedback signals for any proportion of a tracking trial. Four such error tolerances were selected (a) a broad error tolerance group (Group B) which received the augmented feedback signal approximately 68% of the time during the initial trials, (b) a medium error tolerance group (Group M) which received augmented feedback approximately 51% of the time during the initial trials, (c) a narrow error tolerance group (Group N) with augmented feedback present approximately 34% of the time during the initial trials, and (d) zero augmented feedback (Group C) which served as a control procedure. It is apparent that the error tolerances for Groups N, M, and B were selected so as to cover ± .50, ± .75, and ± 1.00 standard deviation of the initial error amplitude distribution. Further, it is apparent from a study by Bahrick, Fitts, and Briggs (1957) that as training continues, the
amplitude distributions become more leptokurtic, and since the error
tolerance for a given group was fixed throughout training, S could
receive more and more augmented feedback as skill was attained.
Theoretically, at least, all Ss eventually could receive augmented
feedback 100% of each trial duration. However, this was not expected
to occur in the present study due to the limited training period.
The same initial instructions were read to each S, who was
told that when the problem began, the control knob should be continu­
ously turned in order to keep the cursor of the tracking display
centered on zero. The S was further told that a click would be heard
when the cursor was close to zero, but this click indicated only
minimal proficiency and that zero error was the ultimate goal in the
task. The latter instructions concerning the clicks were omitted for
Ss in Group C who received no augmented feedback. Before each session,
all Ss were reminded that the ultimate goal in the task was zero
error.

Four 15-minute training sessions were completed over four
successive days. Ten training trials were completed on the first day;
15 training trials were completed on the second and third days, and 10
trials were completed on the last day, making a total of 50 trials
during the training period. Each trial lasted for 30 sec. with a
20-sec. rest interval between trials. The Ss were not given any
quantitative indices of their performance until they completed the
last training session.
Results

The major results are summarized in Figure 1 where tracking proficiency, measured as root mean square (RMS) error on S's display, is shown as a function of practice. Each point in this figure is the mean of ten 30-sec. trials for each S, averaged over the 15 Ss in each group; therefore, each block of 10 trials represents a 75-min. sample of tracking proficiency. The RMS error on S's display was derived from the integrated absolute error scores, which were converted from voltage units to units of linear extent (inches). Since these scores may be considered as average deviations, this measure was multiplied by the constant 1.2532 to yield RMS error in terms of inches on S's display.

A preliminary analysis of variance and the Duncan Range Test established that the difference between Group C and the experimental groups is statistically significant at $P < .01$ for all blocks. This was expected on the basis of previous research where the general finding is that groups provided with augmented feedback perform at levels superior to that attained without this additional knowledge of results. Since this has been so well established, the data for Group C were not employed in further analyses of the present research, and comparable control groups were not included in Experiments II and III of this series.

In order to evaluate the predictions made regarding the effect of augmented feedback on acquisition of the tracking skill, an
Fig. 1. The effect of size of error tolerance on acquisition.
analysis of variance was performed on the logarithms of the data for Blocks 1, 2, 3, and 4. The data of Block 5 were not included in this analysis due to the obvious "end spurt." All Ss knew that the Block 5 trials represented their last day in the experiment and apparently most Ss responded with a considerably increased effort at that time. It is felt, therefore, that the data collected on Block 5 are somewhat spurious. As indicated above, only the data provided by the three experimental groups were included in the analysis. The results of the analysis of variance are shown in Table 1. The significant interaction effect (P < .001) for the Blocks x Groups term can be attributed to the differences in the acquisition functions of the three groups. Specifically, as can be seen from Figure 1, Group B did not appreciably improve in skill after the first block of 10 trials; Group M did not improve in skill after the third block; and Group N continued to improve throughout the entire training period. These changes in the acquisition functions resulted in curve for Group M crossing over that for Group B between Blocks 1 and 2; the trend for Group N crossed over that for Group B between Blocks 2 and 3 and over the acquisition function of Group M on Block 4.
Table 1

Results of the Analysis of Variance on Blocks 1, 2, 3, and 4 for Groups M, N, and B

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
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<tr>
<td>Between</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Subjects</td>
<td>44</td>
<td>.148</td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Groups</td>
<td>2</td>
<td>.042</td>
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<td>---</td>
</tr>
<tr>
<td>Error (b)</td>
<td>42</td>
<td>.153</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blocks</td>
<td>3</td>
<td>4.212</td>
<td>183.13</td>
<td>.001</td>
</tr>
<tr>
<td>Blocks x Groups</td>
<td>6</td>
<td>.095</td>
<td>4.13</td>
<td>.001</td>
</tr>
<tr>
<td>Error (w)</td>
<td>126</td>
<td>.023</td>
<td></td>
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</table>

The above results are based on the RMS error metric. While they are not pertinent to tests of the original predictions, it is of interest to note the amount of augmented feedback received by the three experimental groups. These data are summarized in Table 2. The table entries represent the average percent of each 30-sec. trial that the several groups received augmented feedback. It may be noted that with training, all groups experienced an increase in amount of augmented feedback, with Group N showing the largest relative increase, Group M the next largest, and Group B the smallest relative increase. This rank order corresponds to the terminal (Block 4) levels of performance attained by the three groups on the RMS criterion. The implications of this and other results will be discussed in the following section.
Table 2

Mean Proportion of Time On Target and Percentage of Increase from the First to the Last Block

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Relative Feedback Increase From 1st to 5th Block</th>
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<tr>
<td>N</td>
<td>34</td>
<td>39</td>
<td>41</td>
<td>41</td>
<td>46</td>
<td>35%</td>
</tr>
<tr>
<td>M</td>
<td>57</td>
<td>66</td>
<td>68</td>
<td>63</td>
<td>67</td>
<td>18%</td>
</tr>
<tr>
<td>B</td>
<td>70</td>
<td>74</td>
<td>76</td>
<td>75</td>
<td>80</td>
<td>14%</td>
</tr>
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</table>

