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Contextual Interference in Motor Learning: Dissociated Effects Due to the Nature of Task Variations

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The contextual interference effect in motor learning refers to the interference that results from practising a task within the context of other tasks in a practice session. Several studies have shown that practice under conditions of high contextual interference (i.e. with a random practice order) degrades performance during acquisition trials, compared to low contextual interference conditions (i.e. with a blocked order, where practice is completed on one task before practice on another task is undertaken). In contrast to acquisition performance, random practice usually leads to more effective learning than blocked practice, as measured by retention and transfer tests. One of the hypotheses regarding the effect suggests that a random practice schedule induces more extensive planning operations during practice than a blocked practice condition. If so, then differences between these two conditions should emerge to the degree that the set of tasks requires complete reconstruction of these planning operations on each trial. To address this issue, we compared four groups of subjects: a blocked and random group that practised three timing tasks that shared a common characteristic (same relative timing), and a blocked and random group that practised three tasks that each had different relative timing structures. Subjects practised these tasks on each of two days, with a retention test and two transfer tests that required either a relative timing structure that had been practised previously or had not previously been practised. No random/
blocked differences occurred regardless of the relative timing of the patterns during acquisition or retention. However, for both transfer tests, random practice enhanced learning only for the group that had practised with tasks that each had different relative timing during acquisition. Implications of these results for an explanation of contextual interference are discussed.

A renewed interest in practice effects on the retention and transfer of skill has contributed some important insights into the processes that subserve motor learning (see Adams, 1987; Newell, 1991 for recent reviews). One practice effect that has received considerable attention is the contextual interference effect. Originally noted by Battig (1966) as an anomaly in learning word lists, the effect has seen some attention in the learning of procedural skills (Carlson, Sullivan, & Schneider, 1989; Carlson & Yaure, 1990) but has most extensively been studied in the learning of motor skills (see Magill & Hall, 1990, for a recent review).

The contextual interference effect may be characterized as the influence on performance when more than one task is practised during an experimental session. According to Battig (1979), interference in the performance of a task may arise when it is performed in the context of other tasks. This context effect can be created in two ways: interference may result either from the order under which practice is structured, or from the similarity of the tasks to be practised. The contextual interference effect is considered a performance paradox because increases in interference lead to degraded performance during practice, but to enhanced learning as measured in retention and transfer tests.

Most empirical studies investigating contextual interference have examined the impact of practice order and are typified by Shea and Morgan's (1979) experiment. Interference during the acquisition of three patterns of arm movements was manipulated by organizing practice trials according to either a blocked or a random order. Under blocked practice, performance of all trials for one of the patterns was completed before another task was practised. Under random practice, a different pattern was practised on each trial. Shea and Morgan found that the greater interference caused by the random practice condition resulted in less effective practice performance but in superior retention and transfer performance, relative to the blocked practice condition.

According to Battig's conceptualization, contextual interference effects created by practice orders should interact with the relationship amongst the set of tasks to be learned. Indeed, while Magill and Hall (1990) reviewed many replications of the Shea and Morgan (1979) findings, they noted a particular trend amongst failures to replicate. They found that studies that failed to find differences between practice orders used a set of tasks that shared the same generalized motor program (Schmidt, 1975,
1985). A generalized motor program is the memory representation for a class of actions that share certain invariant motor control characteristics (such as relative timing and relative force). According to this view, generating a movement requires a two-stage process: (1) selecting the appropriate generalized motor program for the goal, and (2) implementing that program by specifying the parameters for movement (such as selecting the absolute time and force as well as which muscles to use). Magill and Hall's review suggested that random/blocked practice order effects are most prominent when the tasks to be learned each have different generalized motor programs, thereby requiring that both the selection and parameterization process be undertaken by the random group on each trial. Random/blocked differences were not observed, however, when all of the tasks shared the same program, thereby requiring that the random group only generate new movement parameters on each trial (see also Wood & Ging, 1991).

Magill and Hall's conclusion from their review of the literature argued against Battig's hypothesis regarding the interactive nature of practice order and task similarity. Battig (1979) suggested that interference should increase as tasks become more similar, resulting in an enhanced contextual interference effect, rather than the diminished effect concluded by Magill and Hall. Of course, these predictions are contingent upon how one defines task similarity. From the generalized motor program view, a set of tasks that differ only in terms of a variant feature are more similar than a set of tasks that each differ in both variant and invariant features. Considering Battig's perspective this way, the prediction is that random/blocked differences would be large for a set of tasks that shared the same generalized motor program as only the variant features of the task are different. In contrast, tasks that differ both in the invariant and variant features could be argued to be quite dissimilar, and random/blocked differences would be predicted to be diminished. Clearly, the conclusion made by Magill and Hall argued against Battig's hypothesis.

