The Relationship Between Perceptual Learning and Psychomotor Task Variety: Contextual Interference Effects

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THE RELATIONSHIP BETWEEN PERCEPTUAL LEARNING AND PSYCHOMOTOR TASK VARIETY: CONTEXTUAL INTERFERENCE EFFECTS

BY

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B.A., University of Central Florida, 1983

THESIS

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ABSTRACT

Task variety during training was manipulated to assess residual effects on skill acquisition during subsequent transfer to a novel perceptual motor task. The task involved tracing a four-point star pattern displayed on a personal computer with a "mouse," while receiving variations in visual feedback from the CRT display. Variety during training involved two cases of abnormal visual feedback (left-right reversal and 90 degree tilt). Task variety (i.e., visual feedback) was manipulated and counterbalanced in four levels: alternated variety (trial by trial), blocked variety (in five trial sets), no variety (i.e., one type of feedback), and a control condition that trained with no displacement (normal feedback). All groups were tested with inverted feedback (up-down reversal) as the novel transfer task. The number of trials was fixed at 10 trials each for the training and transfer phases. Dependent measures were RMS error and time to completion.

During training, significant differences revealed that the alternated variety condition was the most difficult to learn, followed by blocked variety, no variety, and the control condition. The two variety groups did not differ in performance on the first transfer
trial. The alternated group traced faster on transfer trials two through five, however, the blocked group was more accurate. The no variety group performed superior to the two variety conditions combined, on all of the first five transfer trials. Although the control group performed with significantly fewer errors than the treatment conditions on the first transfer trial, the treatment groups performed significantly faster than the control group on transfer trials two through five.

These results indicate that task variety under these circumstances was generally no advantage to transfer performance. It is speculated that variation may indeed improve transfer with longer training periods.
ACKNOWLEDGMENTS

I would like to thank my committee members, Dr. David Abbott, and Dr. Robert Kennedy, for their guidance and editorial comments. Dr. Richard Gilson, the committee chairman deserves a special thank you for providing direction and motivation throughout numerous brainstorming sessions.

A tip of the hat goes to Mr. Martin Smith of Essex Corporation, whose computer programming talents (and countless hours of work) made it possible to automate the task. Special thanks to the staff at Essex Corporation for their moral support, and use of office equipment.

Finally, thank you Mom and Dad for the opportunity to attend college, and for all of your support, both emotional and financial.
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INTRODUCTION

This research set out to investigate the effects of task variation during training on the acquisition of a perceptual motor task. The research encompassed perceptual learning, transfer of training, and perceptual-motor adaptation. The following is intended to be a review of the relevant concepts and issues in these areas and an insight as to how they are interrelated.

Perceptual Learning

Is it possible to increase perceptual acuity through practice and training? E. J. Gibson (1969) defines perceptual learning as, "an increase in the ability to extract information from the environment as a result of experience and practice with stimulation coming from it" (p. 3). Epstein (1967) suggested that through "enrichment techniques" the exposure history of the subject could be enhanced (enriched) such that subjects could become more aware of discriminating stimuli. Gibson (1969) referred to such enrichment techniques as "differentiating techniques." The differentiation theory of perceptual development postulated by Gibson suggests that in an environment of rich and diverse stimuli, organisms become
capable of more specific perceptions. Perceptual learning results in an increased sensitivity to similarities and differences, relationships, patterns, and other distinguishing features of the environment. The organism learns what to attend to as well as what not to attend to. Gibson's theory, while leaning to the cognitive side, could also be applied to motor learning, in that as the subject makes different responses a new variety of stimuli results. Here again, the subject is required to abstract critical distinctive features from the new stimulus information.

Transfer of Training

Transfer of training (TOT) has been defined as "the effect that the practice of one task has on the learning or performance of a second" (Cratty, 1973). In the TOT paradigm, treatment groups are initiated on a training device (e.g., flight simulator) intended to increase performance on a criterion or operational device (e.g., airplane, helicopter). The subsequent testing phase on the criterion task is known as the "transfer condition." "Positive," "negative," and "zero" transfer are terms used to describe the relationship between the experimental groups' performance on the criterion task with that of a control group having had no previous training experience.
under the experimental manipulation(s). As a result of positive transfer there are "savings" in skill acquisition of the criterion task, due to having learned a prior skill. With negative transfer there is a loss. Zero transfer occurs when there are no differences between the experimental and control groups' transfer performance. The objective of TOT studies generally is to uncover those variables that affect the amounts of positive transfer.

Battig (1966) pointed out that a global estimate of overall transfer may be deceptive because within any one TOT design, individual component sources may produce positive and negative effects concurrently, such that different factors could plausibly cancel out each other's effects. This observation emphasizes a recent change in the focus of TOT studies from the investigation of overall performance effects to the analysis of individual factors within a task that facilitate or interfere with transfer to a second task.

A second change of emphasis in TOT research has gone from analyzing overall learning effects as measured by performance on the transfer task to the more specific investigation of the learning processes taking place. A distinction should be made here between learning effects and effects on performance. It is possible to augment a stimulus such that the resultant effect is superior performance, however, when the augmentation is removed,
subsequent performance is liable to decrement. On the other hand, a learning effect is retained (ingrained) even after treatment is removed. Thus, it is possible for a treatment to effect performance (i.e., during training), but not learning (i.e., transfer).