Discussion

The results wholly support the hypothesis that augmented feedback functions as an instructor surrogate. Each of the predictions based upon this hypothesis was confirmed by the results. The beneficial effect of augmented feedback on the acquisition of the simple tracking skill was dramatically illustrated by the difference between the three groups which received augmented feedback and Group C which did not receive the additional information. For the three groups receiving augmented feedback, it was shown that level of performance does not appreciably improve after the early stages of acquisition when relatively broad error amplitudes (Group B) evoke augmented feedback. It was further demonstrated that performance continues to improve throughout the training period when only narrow error amplitudes (Group N) produce augmented feedback. The trend of the acquisition of tracking skill when medium error amplitudes (Group M) produce augmented feedback shows continual improvement up to the middle stages, where appreciable improvement ceases. It appears, moreover, that there is
a differential effect of the three error bandwidths during the initial stages of acquisition. During the first block of 10 trials, performance was distributed as follows: Group B was the best, Group M second best, Group N third best, and Group C was the worst.

These findings tend to support the interpretation that augmented feedback is both a source of information and commendation. If augmented feedback functions as a commendation from an instructor, it is reasonable to expect that S will initially put forth a greater effort to obtain it if it is readily available (Group B) than if it is relatively inaccessible (Group N). It is reasonable to expect also, that this relationship will be reversed if the Ss who found augmented feedback initially to be relatively inaccessible find that it is increasingly available as training progresses (Group N), and the Ss who found it readily available initially, find later in training that they are receiving it almost constantly (Group B). Also, if augmented feedback functions as information from an instructor, it is reasonable to expect that the frequency and precision of this information would be critical. If the signal is received very frequently for gross errors, the directional value would be low, and if the signal is received very infrequently, the directional value would also be low. It can be assumed that during the initial trials, Group B received a large amount of information, but as skill progressed the signal was obtained so frequently that it contained very little information. On the other hand, although Group N received the signal infrequently during the initial trials, the frequency was increasing throughout training, and
the information which Group N received was very precise, i.e., it did not occur when relatively gross errors were made.

It is important to note that the proficiency levels attained by the three experimental groups at the end of training obviously were not determined by the absolute amount of augmented feedback. Indeed, from Figure 1 and Table 2, it is obvious that on the RMS criterion, the most proficient group, Group N, received the least amount of augmented feedback (46%), while Group B received the greatest amount (80%) on Trial Block 5, and yet Group B performance was inferior to that of Group N.

It is obvious that relative not absolute amount of augmented feedback was the primary determinant of terminal tracking proficiency. From Table 2, it is noted that Group N obtained a 35% increase in amount of augmented feedback from Block 1 to Block 5, while Groups M and B achieved 18% and 14% increases, respectively. Thus, the relative change in percent feedback coincides exactly with the rank order of proficiency as measured by RMS error. From this, one may conclude that predictions of advanced proficiency levels may best be made on the basis of relative change in augmented feedback over the training period.
EXPERIMENT II

ACQUISITION OF A TRACKING SKILL WHEN DIFFERENT CONSTANT OR INCREASING AMOUNTS OF AUGMENTED FEEDBACK ARE EMPLOYED

Introduction

This experiment is concerned with changes of performance when augmented feedback is contingent upon changes of skill, and when amount of augmented feedback remains constant throughout training. When the amount of augmented feedback received by S is contingent upon changes of skill, the amount of augmented feedback will increase at the same rate that skill is attained. That is, when S's skill improves and the error tolerance remains fixed, S will receive a greater number of auditory clicks. The increase in amount of augmented feedback as learning progresses, with a fixed error tolerance, is illustrated in Table 2 of Experiment I. However, when the size of the error tolerance is progressively reduced at the same rate that skill improves, then the amount of augmented feedback received by S will remain constant. Obviously, when a constant amount of augmented feedback is obtained, the size of the error tolerance is contingent upon skill level. As S becomes more skilled, the error tolerance must become smaller.

It was predicted that when a relatively broad error tolerance is progressively reduced concommitantly with skill improvement in such a way that S receives a constant amount of augmented feedback, he will
continue to improve in skill proficiency. However, if a narrow error tolerance is progressively reduced as greater skill is obtained, S will constantly receive relatively small amounts of information and commendation. It is expected, therefore, that such a schedule of augmented feedback is likely to produce an asymptotic level of performance early in training. Further, the predictions made in the first experiment concerning the influence on acquisition of a fixed-broad error tolerance and a fixed-narrow error tolerance, which permits amount of augmented feedback to increase as skill level increases, also are made in this experiment. That is, it is expected that a fixed-broad error tolerance will produce early asymptotic performance, but a fixed-narrow error tolerance will produce continual improvement. In summary, it was predicted that a fixed-narrow error tolerance and a changing-broad error tolerance are expected to produce continued improvement, but a fixed-broad error tolerance and a changing-narrow error tolerance are expected to produce an early asymptotic level of proficiency.

Method

Apparatus

The apparatus was identical to that used in Experiment I, with one exception. In this experiment, augmented feedback was given via Wilson Sound Barrier earphones instead of a loudspeaker. Further, low-level white noise was continuously present in the earphones. This change in apparatus was provided in order to prevent ambient noise from distracting S during tracking.
Since the adjustment of the error tolerance sensing device plays a critical role in this experiment, it will herein be described in greater detail. As was stated earlier, when the error voltage fell within a set tolerance limit, the circuit amplifying auditory clicks became operational. The magnitude of the error voltage sufficient for operation of the augmented feedback circuit could be changed by a variable resistor. A knob with a pointer was attached to this variable resistor and an equal-unit scale was located behind the knob. The range of possible adjustments of the variable resistor is 20 equally-spaced units within an error range of \( \pm 0.25 \) in. on S's tracking display.