In contrast, Magill and Hall's conclusions are logically consistent with the theoretical arguments regarding the random/blocked practice order effects suggested by Lee and Magill (1983, 1985). Their position was based

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1 Battig's (1979) arguments regarding contextual interference were made with explicit reference to memory for verbal materials. However, it is clear that the initial foundation for Battig's ideas were related to the learning of motor skills (e.g. Battig, 1966), and Battig later returned to motor skills for an extension of his ideas regarding contextual interference (Battig & Shea, 1980). Battig (1979) referred to inter-item similarity in terms of semantic and orthographic relationships amongst the verbal items to be learned (e.g. Lauer, Streby, & Battig, 1976). However, Battig did not define how similarity, amongst motor tasks might be defined. Our operational definitions regarding similarity, and how the findings are interpreted with respect to Battig's conceptualization of contextual interference, should be viewed within these limitations.
largely on Jacoby's arguments regarding the spacing effect in memory for verbal items (Cuddy & Jacoby, 1982; Jacoby, 1978). Lee and Magill suggested that motor learning involves a problem-solving process, where the problem is to find the best motor solution for the task goal (Adams, 1971; Bernstein, 1967). Under a blocked order of practice, successive attempts on a task do not require new "action planning" because the memory for the previous plan is readily available for revision or reimplementation. Under random practice conditions, however, the action plan for a previous performance of the task is likely to have been forgotten due to the interference of performing intervening tasks. The consequence of having to reconstruct action plans throughout practice is a decrement to practice performance but a later facilitation to retention and transfer.

A problem with this hypothesis, however, is that the precise nature of the action plan was not specified by Lee and Magill (1985), and an acceptable definition remains elusive (Newell, 1978). In terms of the variables manipulated in the present experiment, we suggest that more extensive planning would be required when a succeeding task required both a different generalized motor program and parameterization, compared to a succeeding task which required only a reparameterization of the same program. There is ample evidence that changing a generalized motor program requires more extensive operations than altering the parameters of a program. For instance, Quinn and Sherwood (1983) found that the EMG latencies in response to a stimulus were longer when a reversal in arm direction was required than when an acceleration in the direction of movement was required. Presumably, implementing a change in the parameterization of the movement speed required a less extensive operation than did changing the motor program (see also Roth, 1988). Expanding Lee and Magill's ideas, the extensiveness of the "reconstruction" process can be considered in terms of the planning operations that would be faced by a subject in a random practice condition. If a subject were required to alter both the parameters and the generalized motor program, there would be more extensive reconstruction required than if only a reparameterization of the same program were required. The resultant effect would be a dissociation as a function of task type, random/blocked differences being larger when task variations involve different generalized motor programs than when the set of tasks comprised variants of the same program.

The predictions regarding random/blocked differences as a function of the nature of the tasks may be summarized, then, as follows: from the Battig perspective, random/blocked differences should be larger when the set of tasks practised are all variations of the same generalized motor program, than when they each represent different programs; from the Lee and Magill view, random/blocked differences would be larger when tasks are
subserved by different generalized motor programs than by the same program.

These predictions were tested in the present experiment by comparing four groups of subjects: two groups of subjects (random vs. blocked practice order) practised three trisegment tasks, each of which shared a common relative timing; the other two groups of subjects (also random vs. blocked practice orders) practised three tasks, each of which had a different relative timing. The effects of these practice conditions were compared over two days, where each day included an acquisition phase as well as a retention test and two transfer tests.

Method

Subjects

Undergraduate volunteers (32 females and 16 males) from McMaster University participated as subjects. All subjects received credit in a physical education course for participating in the experiment. Subjects were assigned at random to one of four groups, with the only restriction that each group be balanced for gender. None of the subjects had previously practised the task, and none was told the purpose of the experiment.

Apparatus and Task

The apparatus and task were very similar to that used by Wulf and Schmidt (1988; see their Figure 1, on p. 136, for an illustration of the apparatus). The apparatus consisted of a wooden base upon which were mounted four electromagnetic microswitches. The microswitches were mounted in the shape of a diamond, such that the subject moved from the front-centre (home) microswitch forward and to the left to contact the first target, then forward and to the right to the second (centre-rear) target, then towards the body and to the right for the final target. The distance between each adjacent microswitch was 18 cm.