Berbaum, Kennedy, Welch, and Brannan (1985) demonstrated the positive transfer effects of teaching a complex perceptual-motor task in its entirety (whole-task training) versus teaching subjects a component part of the whole task (part-task training) intended to transfer to the whole task. A control group trained on an even smaller portion of the whole task, and was considered an "impoverished" part-task condition. Although initial training performance for the whole task group was the poorest of the three conditions (presumably because it was the hardest condition), subsequent testing on the whole task revealed a superiority of the whole task training method over the part task and control conditions. In this case, the poorest training performance was followed by the best transfer performance (see Figure 1).

Shea and Morgan (1979) refer to transfer from a difficult task to an easy task as "contextual interference." While it is traditionally assumed that learning should start on an easy skill, it has been shown that transfer can occur (as much as 100%) when a subject is trained first on a skill more difficult than that
required in the transfer condition (Berbaum et al. 1985; Shea & Morgan, 1979). The interference that occurs during training may focus attention on significant cues to result in enhanced performance on the transfer task.

![Graph showing the relationship between training and transfer tasks.](image)

Figure 1. Average Time to Completion of Task Over Three Groups Averaged Across Forty-One Trials. (Reprinted with authors' permission, Berbaum et al., 1985.)

Lee and Magill (1983) describe the contextual interference (CI) effect as an interaction between cognition and skill acquisition. The authors cite two ways of manifesting CI (a) by increasing the similarity among items to be learned and, (b) by increasing the variety in the order tasks are presented. Lee and Magill refer to the latter manipulation as "contextual variety."
Morrisett and Hovland (1959) found temporary decrements in performance on discrimination tasks upon introducing each new task in a task variety sequence. The authors point out that multiple problem training slows the learning process. However, the interference that occurs during training affords contrasts to be made, which allow subjects to learn to "pull out" the critical elements or cues which although difficult during the initial stage of learning, subsequently aid the process of discrimination between relevant and irrelevant stimuli. Once this discrimination process is learned, the subject will be able to generalize beyond the stimulus condition to other novel stimuli. This suggests that when training performance is not critical, similar but varied training tasks may afford critical feature detection better than equal training on the same task. Accordingly, performance on a subsequent task sharing those critical features should be better with selected variations of training.

Shea and Morgan (1979) studied the CI effects generated by introducing task variety into the skill acquisition phase of a perceptual-motor task. The task consisted of a series of barriers to be knocked down manually in a specific pattern. Three different movement patterns were learned and each pattern corresponded to a
specific color of an indicator light. Task variety was manipulated by presenting training tasks under blocked or randomized trials. Under a blocked condition, all trials of a task are completed before moving on to the next task. Under a random task schedule, the task differs on every trial. The retention phase consisted of both blocked and randomized trials of the same three task variations used in training. A retention phase is the same thing as a transfer, or test phase (Lintern, 1985). The results indicated a significant advantage for the random acquisition group on both the random and blocked retention trials.

Lee and Magill (1983) questioned whether the contextual interference effects produced in Shea and Morgan's (1979) study were really produced by the type of practice schedule (blocked vs. random) or whether the CI effect was due to the fact that subjects in the randomized condition never knew which task to expect next. The authors pointed out that two different methodological paradigms were used in the Shea and Morgan study. Under a blocked trials condition, the first trial of a new block of tasks is a choice-reaction task, (the subjects did not know which responses would be required) but all subsequent trials within the block would fall under the simple-reaction paradigm (there would be no doubt as to which response was expected next). A randomized practice
schedule falls under the choice-reaction paradigm, because any possible variation could be presented next, so the subjects never know what to expect.

To test whether there were main effects for practice schedule or reaction paradigm, or an interaction between the two, Lee and Magill (1983) manipulated type of practice schedule in two levels each (blocked vs. random trials, respectively). The task was the same as that used by Shea and Morgan (1979), and the dependent variables were reaction time and movement time. The transfer condition consisted of an uncued-random schedule of the three movement patterns, thus making it a choice-reaction paradigm. An objection that could be raised to this design concerns the fact that the retention phase was a choice-reaction paradigm, so those groups that practiced under choice reaction conditions would have an advantage over those groups trained in the simple reaction paradigm. However, Shea and Morgan (1979) gave both types of reaction paradigms in their retention phase, and found that the random acquisition group maintained retention superiority over the blocked acquisition group on both random and blocked retention conditions.

Although there was a significant trend towards slower reaction times on the last block of acquisition trials for both of the uncued groups, no differences in reaction time remained between the cued and the uncued groups during the
uncued retention phase. These results indicate that, although critical to reaction time during training, the effect of type of reaction paradigm was not manifested during the retention phase. Lee and Magill (1983) concluded that, "The methodological locus of contextual variety effects arises from the manipulation of practice schedules and is not due to the effects of reaction paradigm or to the interaction of practice schedule with reaction paradigm" (p. 736) and further, "It appears that reaction paradigms had an effect on performance, which was not manifested in the differences exhibited on learning" (p. 735).

The results replicated Shea and Morgan's (1979) finding that a randomized practice condition results in better retention performance than does equal training on blocked trials. The blocked practice schedule facilitated skill acquisition (a significant practice schedule effect), but the random schedule enhanced retention to the point of making up for poorer acquisition.