**Subjects**

Sixty-four volunteer undergraduate, female students were paid for service in the experiment. These Ss were randomly assigned to four groups. None had served previously in Experiment I.

**Experimental Procedure**

The specific purpose of the second experiment was to compare the influence of a constant proportion of augmented feedback with a changing proportion of augmented feedback on the acquisition of a perceptual-motor skill. The constant proportion of augmented feedback condition required that E change the error tolerance as skill level changed, whereas the changing proportion condition was achieved by fixing the error tolerance at the start of a session and no further changes were made. That is, Bahrick, Fitts and Briggs (1957)
demonstrated that the distribution of error amplitudes becomes progressively more leptokurtic as training continues. Thus, a greater proportion of the error amplitudes would fall between a fixed error tolerance as the distribution became more leptokurtic. However, if the error tolerance was reduced in such a manner as to include only a certain proportion of the error amplitude distribution, increasing leptokurtosis would have no effect upon the amount of augmented feedback received by S.

The constant proportion of augmented feedback was maintained by adjustment of the error-sensing device. When S received a 3% smaller or larger proportion of augmented feedback than the goal value on any trial, the variable resistor knob was turned one unit, thereby increasing or decreasing the error tolerance bandwidth for the succeeding trial. The comparison was made at two error tolerance bandwidths, a broad error tolerance bandwidth and a narrow error tolerance bandwidth. When the proportion changed, this arrangement was a replication of the augmented feedback conditions employed in Experiment I.

Specifically, the four groups were (a) a broad error tolerance-constant proportion augmented feedback group (Group BC) which received augmented feedback approximately 66% of the trial period throughout training; (b) a broad error tolerance-increasing proportion augmented feedback group (BI) which initially received augmented feedback approximately 66% of the trial period, but which could increase this feedback as skill increased; (c) a narrow error tolerance-
constant proportion augmented feedback group (Group NC) which received augmented feedback approximately 33% of the trial period throughout training; and (d) a narrow error tolerance-increasing proportion augmented feedback group (NI) which initially received augmented feedback approximately 33% of the trial period, but received a greater proportion as skill increased.

The same instructions and trial scheduling used in Experiment I were repeated in this experiment. In the present experiment, however, S was not aware of when the training session would end; instead, they were scheduled for participation in this and other research for a total of seven days. This was done in order to eliminate any tendency for an end spurt in tracking such as noted earlier in Experiment I.

Results

The major comparisons are presented in Figure 2 where tracking proficiency, measured by the RMS error metric, is shown as a function of practice. Each point in this figure is the mean of ten 30-sec. trials for each S, averaged over the 16 Ss in each group, a total of 80 min. of tracking.

From visual inspection of the trends displayed in Figure 2, it is apparent that none of the groups had approached an asymptotic level of performance over the final training trials. This limits the generality of the findings, since there is no way of knowing which of the conditions would produce the best terminal proficiency level.
Ten-Trial Blocks

2 * Acquisition curves for the four groups of Experiment II

RMS Error (inches)

Fig. 2. Acquisition curves for the four groups of Experiment II.
An analysis of variance was computed on the logarithms of the data for Blocks 2, 3, 4, and 5. Block 1 was omitted since the error tolerance for Groups BI and BC, as well as for Groups NI and NC remained fixed for the first five trials. Also, there was very great inter and intra-subject variability during the second five trials, which made a constant proportion of augmented feedback (for Groups BC and NC) difficult to achieve. The results of this analysis are presented in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td>63</td>
<td>20.525</td>
<td>---</td>
<td>N.S.</td>
</tr>
<tr>
<td>Groups</td>
<td>3</td>
<td>2.895</td>
<td>---</td>
<td>N.S.</td>
</tr>
<tr>
<td>Error (b)</td>
<td>60</td>
<td>21.518</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Blocks</td>
<td>3</td>
<td>154.958</td>
<td>98.39</td>
<td>.001</td>
</tr>
<tr>
<td>Blocks x Groups</td>
<td>9</td>
<td>1.748</td>
<td>1.11</td>
<td>N.S.</td>
</tr>
<tr>
<td>Error (w)</td>
<td>180</td>
<td>1.575</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The analysis of variance test did not detect a statistically significant Blocks x Groups interaction effect. The F required at the .05 level is 1.93 for 9 and 180 degrees of freedom and the F obtained was 1.11. However, it is believed that chance assignment of Ss to the experimental conditions contributed to the lack of statistical significance. The basis for this belief is the differences in the initial
proficiency of the groups within the narrow and broad error tolerance conditions during the first five trials, when the experimental treatments were the same. These differences are reflected in the data points for the first block of 10 trials in Figure 2. The initial proficiency level for Group NC was greater than that for Group NI during the first 5 trials. Since there was no difference in the experimental treatment during these trials, the two groups within each of the two error tolerance bandwidth conditions should have been operating at the same proficiency level. This difference in initial performance indicates that Groups BI and NC were "loaded" with more proficient trackers relative to Groups BC and NI. Such a chance assignment of Ss would tend to directly counteract the predicted interaction effect of the schedules of augmented feedback.

Despite the lack of a statistically significant Blocks x Groups interaction term, from Figure 2, it can be noted that the acquisition trends support the predictions made earlier. Specifically, the rate of acquisition for Groups NI and BC appears to be greater during the later trials than the rate of acquisition for Groups NC and BI.