A 1 cm × 4 cm cylindrically shaped magnet was used as the stylus to tap each target. Each switch was connected to a Lafayette Performance Pack, which recorded the segment times to the nearest msec.

The subject's task on each trial of the experiment was to move from the resting home position (the centre-front microswitch) to the three successive targets according to specified goal movement times. A movement segment was defined as the movement required between two targets. Segment 1 was from the home position to the first target; Segment 2 was from the first to the second target; and Segment 3 was from the second to the third target. Each segment was assigned a goal movement time. The
three goal movement times for each task variation were printed on separate cards and mounted on the wall behind the apparatus.

**Procedures**

A summary of the testing sequence is provided in Table 1. A factorial arrangement of task variations (same- vs. different-phasing) and practice conditions (random vs. blocked order), resulted in four independent groups of subjects. Testing for each of the four groups of subjects took place on two consecutive days. On each day the subjects completed four phases of the experiment: 90 acquisition trials, 12 retention trials, 12 same-phasing transfer trials, and 12 different-phasing transfer trials. The order of these phases was not the same on each day, however. On Day 1, the subject first completed the 90 acquisition trials. Following the acquisition phase, the subject completed one of the transfer phases and then the other transfer phase (counterbalanced across subjects within groups). The final phase on the first day was retention. Performance on Day 2 began with 12 retention trials, followed by 90 more acquisition trials. The transfer trials were performed last, with the order of performance of these trials reversed from the previous day.

Only the acquisition trials differentiated the four groups of subjects. Every subject performed the same retention and transfer tests. A summary of the details of the experimental design is provided in Table 2.

**Acquisition Phase.** The four groups of subjects comprised two random and two blocked groups. One random and one blocked group practised three movement variations that had the same relative timing (same-
TABLE 2
Summary of the Details of the Experimental Design:
Absolute Goal Movement Times, Goal Proportions (in parentheses), and
Overall Movement Times

<table>
<thead>
<tr>
<th>Same-phasing Groups</th>
<th>Different-phasing Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acquisition</strong></td>
<td></td>
</tr>
<tr>
<td>150–300–225 (0.22–0.44–0.33) 675</td>
<td>225–150–300 (0.33–0.22–0.44) 675</td>
</tr>
<tr>
<td>200–400–300 (0.22–0.44–0.33) 900</td>
<td>200–400–300 (0.22–0.44–0.33) 900</td>
</tr>
<tr>
<td>250–500–375 (0.22–0.44–0.33) 1125</td>
<td>500–375–250 (0.44–0.33–0.22) 1125</td>
</tr>
<tr>
<td><strong>Retention</strong></td>
<td></td>
</tr>
<tr>
<td>200–400–300 (0.22–0.44–0.33) 900</td>
<td></td>
</tr>
<tr>
<td><strong>Same-phasing Transfer</strong></td>
<td></td>
</tr>
<tr>
<td>300–600–450 (0.22–0.44–0.33) 1350</td>
<td></td>
</tr>
<tr>
<td><strong>Different-phasing Transfer</strong></td>
<td></td>
</tr>
<tr>
<td>600–300–450 (0.44–0.22–0.33) 1350</td>
<td></td>
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</tbody>
</table>

The three tasks practised by the same-phasing groups all had the same proportional segment movement goal times: the segment movement time goals (in msec) for each of the variations were: 150–300–225, 200–400–300, and 250–500–375; the proportions for the three segments relative to the total movement time (sum of the three goal times) were 0.22–0.44–0.33 for each of these variations. The three tasks practised by different-phasing groups each had a different relative timing structure: the segment movement times (in msec) were 225–150–300, 200–400–300, and 500–375–250; the proportions were 0.33–0.22–0.44, 0.22–0.44–0.33, and 0.44–0.33–0.22, respectively.

On each day 30 acquisition trials were performed on each of the task variations (total = 90 acquisitions trials per day). Knowledge of results (KR) in terms of the actual segment performance times was provided by the experimenter on all acquisition trials.

The random practice groups performed the three task variations according to a randomized procedure that had two restrictions: (1) that each task variation be performed twice within each block of six trials, and (2) that no more than two trials on the same task variation could be practised on consecutive trials. On each day, the blocked practice groups performed all 30 trials of one variation before switching to another variation. The order...
by which these variations were practised was counterbalanced across subjects within groups according to a William’s square design. The same order was never used for the same individual on the two days of acquisition.