Morrisett and Hovland (1959) point out that there are discrepancies in the results of task variety studies which may be due to the level of mastery a subject has attained on that task before transferring to a subsequent task. It would seem logical that subjects in a specific training condition would have a better chance at achieving skill mastery than would subjects exposed to several different
tasks. It was hypothesized that if subjects are given the chance to attain a high degree of learning on all single tasks within multiple task training, transfer performance will be superior to that of subjects trained on a single task. It was further hypothesized that subjects trained on a single task would perform better in transfer than subjects who receive task variety during training if the degree of learning on each task of the multiple sequence is minimal. To test their hypotheses, Morrisett and Hovland (1959) trained three groups on 1, 3, or 24 discrimination tasks. All groups received 48 training trials total, i.e., one group practiced 1 task for all 48 trials, a second group received 16 trials on each of 3 tasks, and a third group practiced two trials of each of the 24 tasks (the multiple tasks were administered in blocked trials -- all trials were completed for a single task before moving on to the next). All groups transferred to 24 test trials of the same transfer problem (unfortunately, it was not stated if the transfer problem was novel, or one that had been practiced before). In transfer, the group that trained on 3 tasks was superior to those training with 1 or 24 tasks, however, training on 1 task proved to be superior to 24. These results partially support Morrisett and Hovland's hypotheses. The fact that the single task training groups transfer performance did not exceed that of the 3 task training
group's indicates that subjects in this condition probably experienced "overlearning" during training and this might suggest that subjects' get "stuck" in a response set that does not permit them to adapt their strategies effectively when faced with a new problem. However, the finding the group trained on 24 tasks performed at a level below than that of the 3 task group, and no-variety group during transfer, suggests that there must be some intermediate level of variation that is efficient in enhancing transfer to a subsequent task.

Duncan (1958) considered task variety a continuum, with constant training at one extreme, and unlimited variability at the other. The degree of variety was defined by the number of different tasks subjects' completed. Duncan pointed out that by holding the number of training trials constant, increasing the number of tasks to be learned decreases the amount of training on each task. Duncan hypothesized that there must be some optimal level to which variety enhances learning, and possibly an interaction between amount of practice on each task and the number of tasks presented. He trained four groups on 1, 2, 5, or 10 perceptual-motor paired associate tasks. Three levels of practice, 2, 5, or 10 days (at 20 trials per day), were manipulated within each of the four levels of task variety. All groups transferred to two new sets of stimuli that were counterbalanced within groups.
The results of this study indicated that the amount of positive transfer increased as a direct function of the number of task variations. When the number of training trials was held even, all variety groups performed better in transfer than the no variety condition. There was no interaction between amount of practice and the number of training tasks, therefore, the amount of training did not have a significant effect on the transfer superiority of task variety over constant training.

This review of the effects of variety in training on the transfer of perceptual-motor performance has covered many findings that lend suggestion to the design of yet another TOT study. Many of the transfer tasks in this review consisted of the same task subjects were trained on. Others consisted of slight variations of the original training task(s). It was decided that the present study would utilize a novel transfer task, to determine the effects of task variety during training on strategy formation when faced with a novel situation.

Duncan (1958) demonstrated that even when the number of training trials is held constant, task variety still leads to better transfer performance than does single task training. The present study was conducted from the viewpoint that a training manager only has a fixed time frame in which to train subordinates, and the intent is to assess which method leads to the best transfer performance.
The findings of Shea and Morgan (1979) and Lee and Magill (1983) had several implications for the present design. In the Shea and Morgan study, it was shown that random training led to better transfer performance than blocked training on both blocked and random acquisition trials. This suggests that not only task variety per se, but also variety in the order of task presentation effects subsequent transfer performance. Morrisett and Hovland (1959) demonstrated that too much variety will not produce the desired CI effects.

Lee and Magill (1983) found that the basis for contextual variety effects arises not from the manipulation of reaction paradigm (i.e., cued versus uncued) but from the manipulation of practice schedule during training. It was also shown that given cued conditions, blocked and randomized training produce equal transfer performance. Based on these findings, reaction time paradigm was held constant in the present design, that is, all subjects were informed of the exact nature and sequence of all upcoming tasks. This was done by training one variety group two tasks in an alternated task sequence as opposed to a randomized sequence, which requires three tasks or more. The alternated variety was a cued condition because, based on the nature of the task at hand, it was then obvious that the next task would be the alternate.
Perceptual-Motor Adaptation

Since this study will focus on the transfer of a perceptual-motor skill to a novel task, a discussion of relevant perceptual motor issues is appropriate.

Organisms perceive their environment as a result of sensory inputs. There is an orderly relationship between the organism's movement and subsequent sensory feedback. If an organism is restricted in movement (motor deprivation) or in feedback (sensory deprivation), a decrement in performance will result (Held & Freedman, 1963).

It is possible to displace, distort, or rearrange sensory feedback such that there becomes a discrepancy between a subject's input and the subsequent adjustment made in a system. Examples of rearranged feedback include control-display reversal, delayed auditory feedback, and prismatic displacement. Since many stimulus-response relationships can be predicted from what one has learned, distorted feedback causes a conflict between what one "knows" to be true and perceives to be true.

Sensory rearrangement causes incoming information to conflict with information received by the other senses. The sensorimotor system exhibits surprising lability with regard to adaptation to the rearranged feedback. This is known as perceptual-motor plasticity (Held & Freedman,
1963). An example is when subjects are asked to point at visual targets while wearing prism distorting lenses. There is sensory conflict between the information provided by the visual system as to where the target is located and from proprioceptive feedback concerning where the target feels like it is located. A second conflict that occurs in the same situation is contradictory information from the visual and proprioceptive senses with regard to where the eyes "see" the arm as pointing, and where the arm "feels" it is pointing. With practice, individuals can adapt to this kind of sensory distortion. Gibson (1969) refers to the adaptation to distorted stimuli as "rehabilitation."