Since the two fixed error tolerance groups (Groups BI and NI) were treated the same as Groups B and N of Experiment I, a comparison of only these two groups was performed. The results of an analysis of variance computed only with the data of Groups BI and NI are presented in Table 4. The significant Blocks x Groups interaction term (p < .05) supports the results obtained in Experiment I.
Table 4

Results of the Analysis of Variance Performed only on the data of Groups BI and NI of Experiment II

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td>31</td>
<td>25.846</td>
<td></td>
<td>N.S.</td>
</tr>
<tr>
<td>Groups</td>
<td>1</td>
<td>4.709</td>
<td></td>
<td>N.S.</td>
</tr>
<tr>
<td>Error (b)</td>
<td>30</td>
<td>26.550</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blocks</td>
<td>4</td>
<td>380.276</td>
<td>122</td>
<td>.001</td>
</tr>
<tr>
<td>Blocks x Groups</td>
<td>4</td>
<td>8.128</td>
<td>2.03</td>
<td>.05</td>
</tr>
<tr>
<td>Error (w)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In order to indicate the effectiveness of the procedure for administrating augmented feedback for a constant proportion of each trial period, the average proportion and the variance of this proportion of augmented feedback received by each group during each block of 10 trials is presented in Table 3. The data of Table 3 indicate that the goal of a constant proportion of augmented feedback for Groups BC and NC was attained with a variance of 0.5% to 2.0%. Thus, the technique employed to hold augmented feedback constant for Groups BC and NC was quite successful except for the initial block of 10 trials.
Table 5

Average Proportion and Variance of Proportion of Augmented Feedback Received During each Block of Ten Trials

<table>
<thead>
<tr>
<th>Groups</th>
<th>Ten-Trial Blocks</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NI</td>
<td>Mean</td>
<td>28</td>
<td>37</td>
<td>38</td>
<td>40</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>10</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>NC</td>
<td>Mean</td>
<td>30</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>BI</td>
<td>Mean</td>
<td>64</td>
<td>70</td>
<td>75</td>
<td>75</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>BC</td>
<td>Mean</td>
<td>60</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

As indicated above, intra-subject variability was quite high during these initial trials.

Further, from Table 5, it may be seen that like the results of Experiment I a broad error tolerance group received a greater absolute amount of augmented feedback during the entire training period (Group BI) but that the narrow tolerance group (Group NI) experienced a greater amount of increase in this feedback. Whereas, on Block 5 Group BI received augmented feedback on 78% of each trial, on the average, and Group NI received only 42%, the former group experienced only a 22% increase in feedback relative to that on Block 1, while Group NI enjoyed 50% more feedback on Block 5 than was received on Block 1. Again, then, the rank order of terminal tracking proficiency for a "broad" and a "narrow" error tolerance group was determined by relative change in augmented feedback, not by the absolute amount of
such feedback. The implications of these results will be discussed in the following section.

**Discussion**

Perhaps the result of most practical and theoretical interest from Experiment II was that rate of skill acquisition is at least partially determined not only by the error tolerance limits for such feedback, as shown earlier in Experiment I, but that the schedule of such feedback (a constant vs. a variable amount) also exerts an influence. However, this influence did not result in statistically significant differences, although it can be noted in the acquisition trends shown in Figure 2. Further, as predicted, these two determinants of skill acquisition rate probably do not exert their influence independently of one another; rather, a difference in the acquisition trends shows a high rate of skill acquisition for groups receiving either a constant amount of feedback with a broad error tolerance limit (Group BC) or an increasing amount of feedback (with increases in tracking proficiency) with a narrow tolerance limit (Group NI).

These results suggest that for practical applications of augmented feedback in a training task, one cannot arbitrarily set both the error tolerance limits for the activation of feedback and the schedule of such feedback. Instead, not only must one select the tolerance limits with care, but also, having selected a particular tolerance limit, the schedule of feedback (either constant or responsive to changes in proficiency) is thereby determined.
The above must remain speculative until additional research can provide more statistically conclusive results on the effects of schedules of augmented feedback over the training period.
EXPERIMENT III

TRANSFER OF TRACKING PERFORMANCE WHEN THE TARGET SIZE FOR
PRESENTING AUGMENTED FEEDBACK IS CHANGED

Introduction

This experiment is concerned with transfer performance when
the error tolerance is changed after a period of training from one
fixed error tolerance to a different fixed error tolerance. So little
is known about transfer performance when dealing with this variable
that only tentative predictions are attempted. It was predicted that
withdrawal of augmented feedback and a change to a broader error
tolerance might produce an asymptotic level of performance and a
change to a narrower error tolerance might produce continued improve­
ment. That is, it was expected that the change to a broader error
tolerance would provide augmented feedback almost continuously. There­
fore, both withdrawal of augmented feedback and a change to a broader
error tolerance should provide no additional information. Further,
within a short time interval, the continuous reception of augmented
feedback would provide little in the way of commendation. However, a
change to a narrower error tolerance might provide a challenge to $S$
and the signal was expected to continue to be perceived as a commen­
dation. Therefore, a reduction in the size of the error tolerance
was expected to increase $S$'s proficiency level.
Method

Apparatus

The apparatus was the same as that used in Experiment II.

Subjects

Seventy-two undergraduate, female students volunteered and were paid for service in this experiment. These Ss were matched on the basis of their performance during thirty training trials and assigned to one control and three experimental groups in a transfer of training paradigm, with a total of 18 Ss per group. None of the Ss had served previously in either Experiment I or Experiment II.

Experimental procedure

The specific purpose of Experiment III was to determine the effect on tracking performance of a transfer from one error tolerance bandwidth (for the activation of augmented feedback) to another in a transfer of training paradigm. After preliminary training with a fixed-medium error tolerance, the error tolerance was either narrowed, broadened, removed, or left unchanged. The preliminary training consisted of thirty 30-sec. trials with a medium error tolerance. This error tolerance was set, on the basis of data from Experiment I, to provide augmented feedback approximately 51% of the trial period during the initial trials. Like Group M of Experiment I, the Ss in the present study could receive more feedback as proficiency increased. After the preliminary training trials, one control and three transfer conditions were imposed as follows (a) the error tolerance was
changed to that which has previously been described (Exp. I and II) as a fixed-broad error tolerance (Group B), (b) the error tolerance was changed to that which has previously been described (Exp. I and II) as a fixed-narrow error tolerance (Group N), (c) the error tolerance was removed (Group C) so that zero augmented feedback was given, and (d) the error tolerance was left unchanged (Group M) which served as a control condition.