Retention. The 12 retention trials were performed on the only task variation that all subjects had practised (200–400–300). The retention trials were conducted without KR. The rationale for conducting the retention trials as the last phase on Day 1 and as the first phase on Day 2 was to assess contextual interference effects following both a brief and a long delay, uninfluenced by performance on any of the other tasks.

Same-phasing Transfer. This transfer test (300–600–450) shared the same relative timing requirements as the three versions practised by the same-phasing groups and had the same relative timing as one of the variations practised by the different-phasing groups (0.22–0.44–0.33). However, the same-phasing transfer test required an absolute timing parameterization that had a longer overall duration than any version that had been practised. The 12 trials on each day of practice were performed without KR.

Different-phasing Transfer. This transfer test (600–300–450) had both absolute and relative timing requirements that differed from any task variation that had been performed previously (0.44–0.22–0.33). The overall duration for this transfer test was the same as the overall duration for the same-phasing transfer. The different-phasing transfer test was also performed without KR.

To summarize, the four groups of subjects differed in terms of the nature of task variations practised and the order by which they were practised during the acquisition phases of the experiment. One blocked group and one random group practised three task variations with the same relative timing (but different overall duration), and a blocked and random group practised three task versions with different phasings (and different overall durations). These four groups are called: (1) same-phasing/blocked-order, (2) same-phasing/random-order, (3) different-phasing/blocked-order, and (4) different-phasing/random-order. Practice was conducted on each of two consecutive days, which also included a retention test and two transfer tests.

Data Analyses

Absolute error (AE), calculated as the differences (without regard to sign) between the actual times on each movement segment and the respective goal times, was averaged over blocks of six trials for the purpose
of statistical analyses (similar to the analyses performed by Wulf & Schmidt, 1988). Separate ANOVAs were performed on the same-phasing and different-phasing groups for acquisition, retention, and transfer. The acquisition data were analysed using a 2 (Group) \( \times \) 3 (Task) \( \times \) 2 (Day) \( \times \) 5 (Trial Block) ANOVA with repeated measures on the last three factors. The design for the retention and transfer data were 2 (Group) \( \times \) 2 (Day) \( \times \) 2 (Trial Block) ANOVAs, with repeated measures on the last two factors. All significant effects are reported at the \( \leq 0.05 \) level of significance.

Results

Acquisition

Same-phasing Practice. Under the same-phasing task variations, the blocked group and random group performed very similarly during the acquisition phases on both Day 1 and Day 2. Both groups showed negatively decelerating performance curves on the first day and only a small further reduction in AE on the second day (see Figure 1). The main effect of group was not significant (\( F < 1.0 \)). The only significant effects found in the ANOVA were due to the typical benefits of practice with KR. The main effects of day, \( F(1, 22) = 15.60, MSe = 2290.47 \), trial block, \( F(4, 88) = 33.91, MSe = 331.81 \), and the Day \( \times \) Block interaction, \( F(4, 88) = 2.58, MSe = 356.66 \), were significant.

Different-phasing Practice. There was essentially no difference between the blocked and random groups that practised the different-phasing task versions on either Day 1 or Day 2. Both groups demonstrated relatively greater improvements on Day 1 than on Day 2 of practice (see Figure 1). The group effect was not significant. However, the effects of day, trial block, and the Day \( \times \) Block interaction were all significant, all \( F's > 10.0 \). In addition, performance of the 500–375–250 task was both poorer overall and improved less rapidly than did the performance of the other two task versions. The result was a significant task main effect, \( F(2, 44) = 13.47, MSe = 4761.81 \), a Task \( \times \) Day interaction, \( F(2, 44) = 3.89, MSe = 1778.50 \), and a Task \( \times \) Trial Block interaction, \( F(8, 176) = 7.18, MSe = 449.98 \).

\( ^2 \)Wulf and Schmidt also reported a proportional error score, which was the absolute difference between actual duration of each segment relative to the total duration and the goal of each segment relative to the total duration. This measure was considered an index of how well the relative timing component of the generalized motor program was represented in memory, as assessed by the retention and transfer tests. This proportional AE measure was also computed and analysed in the present experiment. Similar to the findings of Wulf and Schmidt, the results for this proportional AE measure paralleled the AE results very closely. Details of the results of these analyses are available from the first author.
Retention

Same-phasing Practice. Retention performance of the blocked and random groups that practised the task versions with the same phasing are shown at the left of Figure 2. The random group tended to have less AE than the blocked group on Day 2. However, the main effect of Group and all interactions with Group were not significant. In fact, no significant differences at all were revealed in this analysis.