Can variability of sensory distortion ease adaptation to novel distortions, and if so, how does this relate to task variety in TOT studies? Karl U. Smith conducted numerous studies concerning how subjects resolve various visuo-motor conflicts by rearranging the directional relationship between the subject's response and subsequent visual feedback. Smith used a video monitor to distort visual feedback of the subject's tracing response. The monitor could also provide a lag between the response and feedback. In this manner, Smith (1962) reported, "We can compare exactly the effects of different conditions of space displacement -- inversion, reversal, inversion and reversal, angular dislocation, angular deviation,
rotation, and size distortion -- of the sensory feedback of specific movements, upon various patterns of human behavior" (p. 358).

Smith and Wargo (1963) examined the differential effects of three different training regimens on the rate of adaptation on twenty trials of a star-tracing task. A video camera was used to systematically reverse and invert feedback. The constant training group received constant training under the combined distortions. The second treatment group alternated between inverted/reversed feedback and normal feedback (no distortion) on every other trial (alternated training). A control group trained only with normal feedback from the video monitor. The dependent variable was time to completion (although it was mentioned that an error measure was used, neither details, nor results, were provided). It should be noted that this was not a TOT design, as there was no transfer condition. Not surprisingly, the control subjects who traced under conditions of normal feedback were the fastest. The constant training group took the longest time to completion, and the alternated training group performed at a level of performance between the other two. The authors concluded that because star-tracing took less time for subjects in the alternated group than the subjects in the constant training group, the interaction in practice of alternating between normal and
inverted/reversed stars was not strong enough to cause a decrement in the alternated groups' tracing performance. This latter finding may not be surprising, because the alternate task used in the variety condition was a normal feedback task. Consider an alternative of having subjects alternate between two types of distortion as opposed to one distortion and a normal condition. Such a manipulation would increase the task difficulty, but also would give the subjects a chance to contrast different types of distortions, and learn response discrimination.

In a critique of Smith's work, Cratty (1973) reports, "His experiments with distorted vision and temporal displays have established beyond doubt the rather exact pairing of vision and movement, together with a time dimension for the production of perceptual-motor behaviors" (p. 82). However, Cratty criticizes Smith's "electronically created confusions" as crude experiments, on apparatus that was not amenable to measuring the relative trade-offs on the speed vs. accuracy dimension. The fact that Smith reported his results only in terms of seconds to completion ignores the trade-off between speed and accuracy in that faster tracers may trace "poorer" stars. Howard and Templeton (1966) objected to Smith's results and subsequent conclusions in that they were based on time measures only. They also raised the concern that Smith had ignored the relative contributions of what they
suggested were two relevant factors: (a) the subject's visual field had been displaced from the front of the body (the video monitor was viewed directly ahead, and tracing activity was taking place on a desk out to the side of the subject's body), and (b) the subject experienced distortions in both space and time.

Notwithstanding the above concerns, the present experiment was similar to Smith's in that subjects were required to trace stars under conditions of distorted feedback. Many of the criticisms of Smith's study were addressed. Although the task was essentially the same, the method of presentation was more sophisticated; feedback was instantaneous and displaced through coordinate transposition which alters the directional relationships between the control device input and corresponding cursor movement on the screen of a personal computer. The computer programming freed the dependent measures from human data collection and potential error, and allowed for both speed and accuracy measures to be taken. Finally, the task took place in front of the subject's body, and feedback was provided directly ahead. Subjects did not need to turn their head, nor alter their posture, as was necessitated in Smiths' study.
Expected Outcomes

- Based on Shea and Morgan's (1979) findings, it was hypothesized that those subjects who trained under blocked trials would perform better during training than those given alternated variety. However, it was anticipated that the alternated variety group would have a transfer advantage, because the training condition required a change in strategy on every trial, and subjects would become more adept at problem solving.

- Based on previous findings (e.g., Morrisett and Hovland, 1959) it was anticipated that during training, subjects who were confronted with only one type of distortion would perform better than those who were trained on two types (i.e., the variety groups would do less well in training than the no variety experimental group). However, it was anticipated that the contrasts afforded by variety in training would facilitate perceptual learning to the point that the variety groups would perform better than the no variety group during transfer.

- Based on Smith and Wargo's (1963) findings, it was anticipated that compared to the three treatment
conditions, the control group would perform the best in training, because they were not exposed to any distorted feedback. However, the control group would be at a disadvantage in transfer, because no experience with displacement was provided during training, and further, the control group had not been exposed to variety during training.
METHOD

Subjects

Forty right-handed subjects were solicited from the University of Central Florida undergraduate psychology classes. Equal numbers of males and females were employed. All subjects were paid $5 for their participation (approximately one hour). Ten subjects (five males and five females) were assigned to four experimental groups, based on order of sign up.

Equipment

The equipment included software designed for an AT&T personal computer. This software allowed for a Cartesian coordinate transposition such that the subjects' input could be displaced through left-right reversal, inversion, or tilt. A "Mouse Board" (Mouse Systems Corporation, Santa Clara, CA 95051) was incorporated into the program such that subjects would be able to trace on the pad without visible lag from the visual cues displayed on the computer screen. The screen resolution was 640 X 400 pixels. The Mouse Board has an active surface area of approximately 9 x 11 inches. A "mouse" was used as the
input device (see Figure 2). The mouse has a flat bottom that allows it to slide freely across the Mouse Board. The subject's drawing hand was covered with a table that precluded a view of the hand. Figure 2 shows the experimental setup.

Figure 2. Laboratory Setup: Personal Computer and Mouse Board.