The same initial instructions used in Experiment II were read to S in this experiment. In addition, before beginning the transfer trials all Ss were told that they might notice something different, and if they did, they were instructed to continue tracking as before— the ultimate goal was still zero error.

Thirteen training trials were completed the first day; 17 training trials were completed the second day; and 15 transfer trials were completed during each of the next two days, making a total of 30 training and 30 transfer trials during the four days. The trial durations and rest periods were identical to those of Experiment II. Further, as in the earlier study, an effort was made to avoid an "end spurt" in performance on the fourth day by scheduling all Ss for a total service of seven days. The final three days were spent in other research, although no S was appraised of this until after the fourth day.

Results

The major results are summarized in Figure 3 where tracking proficiency, measured as RMS error, is shown as a function of practice
Fig. 3. Training and transfer performance levels in Experiment III.
during the preliminary training and the subsequent transfer trials. Each point in this figure is the mean of ten 30-sec. trials for each S, averaged over the 18 Ss in each group, representing a total of 90-min. of tracking.

It can be seen from visual inspection of Figure 3 that the transfer trials began before Ss had acquired an asymptotic level of tracking proficiency. The overlapping of the acquisition trends of the four groups during the preliminary training blocks (Blocks 1, 2, and 3) demonstrates the effectiveness of the matching procedure employed. However, marked differences occurred during the transfer trials (Blocks 4, 5, and 6), and these differences show quite clearly that the changes in the experimental procedure had a major effect on the acquisition of tracking skill during the transfer trials. The acquisition trends over Blocks 4, 5, and 6 show that Group C failed to improve appreciably in skill; Groups B and N continued to improve in skill but at a reduced rate; and, it appears that Group M continued to acquire skill with the fastest over-all rate.

In order to evaluate the effect of the changes in training procedure on the acquisition of the tracking skill, an analysis of variance was performed on the data of the transfer blocks. The results of the test are shown in Table 6. The statistically significant interaction effect (p<.05) can be attributed to a differential effect of the error tolerances employed during the transfer trials.
Table 6
Results of the Analysis of Variance Performed On Blocks 4, 5, and 6 of Experiment III

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects</td>
<td>71</td>
<td>28.958</td>
<td>---</td>
<td>N.S.</td>
</tr>
<tr>
<td>Groups</td>
<td>3</td>
<td>21.367</td>
<td>---</td>
<td>N.S.</td>
</tr>
<tr>
<td>Error (b)</td>
<td>68</td>
<td>29.292</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blocks</td>
<td>2</td>
<td>59.617</td>
<td>25.15</td>
<td>.001</td>
</tr>
<tr>
<td>Blocks x Groups</td>
<td>6</td>
<td>5.151</td>
<td>2.17</td>
<td>.05</td>
</tr>
<tr>
<td>Error (w)</td>
<td>136</td>
<td>2.370</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On the first transfer block, Group N performed at a level superior to Group B and Group C, and its performance was slightly inferior to the performance of Group M. On the second block, the rank order of the groups was M, B, N, and C, with Groups M and B not differing very much from one another. On the last block, the means of Groups B and N were fairly close together, but the proficiency of both groups was higher than that of Group C. The proficiency of Group M was markedly superior to the proficiency of all the other groups on this last block.

It follows from these results, then, that the performance of Group C suffered the greatest during transfer. However, the effect of removing all augmented feedback did not result in an actual deterioration of performance; rather, Group C appears to asymptote exactly at the level attained by Block 3 when, of course, a medium error tolerance limit was present. If one considers only the acquisition trends of
the other two transfer groups, it is apparent that Group B initially continued acquisition following transfer at approximately the same rate as the control group (Group M), and Group N did not appreciably improve. However, later in the transfer period, the acquisition rate for Group B is slower than that for the control group (Group M) and the acquisition rate for Group N is approximately the same as that for the control group (Group M). It is important to note, however, that the performance of all groups was adversely affected by the transfer when compared to the performance of the control group (Group M). The implications of these results are discussed in the following section.

Discussion

The results of Experiment III show that a change in the error tolerance bandwidth for the activation of augmented feedback may have a disruptive effect on performance during the acquisition of a perceptual-motor skill. A complete withdrawal of augmented feedback (Group C) has the most severe effect on performance; however, deleterious effects on acquisition were noted for those groups which experienced either a decrease or an increase in amount of augmented feedback (Groups N and B, respectively). A decrease in the error tolerance (Group N) produces virtually asymptotic performance early in the transfer period; however, the rate of acquisition is increased later in the transfer period. An increase in the error tolerance (Group B) produces an initial high rate of acquisition, with the rate becoming considerably slower later in the transfer period. A group which experiences no
changes in the error tolerance setting (Group M) has the highest rate of acquisition over the entire transfer period.

Although these results are not entirely consistent with the tentative predictions made earlier, the changes in performance still can be interpreted by the assumption that augmented feedback serves as an instructor surrogate. It is reasonable to expect that the group which experienced no change in the error tolerance (Group M) would continue to improve at a high rate, since the information and commendation were adequate for this group and no adjustments to new conditions had to be made. Although the initial high rate of acquisition of the group which experienced a sudden increase in the amount of augmented feedback (Group B) was not expected, perhaps the loss of information (due to almost continuous reception of the additional signal) was partially compensated for by an increase in the amount of commendation. However, as was predicted earlier, the almost continuous reception of augmented feedback probably caused the signal to be longer viewed as a commendation later in the transfer period, causing acquisition to be considerably slower. Perhaps the initial asymptotic performance of the group which experienced a decrease in the amount of augmented feedback (Group N) can be attributed to a loss of both information and commendation which resulted in a higher rate of acquisition only after a period of adjustment to the new conditions. That is, it may have taken a certain amount of time for S to respond to the more precise information resulting from a decrease in the error tolerance, and to the challenge of increasing the frequency of the diminished amount of
augmented feedback. It should be noted that, except for the high proficiency level of the control group (Group M), the changes in performance of all groups during the later part of the transfer period were as predicted.