Different-phasing Practice. Performances of the blocked and random groups with different-phasing practice are illustrated at the right of Figure 2. Although the random group tended to be more effective than the blocked group on the first trial block of each day, the Group × Block interaction failed to reach significance \( [F(1, 22) = 2.08, MSe = 196.32, p = 0.16] \). The only retention effect to reach significance was the trial block main effect, \( F(1, 22) = 5.23, MSe = 196.32 \). The second block of trials was performed better than the first block of trials on both retention tests.
**Same-phasing Transfer**

*Same-phasing Practice.* On the transfer test with the same relative timing as the three task versions practised under same-phasing conditions, the blocked and random groups performed similarly (see left side of Figure 3). There were no effects of Group or interactions with Group (all $F$'s $< 1.0$). Both groups consistently improved their AE from the first block of trials on Day 1 to the second block of trials on Day 2. These improvements resulted in significant main effects for day, $F(1, 22) = 8.87, MSe = 645.84$, and trial block, $F(1, 22) = 5.91, MSe = 636.82$.

*Different-phasing Practice.* Same-phasing transfer performances of the blocked and random groups that practised the phasing requirements of this transfer task on only one task version (medium duration) are shown on the right-hand side of Figure 3. The performance of the random group on the first block of trials on each day was better than the performance of the blocked group on these trials. These differences did not extend into the
second block of trials, however. The result was a Group × Trial Block interaction, $F(1, 22) = 8.24$, $MSe = 724.80$. No other significant effects were found.

**Different-phasing Transfer**

*Same-phasing Practice.* Performances of the blocked and random groups with same-phasing practice on the transfer task with new phasing requirements are illustrated at the left of Figure 4. Consistent with the retention and same-phasing transfer performances, there were no differences between the random and blocked practice orders on the different-phasing transfer trials. Although there does appear to be an advantage for the random group on Day 2 of transfer, the Group × Day interaction fell short of significance [$F(1, 22) = 3.06$, $MSe = 1640.28$, $p = 0.09$]. The only significant effect to emerge in this analysis was an improvement in performance from the first to the second block of trials on both days, $F(1, 22) = 15.10$, $MSe = 986.69$. 

FIG. 3. Average absolute error during the same-phasing transfer test. Each data point represents the AE averaged over six trials on each segment of the 300–600–450 task. The data are presented over two blocks of trials on each of two days.
Different-phasing Practice. Different-phasing transfer performances of the groups that experienced different phasing patterns during practice are illustrated at the right of Figure 4. The random group performed with less AE than the blocked group, resulting in a significant group main effect, $F(1, 22) = 6.21, \ MSe = 3303.98$. This difference between groups did not interact with any other factor. The only other significant effects found were due to the consistent performance improvements from the first block of trials on Day 1 to the second block of trials on Day 2 (see Figure 4). This reduction in AE resulted in main effects for day, $F(1, 22) = 7.38, \ MSe = 1954.82$, and trial block, $F(1, 22) = 8.52, \ MSe = 784.48$.

Discussion

Key ingredients that are particular to motor learning phenomena include subject and task variables, practice, feedback, and criterion tests used for assessing learning. It should not be surprising that these factors interact in
a complex manner when combined in different ways. Indeed, based upon the recent review of the contextual interference literature by Magill and Hall (1990), it seems unlikely that a simple theoretical formulation of even this learning phenomenon is forthcoming. Nevertheless, the results of the present experiment appear to clarify some of the issues regarding the interaction of practice schedules with the nature of the set of tasks practised.

Based on the theoretical formulation of Battig (1979), tasks that are highly similar should produce more interference under random practice conditions than tasks that are not similar. These effects would be manifested by large random/blobbed learning differences for highly similar tasks, but small random/blobbed differences for tasks of low similarity. Based on Lee and Magill's (1985) arguments, however, there should be more interference between tasks of low similarity than between highly similar tasks. Considered in terms of the variables manipulated in the present experiment, Battig's perspective predicts that tasks that differed only in terms of overall duration, and not relative timing, should have produced larger random/blobbed differences than tasks that differed in both the overall duration and the relative timing. In contrast, Lee and Magill's hypothesis predicted that larger random-blocked differences would occur when the task revisions differed in both the overall duration and the relative timing than when only the overall duration was different.