Training Task

The task involved tracing a four-point star pattern (see Figure 3) on the Mouse Board with a data pen while
viewing the pattern on the computer display. Prior to training, subjects received a written introduction to the purpose of the study in an informed consent sheet (see Appendix A). They were each given an information sheet to read (see Appendix B) and were permitted to ask the experimenter any questions regarding those instructions.

Figure 3. Star Pattern Used in Tracing Task (Reduced).

Subjects were asked to draw with their right hand and receive all visual feedback from the computer screen. Subjects were shown how to hold the mouse. The star was to be traced, starting at the top point and moving in a clockwise direction. The computer beeped when the subject
located the top of the star with the mouse, indicating the
start of the trial. Following completion of the star, the
computer beeped to signify that the subject reached the
top and that the trial had ended. No data were recorded
prior to the first beep nor after the second. There was a
10-second pause before the next star pattern appeared on
the screen, during which the previous tracing could be
viewed. The instructions stressed that speed and accuracy
were equally important. The experimenter verbally
emphasized this point before allowing the subject to begin
the experiment.

Task Variety was manipulated during training in four
levels. Subjects trained under alternating variety,
blocked variety, or one of two no-variety conditions: an
experimental and a control. Subjects in the no-variety
experimental condition practiced only one of the training
tasks for 10 trials. Subjects in the no-variety control
condition practiced star tracing but received no
experience in tracing with distorted feedback. The
no-variety conditions were manipulated by practicing only
one of the following tasks:

- A normal tracing task (Normal). Visual feedback
was not distorted. This was the task used in the
control condition.
• A mirror drawing task. Feedback was distorted through left-right reversal (L-R REV).

• A 90-degree tilt task (Tilt) such that feedback was displaced 90 degrees clockwise from the direction the subject was moving the mouse.

The two variety groups received the latter two tasks in training. Under the alternating variety condition subjects completed a total of 10 trials, but alternated between the left-right reversal and tilt tasks. Under the blocked variety condition, subjects completed five trials of one condition of distortion, followed by five trials of the other. The experimental design was counterbalanced to control for task sequence effects and balance the tasks used in the no-variety conditions. All groups were informed (prior to beginning training) of the exact nature of each task and the sequence each task would be presented in, if multiple tasks applied.

**Experimental Design and Procedure**

The design included three phases: a practice trial, the experimental manipulation (training), and a transfer condition. The practice trial and the transfer condition (inversion) were the same for all groups.
Phase I (Orientation Trial)

Prior to participating in the design all subjects completed one practice trial of tracing the star pattern with normal (undistorted) visual feedback. (This was intended primarily to orient the subjects to the media.) During the practice trial the experimenter assured that the subject was employing the correct techniques (holding the mouse correctly, tracing clockwise, etc.).

Phase II (Training)

All subjects completed a total of 10 trials of their experimental condition during training. This took approximately 30 minutes. Subjects were given a 5-minute break after the training session. The computer timed the break and beeped to signal when it was time for the subject to begin the transfer session.

Phase III (Transfer)

A fourth type of visual rearrangement, up-down reversal (inversion) served as the "novel" transfer task. In the literature review, no studies were found which revealed that inversion has been experimentally compared to the these three training tasks in terms of relative levels of task difficulty. All subjects completed 10 trials of inversion as the transfer condition.
TABLE 1
GROUP BY PHASE EXPERIMENTAL DESIGN: COUNTERBALANCED FOR TASK SEQUENCE EFFECTS

<table>
<thead>
<tr>
<th>TREATMENT GROUP</th>
<th>TRAINING PHASE</th>
<th>TRANSFER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALTERNATED VARIETY</td>
<td>A: (L-R REV/TILT ALTERNATE X)</td>
<td>INVERSION</td>
</tr>
<tr>
<td></td>
<td>B: (TILT/L-R REV ALTERNATE X)</td>
<td></td>
</tr>
<tr>
<td>ALTERNATED VARIETY</td>
<td>C: (L-R REV 5 X TILT 5 X)</td>
<td>INVERSION</td>
</tr>
<tr>
<td></td>
<td>D: (TILT 5 X L-R REV 5 X)</td>
<td></td>
</tr>
<tr>
<td>NO VARIETY</td>
<td>E: (L-R REV 10 X)</td>
<td>INVERSION</td>
</tr>
<tr>
<td></td>
<td>F: (TILT 10 X)</td>
<td></td>
</tr>
<tr>
<td>CONTROL</td>
<td>G: (NORMAL 10 X)</td>
<td>INVERSION</td>
</tr>
</tbody>
</table>

X = Trials

Dependent Variables

Data points were compiled at 16.35 points per second, and were used to derive Root Mean Square (RMS) error scores from the desired star outline. The amount of time to complete each trial (to trace the star) was also recorded.

RMS error is a measure commonly used to describe and evaluate performance on tracking tasks. RMS is the square root of the mean of the sum of squared deviations and is
a measure of the magnitude of deviation from the star outline. Each deviation was calculated by measuring the perpendicular distance from the point to the star outline.