Again, it is instructive to note that the complete withdrawal of augmented feedback (Group C) did not result in a deterioration of performance; rather, this group merely asymptoted at the level of proficiency attained when a moderate amount of such feedback had been provided. This is the strongest evidence, so far, in this series of experiments to support the interpretation that augmented feedback, of the sort employed here, has a direct effect on the acquisition of a skill and not merely an effect on performance level. That is, if the additional signal had only an effect on performance level but not an effect on learning, then withdrawal of the signal should result in actual deterioration of performance.
EXPERIMENT IV
TRANSFER OF TRACKING PERFORMANCE WHEN AUGMENTED FEEDBACK IS WITHDRAWN
AFTER TRAINING WITH EITHER AN AMBIGUOUS OR UNAMBIGUOUS TARGET

Introduction

This experiment concerns transfer performance when augmented feedback is withdrawn after S has been trained with either an ambiguous target or an unambiguous target. There is a large body of evidence (Ammons, 1956) showing that withdrawal of augmented feedback results in deterioration of performance when S is trained with the Pedestal Sight Manipulation Test (PSMT). However, when either the pursuit-rotor or the OSU SETA are employed, withdrawal of augmented feedback generally does not result in the deterioration of performance. One of the obvious differences between these task environments is that in the PSMT situation, the cues for ranging responses are extremely ambiguous; whereas, the cues for appropriate responding in the other two situations are clearly discernable.

In order to establish the relationship of target ambiguity and deterioration of performance when augmented feedback is used during training, the performance of two groups were compared. One group was trained with an unambiguous target and the other was trained with an ambiguous target. It was predicted that, when the exact location of the target is not clearly discernable, S will utilize the augmented feedback signal as a primary source of information concerning the
location of the target. On the other hand, when the target is clearly discernable, augmented feedback will serve primarily as an instructor surrogate. When augmented feedback is used primarily as a source of information regarding the location of the target, performance would be expected to deteriorate after the signal is withdrawn. However, when augmented feedback serves both as a source of information and commendation, performance is not expected to be greatly affected by withdrawal of the additional signal.

**Method**

**Apparatus**

The apparatus was identical to that used in Experiment III, with two exceptions. In this experiment, the voltmeter-dial display was replaced by a 4-in. cathode ray tube (CRT) display. Further, a Gaussian noise generator was added to the equipment. These changes enabled E to make the exact location of the null position of the tracking display ambiguous. When E turned on the noise generator, the target oscillated at amplitudes which were equal on either side of the fixed null position at frequencies between 0.01 and 1.0 cps., with an amplitude range of 0.75-in. on the S's display. It may be recalled that a compensatory display was used in all four experiments. The visual noise of Experiment IV affected only the fixed reference (target) and not the movable cursor of the display. That is, instead of a stationary reference for zero error, the reference indicator was perturbed by a random (but normally distributed) signal, and the movement of the cursor was unaffected.
Subjects

Sixty volunteer, undergraduate, female students were paid for service in the experiment. The Ss were matched on the basis of their performance during 8 initial trials and were assigned to one of four conditions. None of Ss had served previously in any of the preceding experiments.

Experimental procedure

The specific purpose of Experiment IV was to determine the effect on tracking performance of withdrawal of augmented feedback after training with either an unambiguous target or with an ambiguous target. Before the experimental treatments were introduced, eight 30-sec. trials with no augmented feedback and a stable zero error reference indicator were completed. The Ss were matched on the basis of these trials and were then randomly assigned to groups. There were two experimental and two control groups where presence of augmented feedback defined the difference between experimental and control groups. One of the experimental and one of the control groups did not have a stable zero error reference indicator, whereas the remaining two groups did have a stable target. Each of the four groups completed 40 training trials and then the augmented feedback signal was removed for the two experimental groups, and 24 transfer trials were completed. During the preliminary training trials, the error tolerance was set at a bandwidth which was analogous to that previously described (Exp. I, II, III) as "broad." Thus, the experimental group with no
visual noise imposed on the target was expected to receive the augmented feedback signal approximately 66% of the initial trials. Such a broad error tolerance was chosen so that the experimental group with visual noise imposed on the target would receive some augmented feedback during the initial trials.

Specifically, the four conditions employed in this study were (a) augmented feedback was present when S's error was within the fixed error tolerance, and visual noise was not imposed on the zero error reference indicator (Group Eo); (b) augmented feedback was not present, and the target did not oscillate (Group Co); (c) augmented feedback was present when S's error was within the fixed error tolerance, and visual noise was imposed on the target (Group En); and (d) augmented feedback was not present and the target was perturbed by the noise generator (Group Cn).

The same initial instructions used in Experiment III were read to S in this experiment. In addition, Ss who were to track with visual noise imposed on the target were told to estimate the center of the perturbations of the target, and to keep the cursor on that estimated zero reference. Again, zero error was stressed as the ultimate goal of the task. After every two 30-sec. trials, the location of the null position on the CRT was changed. This was done in order to prevent S from locating the target position with respect to some external reference.

Eight matching and 4 training trials were completed on the first day; 16 training trials were completed on each of the following
two days; on the fourth day, 4 training and 12 transfer trials were completed; and, on the last day, 12 transfer trials were completed, making a total of 40 training and 24 transfer trials. The trial durations and rest periods were identical to those of Experiments I, II, and III.

Results

The major comparisons are presented in Figure 4 where tracking proficiency, measured by the RMS error metric, is shown as a function of practice. Each point in the Figure is the mean of four 30-sec. trials for each S averaged over the 15 Ss in each group, representing a total of 30 min. of tracking.