The results of both the acquisition data and the retention data were equivocal in terms of the predictions made based on both Battig's and Lee and Magill's hypotheses. For acquisition and retention, the differences between the random and blocked groups were not significant. One possibility for this result could be the nature of the task. The multiple goal timing task used here is considerably more difficult than the movement pattern tasks, duration-goal timing tasks, and coincident timing tasks that have often been used in contextual interference studies (see Magill & Hall, 1990, for a review). Indeed, the absence of acquisition differences between blocked and random practice orders has also been noted for subjects learning computer games (Lee & White, 1990).

Another possibility is that the concept of a "typical" contextual interference effect is incorrect. Two findings support this contention. In one study, segmental training (of the type reported here) resulted in better transfer than practice on a single movement duration (Langley & Zelaznik, 1984). This finding was suggested to be a within-movement type of contextual interference that influenced acquisition performance, but not transfer (Carnahan & Lee, 1989). Thus, the differences between acquisition groups might have been "typical", although transfer was not. Another study by Pollock and Lee (submitted) showed a different trend to the typical contextual interference effect. Random and blocked groups of adults and seven-year old children were compared. The performance of the
adult subjects conformed to expectations; blocked practice better than random during acquisition, and random better than blocked during retention and transfer. However, there were no differences during acquisition trials between the seven-year old, blocked and random groups. Nevertheless, the children who had practised under a random order later performed better than the blocked group on tests of retention and transfer. It is clear that there is no "typical" contextual interference effect, and factors such as task and subject variables interact in complex ways to affect performance on acquisition, retention and transfer tests (Jenkins, 1979; Shea & Zimny, 1983).

Retention and transfer place quite separate and distinct processing demands on the subject. Retention tests require the subject to perform a task that had previously been practised, while transfer tests require the subject to extrapolate from their previous experiences in an attempt to achieve novel task demands. The interaction of processing demands constrained by the test for learning and the processing demands encouraged by the acquisition conditions are prime determinants of performance (Lee, 1988). Thus, it should not be surprising when retention and transfer data provide incongruous results (e.g. Magill, Meeuwsen, Lee, & Mathews, unpublished manuscript).

Despite the incompatibility of the retention and transfer results, the conclusions regarding the theoretical predictions on transfer were relatively straightforward. Based on Battig's ideas, the random/ blocked differences for the same-phasing groups should have been the largest. The present findings provided no support for this prediction in any of the retention or transfer tests. Based on the Lee and Magill hypothesis, however, the random/blocked differences were predicted to be the largest for the different-phasing groups. Though no differences were found during retention, the results for both the same-phasing and different-phasing transfer tests did support the prediction. On the same-phasing transfer test the random group performed more effectively than the blocked group on the first trial block of each day. On the different phasing transfer test the random group was more effective overall than the blocked group.

The reconstruction hypothesis (Lee & Magill, 1983, 1985) provides a reasonably good explanation for some of the present results. The advantage for learning under random practice conditions (compared to blocked practice) occurred when successive trials required that a different relative timing structure be executed. However, no advantage was found when successive trials required only that a different overall duration, with the same relative timing, be executed. The advantage for random practice conditions, then, appeared to depend upon the relationship of the invariant, and not the variant, feature of successive trials. When a different phasing was required on a subsequent trial, the subject had to abandon the relative timing structure that had been executed on the preceding trial.
and construct a new phasing. However, when a trial necessitated only a different overall duration for the same relative timing as the preceding trial, short-term retention of the previously executed invariant structure obviated a more complete reconstruction. The abandonment and subsequent reconstruction of relative timing, and not overall duration, resulted in the contextual interference effects that later emerged on the transfer tests.

The results of the present experiment also help to clarify the relationship between contextual interference effects and variability of practice tests of schema theory (Schmidt, 1975; Shapiro & Schmidt, 1982). Previously, the suggestion was made that schema theory could not explain the effects of random versus blocked practice orders when the amount of practice variability was equated (Lee, Magill, & Weeks, 1985). However, as schema theory is closely tied to the concept of the generalized motor program, this limitation would be true only if random/blocked effects were found using task variations of the same motor program. The results of the present experiment and the conclusions of Magill and Hall (1990) do not support this limitation to schema theory, as practice order effects were found only for task variations of different generalized motor programs.

The effects of practice on motor performance and learning is often discussed under the term "repetition" (e.g. Bartlett, 1932). The present experiment revealed that the impact of practice orders on motor learning was different if the task variations were considered in terms of a motor control characteristic (i.e. phasing). Thus, what is repeated on consecutive trials may assume a different meaning, depending on the level of analysis of the task. Closer attention to task analysis may help to identify not only what is repeated in a repetition, but what it is important to repeat and not to repeat when attempting to enhance motor learning.

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