It was necessary for a rater to judge which leg the subject was intending to trace when tracing around the points of the star, because the computer could not interpret which leg the subject was trying to trace. This was accomplished by viewing a time compressed playback of the subject's tracing response. While this enters a degree of subjectivity into the error-dependent variable, the risk of error was very minimal, as the direction the subject was heading is relatively easy for a viewer to judge (i.e., not arbitrary). The rater was blind to the subjects as well as to the experimental conditions.
RESULTS

The data were analyzed as a 4 X 2 X 2 X 10 mixed factorial design within a transfer of training paradigm. The between-group factors, variety and gender, have four and two levels respectively. "Trials" is a within-group variable with 10 levels, analyzed within the two levels (training and transfer) of "phase." Planned comparisons were conducted to evaluate each of the stated hypotheses using one-tailed tests of significance, in lieu of an overall F test. Figures 4 and 5 show learning curves across all training and transfer trials for time to completion and RMS error scores, respectively.

Missing scores (12 out of 800) were replaced by calculating an average z score which is indicative of the person's relative position within the group on the trials prior to and subsequent of the missing trial. The average z was multiplied by the group standard deviation of the missing trial, and added to the group mean for that trial to derive the missing score. If the missing trial was the first trial of either training or transfer, a z score was calculated on the subsequent trial only.

One RMS error score was replaced for one subject only in the blocked condition, in the same fashion, when it became apparent that the highest RMS score in the study
was inflated artificially due to the mouse being traced off the bitpad. This was the only change made to the data. The group means evaluated in the planned comparisons are presented in Table 2.

**TABLE 2**

GROUP MEANS FOR TIME TO COMPLETION AND RMS ERROR SCORES USED TO EVALUATE TRAINING AND TRANSFER HYPOTHESES

**TRAINING TRIALS 6 TO 10**

<table>
<thead>
<tr>
<th></th>
<th>TIME</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>76.07</td>
<td>3.30</td>
</tr>
<tr>
<td>No Variety</td>
<td>107.89</td>
<td>9.59</td>
</tr>
<tr>
<td>Alternated</td>
<td>187.04</td>
<td>13.17</td>
</tr>
<tr>
<td>Blocked</td>
<td>171.63</td>
<td>9.31</td>
</tr>
</tbody>
</table>

**FIRST TRANSFER TRIAL**

<table>
<thead>
<tr>
<th></th>
<th>TIME</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>168.23</td>
<td>9.06</td>
</tr>
<tr>
<td>No Variety</td>
<td>167.59</td>
<td>21.28</td>
</tr>
<tr>
<td>Alternated</td>
<td>199.97</td>
<td>13.04</td>
</tr>
<tr>
<td>Blocked</td>
<td>168.19</td>
<td>10.20</td>
</tr>
</tbody>
</table>

**TRANSFER TRIALS 2 TO 5**

<table>
<thead>
<tr>
<th></th>
<th>TIME</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>124.70</td>
<td>8.30</td>
</tr>
<tr>
<td>No Variety</td>
<td>107.51</td>
<td>6.69</td>
</tr>
<tr>
<td>Alternated</td>
<td>125.80</td>
<td>10.09</td>
</tr>
<tr>
<td>Blocked</td>
<td>135.74</td>
<td>6.77</td>
</tr>
</tbody>
</table>
Training

Training phase hypotheses were evaluated using the last five training trials. The first comparison contrasted the two groups receiving variety in training. It was hypothesized that the blocked variety condition would be less difficult than the alternated variety condition as would be evidenced by lower RMS and time to completion scores. The means for time were 171.63 and 187.04 seconds for the blocked and alternated groups, respectively, and this was a significant difference in time to completion scores, $F(1, 32) = 6.74$, $p < .007$. The means for RMS error were 9.31 and 13.17 for the blocked and alternated groups, respectively, however, this was not a significant difference, $F(1, 32) = 1.46$, $p < .16$.

The second planned comparison contrasted the no variety and variety treatment conditions. The predicted superiority of the no variety condition over the variety treatment groups during training was examined by comparing the mean time for the no variety group with the mean time for the two variety conditions. The mean time to completion scores were 107.89 and 179.34 for the no variety group and the variety groups, respectively, and this was a significant difference, $F(1, 32) = 8.66$, $p < .003$. The mean RMS scores were 9.59 and 11.24 for the no variety and variety groups, respectively, and this difference was not significant, $F(1, 32) = .02$, $p < .43$. 
Figure 4. Learning Curve Across All Training and Transfer Trials For Time to Completion.
Figure 5. Learning Curve Across All Training and Transfer Trials For RMS Error Scores.
The third comparison evaluated the hypothesis that during training, the control group would perform better than the treatment conditions on both dependent variables. The mean times were 76.07 and 155.52 for the control group and treatment conditions, respectively, and this was a significant difference for time to completion scores, $F (1,32) = 8.67, p < .003$. The mean RMS error scores were 3.30 and 10.69 for the control and treatment groups, respectively, and this was a significant difference, $F (1,32) = 5.69, p < .05$.

Transfer hypotheses were tested in two ways. The data on the first transfer trial only was analyzed to evaluate all stated hypotheses. Also, the mean of the second through fifth transfer trials was analyzed to evaluate the stated hypotheses, although it is realized that performance on these trials would be effected by learning on the first transfer trial. The first trial only is a clean look at performance in a novel situation, while all subsequent trials reflect new learning in the novel situation. These two approaches give slightly different views of the effects of training conditions on "transfer."
Planned comparisons for the first trial only data will be presented first. It was expected that the alternated variety group would perform faster and with fewer errors than the blocked condition during transfer. The mean time to completion scores were 199.97 and 168.19, for the alternated and blocked variety groups, respectively, however, this was not a significant difference, $F(1,32) = .75, p < .20$. The means for RMS error were 13.04 and 10.20, for the alternated and blocked variety groups, respectively, and this difference was not significant, $F(1,32) = 1.46, p < .12$.