It can be seen from visual inspection of Figure 4 that withdrawal of augmented feedback after the last training block (Block 10) produced an abrupt deterioration in the performance of the experimental group which was trained with noise imposed on the target (Group En) during the first transfer block (Block 11). However, the performance of the experimental group with no noise imposed on the target (Group Eo) was unaffected by the withdrawal of augmented feedback.

In order to evaluate the predictions made regarding the effect of removal of augmented feedback on performance after training with either an ambiguous or unambiguous target, a t-test was performed on the differences between the last block of 4 training trials and the first block of 4 transfer trials. A summary of the results of these tests is presented in Table 7. From Table 7, it can be seen
Fig. 4. Training and transfer as a function of augmented feedback and visual noise.
that the only group which was seriously affected by the withdrawal of
the augmented feedback signal was Group En. However, from Figure 4,
it can be seen that the proficiency of Group Cn also deteriorated
slightly on the first transfer block. Therefore, a different index of
the effect of withdrawal of augmented feedback was subjected to a
t-test. This index is \((\text{Block 40, Cn - En}) - (\text{Block 41, Cn - En})\).
Thus, the loss in proficiency of Group Cn is taken into account by this
index. The test of the differences showed that the deterioration in
performance of Group En was still statistically significant \((p < .05)\).
It follows, therefore, that these data completely support the
predictions.

Table 7
Summary of the T-tests of the Mean Differences Between The
Last Training and First Transfer Block, For Each Group

<table>
<thead>
<tr>
<th>Mean Group Difference</th>
<th>md</th>
<th>P</th>
<th>Mean Group Difference</th>
<th>md</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eo</td>
<td>6.47</td>
<td>6.72</td>
<td>N.S.</td>
<td>Co</td>
<td>5.00</td>
</tr>
<tr>
<td>En</td>
<td>59.80</td>
<td>17.05</td>
<td>.01</td>
<td>Cn</td>
<td>16.80</td>
</tr>
</tbody>
</table>

In order to evaluate the effect of the presence of augmented
feedback during the training trials, an analysis of variance was
performed on the last 6 training blocks. The results of the analysis
of variance are shown in Table 8. The statistical significance \((p < .025)\)
of the augmented feedback variable indicates that the presence of
augmented feedback benefited tracking performance during these training
trials. In addition, the Duncan Range Test showed that there was a significant difference \((p < .05)\) between Groups Eo and Cc, and between Groups En and Cn. These results show that the performance of both experimental groups was superior to the performance of both control groups during the training period.

### Table 8

Results of the Analysis of Variance  
On Blocks 5, 6, 7, 8, 9, 10  
For All Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>M.S.</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Augmented Feedback (A)</td>
<td>1</td>
<td>542159</td>
<td>6.06</td>
<td>.025</td>
</tr>
<tr>
<td>Target Noise (T)</td>
<td>1</td>
<td>1234218</td>
<td>14.40</td>
<td>.001</td>
</tr>
<tr>
<td>A x T</td>
<td>1</td>
<td>145198</td>
<td>1.62</td>
<td>N.S.</td>
</tr>
<tr>
<td>Error (b)</td>
<td>56</td>
<td>89489</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blocks (B)</td>
<td>5</td>
<td>47018</td>
<td>19.10</td>
<td>.001</td>
</tr>
<tr>
<td>B x A</td>
<td>5</td>
<td>2120</td>
<td>.86</td>
<td>N.S.</td>
</tr>
<tr>
<td>B x T</td>
<td>5</td>
<td>4928</td>
<td>2.00</td>
<td>N.S.</td>
</tr>
<tr>
<td>B x T x A</td>
<td>5</td>
<td>2219</td>
<td>.90</td>
<td>N.S.</td>
</tr>
<tr>
<td>Error (w)</td>
<td>280</td>
<td>2464</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Discussion**

The results are entirely consistent with the predictions made earlier. These predictions were based on the hypothesis that augmented feedback functions either as a primary source of information or as an instructor surrogate. When functioning as an instructor surrogate, augmented feedback is assumed to provide both information and
commendation. However, the information supplied by the additional signal is assumed to be of a general nature and is not critical to appropriate responding. That is, the information contained in the augmented feedback signal when it is employed as an instructor surrogate probably concerns the definition of goals and of relevant and irrelevant cues in the task situation. However, when augmented feedback functions as a primary source of information, the signal is assumed to be critical to appropriate responding. It was predicted that when Ss were trained with an unambiguous target, augmented feedback would function as an instructor surrogate, and when Ss were trained with an ambiguous target, augmented feedback would function as a primary source of information. Thus, performance was expected to deteriorate upon removal of the augmented feedback signal when an ambiguous target was employed during training, but removal of augmented feedback would have little effect on performance when a clearly discernable target was present during training.

It was found that withdrawal of augmented feedback does have a deleterious effect on the performance of Ss trained with an ambiguous target, but it has very little effect on the performance of Ss trained with an unambiguous target. These findings support the hypothesis that augmented feedback serves either as a primary source of information or as an instructor surrogate. In other words, when the target is ambiguous, augmented feedback functions as a "psychological crutch" (Bilodeau, 1952).
These results suggest that for practical applications of augmented feedback in a training task, one must be certain that the target is clearly defined. Otherwise, the operator will utilise the additional signal as a source of information concerning the location of the target and performance will be adversely affected when augmented feedback is no longer present. That is, the operator's performance will be worse than that displayed when augmented feedback was present. However, the operator's performance will not differ from what his performance would have been if he had not had augmented feedback during training. On the other hand, when the target is clearly defined, training with augmented feedback has a beneficial effect on the acquisition of a perceptual-motor skill and proficiency does not deteriorate when the additional signal is removed.
GENERAL DISCUSSION

The development of automatic training devices is one of the most active areas of research in psychology today. The effort to date has been directed primarily to methods of task construction which permit S to train himself via devices which provide for automatic increments in task difficulty, automatic feedback on correct and incorrect responses, and automatic scoring of performance. The goal of this research is, of course, to reduce the complexity of the instructor's role by reducing his routine functions during a learning period. While not present in the learning situation himself, the instructor is very much in evidence via his surrogate—the training device.