It was hypothesized that the no variety group would be at a disadvantage during transfer when compared to the mean of the variety groups. The mean time to completion scores were 167.59 and 184.08 for the no variety and variety groups, respectively. The difference between group means was in the direction opposite of that which had been predicted, therefore, the two-tailed level of significance was used to evaluate the comparison, and the difference was found to be significant, $F(1,32) = 4.76, p < .05$. The mean RMS error scores were 21.28 and 11.62 for the no variety and variety groups, respectively, however, no difference existed for the error measure, $F(1,32) = .21, p < .33$.

It was expected that the control group would have poorer performance as reflected in higher scores on both
speed and RMS, than the mean of all of the treatment groups during transfer. The mean time to completion for the control group was 168.23, and the mean of the treatment conditions was 178.58, however, this difference was not significant, \( F(1,32) = 2.26, p < .07 \). There was a significant difference on mean RMS error scores between the control group and the treatment conditions, whose means were 9.06 and 14.84, respectively, \( F(1,32) = 3.46, p < .05 \).

Next, the planned comparisons for transfer trials two through five were analyzed to evaluate the stated hypotheses. Again, it was expected that the alternated variety group would perform faster and with fewer errors than the blocked variety group. There was a significant difference in mean time to completion scores between the variety groups, whose means were 125.8 and 135.74, for the alternated and blocked groups, respectively, \( F(1,32) = 4.87, p < .05 \). The means for RMS error scores were 10.09 and 6.77, for the alternated and blocked groups, respectively, and this difference was in the direction opposite of that which had been predicted, so the comparison was evaluated at the two-tailed level, and the difference was found to be significant, \( F(1,32) = 8.00, p < .01 \).

The expected superiority of the mean of the variety groups over the no variety group on both dependent
measures was tested for transfer trials two through five. There was a significant difference in time to completion scores for the no variety and variety groups, whose means were 107.51 and 130.77, respectively, however, the comparison was evaluated at the two-tailed level of significance because the difference was in the direction other than that which was predicted, $F (1,32) = 5.25$, $p < .01$. The mean RMS error score for the no variety group was 6.69 and the mean for the variety conditions was 8.43, however, this was not a significant difference at the two-tailed level of significance, $F (1,32) = 2.00$, $p < .16$.

Next, the control group was compared with the treatment groups on the second through fifth transfer trials. It was expected that the treatment conditions would be superior to the control group on both dependent measures. The mean time to completion scores were 124.7 and 123.02 for the control group and treatment conditions, respectively, and this difference was significant, $F (1,32) = 5.25$, $p < .01$. The mean RMS error score for the control group was 8.30, and the mean of the treatment conditions was 7.85, however, this was not a significant difference, $F (1,32) = 1.37$, $p < .12$. 
DISCUSSION

The experimental hypotheses predicted that the poorest training performance would be followed by the best transfer performance. Such a hypothesis is counter to the traditional assumption that superior training performance leads to superior transfer performance. Contextual variety effects were offered as the basis for the predicted treatment effects. A summary of the planned comparisons and results appears in Table 3.

Training

The treatment conditions were substantially harder than the control condition, as evidenced by the significant difference in time to completion scores and RMS error scores in favor of the control group, when compared against the mean of the treatment groups on the average of the last five training trials.

The hypothesized order of difficulty between treatment groups was confirmed. Within the variety conditions, subjects in the alternated group traced significantly slower than the blocked group during training, however, there was no difference between variety groups on RMS error. The variety groups traced
### TABLE 3
SUMMARY OF PLANNED COMPARISON RESULTS

Results of Planned Comparisons for Time to Completion Scores

<table>
<thead>
<tr>
<th></th>
<th>TRIALS 6 - 10 TRAINING</th>
<th>TRIAL 1 TRANSFER</th>
<th>TRIALS 2 - 5 TRANSFER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALT v. BLK</td>
<td>187 &gt; 172 SIG*</td>
<td>200 &gt; 168 NSD</td>
<td>126 &lt; 136 SIG*</td>
</tr>
<tr>
<td>ALT + BLK v. NO VAR</td>
<td>179 &gt; 108 SIG*</td>
<td>184 &gt; 168 SIG'</td>
<td>131 &gt; 108 SIG'</td>
</tr>
<tr>
<td>ALT + BLK v. NO VAR v. CONTROL</td>
<td>156 &gt; 76 SIG*</td>
<td>179 &gt; 168 NSD</td>
<td>123 &lt; 125 SIG*</td>
</tr>
</tbody>
</table>

Results of Planned Comparisons for RMS Error Scores

<table>
<thead>
<tr>
<th></th>
<th>TRIALS 6 - 10 TRAINING</th>
<th>TRIAL 1 TRANSFER</th>
<th>TRIALS 2 - 5 TRANSFER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALT v. BLK</td>
<td>13 &gt; 9 NSD</td>
<td>13 &gt; 10 NSD</td>
<td>10 &gt; 7 SIG'</td>
</tr>
<tr>
<td>ALT + BLK v. NO VAR</td>
<td>11 &gt; 10 NSD</td>
<td>12 &lt; 21 NSD</td>
<td>8 &gt; 7 NSD</td>
</tr>
<tr>
<td>ALT + BLK v. NO VAR v. CONTROL</td>
<td>11 &gt; 3 SIG*</td>
<td>15 &gt; 9 SIG'</td>
<td>8 = 8 NSD</td>
</tr>
</tbody>
</table>

NSD = No significant difference  
SIG* = Significant in the predicted direction  
SIG' = Significant in direction other than predicted
significantly slower than the no variety during training, however, there were no differences between the no variety and variety groups on RMS error. These results indicate that in terms of time to completion, training with alternated variety was more difficult than training with blocked variety, and combined, the variety conditions were harder than the no variety condition.

**Transfer**

Although there were no significant differences on either dependent variable on the first transfer trial between the variety groups, analysis of trials two through five revealed a significant difference on time to completion scores in favor of the alternated variety group, however, the significant difference on RMS error over the same trials was in favor of the blocked variety condition. Therefore, although the alternated variety group traced faster, the blocked variety group traced with fewer errors.

The fact that the alternated and blocked variety groups did not differ during the first transfer trial on either dependent variable, and performance between the two variety groups was a washout on the second through fifth transfer trials supports Lee and Magill's (1983) findings that when blocked and randomized variety groups are
informed as to the nature of each upcoming task (simple reaction paradigm), no transfer differences will occur. Contrary to the hypothesis, the no variety group performed the transfer task faster than the mean of the variety groups on all of the first five transfer trials. Although there was no difference between the variety and no variety groups on RMS error on either transfer analysis, the fact that the no variety group was faster makes the no variety condition superior to the variety conditions.

It was hypothesized that training with displaced feedback would result in superior transfer performance to a novel displacement, however, mixed results were obtained in the transfer comparisons between the control group and the mean of the treatment groups. Although the control group displayed more accurate performance on the first transfer trial, there was a slight advantage for the treatment groups on time to completion on transfer trials two through five.

The transfer advantage conveyed by the control group was probably a result of the nature of the training condition (normal feedback). The control condition was a part-task training manipulation. Subjects in the control group were able to familiarize themselves with the use of the mouse, and received practice on the fine motor movements required by the task without the confusion and
errors created as a result of displaced feedback. The initial degree of learning on the tracing task resulted in superior transfer performance, when exposed to displaced feedback for the first time. These results suggest that future studies involving transfer with displaced feedback should incorporate several learning trials on the task under normal feedback conditions.

Clearly, the variety groups did not have a transfer advantage, and indeed, appeared to be at a disadvantage in the transfer session. The transfer disadvantage in the variety conditions may be due to shorter practice on any one task during training. Thus, less learning was taking place within the variety conditions, and subjects were probably experiencing confusion due to the variety manipulation and the nature of the displacements. Extended training may resolve the confusion created by the variety manipulations. It is speculated that variation may indeed improve transfer if longer training periods were provided.
APPENDIX A

EXPERIMENTAL BRIEF

The purpose of this research is to investigate the effects of task variety during training on perceptual-motor learning. The study consists of a computer drawing task, however, no prior "drawing skill" is required, as you will actually be tracing. The experiment takes about one hour to complete, and one five minute break will be provided. You will be paid $5.00 for your participation.

Visual feedback of your tracing response will be altered through one of three different distortions: left-right reversal, up-down reversal, or 90 degree tilt such that your tracing line will appear 90 degrees to the right of the direction you are actually tracing). Some people find this frustrating, but learning will take place. There are twenty trials, and most people accomplish this within one hour.

Informed Consent

I have been told that no adverse effects (other than possible frustration or boredom) are expected in connection with my participation in this study. All data will be held in confidence and care will be taken to ensure privacy. My participation in this study is voluntary, and refusal to do so will not result in any penalty or loss of benefits to which I am otherwise entitled. If at any time I wish to withdraw my participation as a subject, I may do so, without penalty.

Signed ____________________________ Date ____________
Experimenter __________________________ Date ____________

Thank you for your participation in this study, and your contribution to scientific research
APPENDIX B
INFORMATION SHEET

In this experiment, you will be asked to trace the pattern of a star under varying conditions of visual feedback. You are asked to draw with your right hand. Your drawing hand will be covered, so it will be necessary to receive visual cues from the computer display.

This experiment will consist of two phases, each requiring ten trials. There will be a five minute break after the first ten trials. The computer will instruct you when to take your break, and a buzzer will sound when you are to return to your task. Your very first trial will be a practice trial. No data will be recorded, and feel free to ask questions at that time.

The apparatus you will use to trace the star is called a "mouse." The mouse is to be held with the fingers of your right hand, and you will notice that it slides easily across the drawing surface. Find a comfortable position to hold the mouse, and maintain that position until you have completed the trial (rotating the mouse while tracing "rolls" your point around on the screen). The computer will instruct you where to position the mouse on the bit pad. Notice that the initial position may change throughout your session, so be sure to read exactly where to position the mouse each time. The computer will instruct you to press either of the two buttons on the mouse to make the star pattern appear on the screen (if you accidentally hit those buttons during a trial, not to worry, nothing will happen...but do not press either button before positioning the mouse).

When the star appears on the screen, the cursor (little light dot) will appear at the top point of the star. This is your point. No data are recorded until you touch the top point of the star, and the computer beeps. From that beep on, your data are being recorded. You will begin to see data points appear on the screen as you move the mouse over the drawing surface. Trace on the star outline in a clockwise direction (to the right). It is important that you work swiftly, but with accuracy. Try not to lift the mouse off of the bit pad during the trials. When you return to the top of the star the computer will buzz to indicate that the trial has ended. When the buzzer sounds, and the trial has ended, leave the mouse at that point on the bit pad, and the computer will instruct you as to where to position the mouse next.

This is a repetitive task, but please try to do your best on every trial. Remember, do not sacrifice accuracy for speed!!!
REFERENCES