Since one of the historical aspects of an instructor's role, in addition to providing information, is that of commendation and encouragement for improvements in skill, it becomes important to provide for this aspect in automated training devices. The research reported herein was directed toward such an aspect. Specifically, it was demonstrated that augmented feedback, feedback in addition to that provided by the task itself, can be a major determinant of skill acquisition in a continuous control task when an unambiguous target is employed. In this sense, then, augmented feedback can be interpreted as being analogous to an instructor surrogate, since it probably provides S with both information and commendation.

Predictions based upon the assumption that augmented feedback serves as an instructor surrogate were supported in this series of
experiments. Experiment I illustrated that an error tolerance limit for the activation of augmented feedback which is relatively narrow results in a greater rate of acquisition than either a relatively broad or medium error tolerance. This was attributed to the fact that an error tolerance limit which is relatively narrow will clearly emphasize that high accuracy is the appropriate goal. Also, a narrow error tolerance permits a larger increment in the amount of augmented feedback received by $S$ during training, and this probably serves as a commendation for $S$. However, if the tolerance limit is set such that $S$ receives augmented feedback practically 100% of the time, the additional signal obviously cannot define highly proficient performance levels, because $S$ would receive the signal for relatively gross errors. Therefore, a relatively broad error tolerance provides little in the way of defining goals or providing commendation. A word of caution is appropriate here, in that an error tolerance can be too narrow. In Experiment I, the group which experienced a condition in which the error tolerance width was zero produced an inferior level of performance. It is probable that the optimum width of the error tolerance is some function of the level of skill attained by $S$ at any particular time. This follows from Experiment I where an interaction was noted between the width of the tolerance limit and amount of training: early in training, a broad tolerance limit provided superior performance whereas, a medium tolerance was superior at later stages of practice, and, finally, the narrow tolerance limit produced superior performance levels late in the training period.
Thus, it may be misleading to conclude simply that error tolerance limits can be either too broad or too narrow. Rather, a general conclusion from the above research is that the most effective width of a tolerance limit will decrease with increasing training and, therefore, a limit which is too narrow at an early stage of training may become too broad as training continues. It follows from this conclusion, that the most effective schedule for the administration of augmented feedback during training is one which employs a very wide error tolerance band early in training and causes this band to diminish with training to a very narrow limit. It is possible that the extremes of this schedule may be almost 100% feedback during the initial trials to almost 0% augmented feedback as \( S \) attains truly high levels of skill. From the tentative results of Experiment II, it is probable, also, that the initially wide error tolerances should be manipulated by the instructor such that \( S \) always achieves a high percentage of augmented feedback, but that as skill is acquired (and the tolerance limit is decreased in size) the amount of feedback should be responsive to momentary fluctuations in proficiency.

The latter conclusion agrees with the common observation that early in practice, \( S \) is concerned primarily with the very gross aspects of skill, such as the appropriate direction to move a control device in order to reduce error; whereas, later in training, he begins to attend to the finer facets of the skill including the effects of particular rates of change and accelerations in movement of the control device on the magnitude, velocity, and acceleration aspects of system
system error. Thus, a schedule of augmented feedback should be arranged to provide an optimal "fit" to S's needs as dictated by the level of learning attained at any particular point in the acquisition of skill; early in training, only the gross aspects are important to S, thus a wide tolerance limit must provide a schedule of augmented feedback which is increasingly responsive to minor fluctuations in performance since S, at this time, is striving for such high accuracy that slight errors in the higher derivatives of control movement must be perceived and corrected in order to show further improvement in skill.

The optimum scheduling to "mean" from augmented feedback remains to be determined by future research. The above research has sketched out some gross facets of this process and Experiment III has demonstrated clearly that a schedule with abrupt changes is not effective. Just how responsive augmented feedback must be to changes in levels of proficiency is a question that must be answered by further research. Although it is clear that an abrupt change is not effective after a relatively long training period, such a change might be more effective if it is introduced earlier in training. However, an abrupt change might always be ineffective and a series of small changes which are contingent upon individual S's level of proficiency might be required to produce optimum proficiency throughout training.

It appears, from the data of Experiment IV, that although augmented feedback produces high levels of performance during training, it affects skill acquisition only when the target is clearly
discernable. Thus, when augmented feedback is administered during training and the target is ambiguous, proficiency is higher than when augmented feedback is not administered during training; but, when the augmented feedback signal is no longer available, the level of proficiency abruptly deteriorates to the performance level of the group which never had augmented feedback. However, when the target is clearly discernable and augmented feedback is withdrawn after a period of training with augmented feedback, there is no loss in proficiency.

The conceptualization of augmented feedback serving as an instructor surrogate in a continuous tracking task when the target is unambiguous provides some basis for predicting the effects of manipulating augmented feedback variables. This statement is substantiated by the success of the predictions made in this series of experiments. However, the conceptualization is so general and it permits such a wide range of possible alternative predictions that it is advanced only as a tentative beginning for further theorizing in this area. Obviously, more empirical relationships must be established and relevant variables must be discovered before precise theorizing in this area is possible.
BIBLIOGRAPHY


I, Robert G. Kinkade, was born in Nogales, Arizona, February 2, 1931. I received my secondary school education in the public schools of San Diego, California, and Kirkwood, Missouri, and my undergraduate training at the University of Missouri, which granted me the Bachelor of Arts degree in 1955. I also received the Master of Arts degree, in 1957, from the University of Missouri. While in residence there, I was a research assistant under Dr. M. H. Marx during the years 1954-1957. In October, 1958, I was admitted to the graduate school at Ohio State University where I specialized in the Department of Psychology. During the years 1957-1960, I was a research assistant or research associate under Dr. G. E. Briggs while completing the requirements for the degree Doctor of Philosophy.