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CONTEXTUAL INTERFERENCE EFFECTS ON ACQUISITION AND TRANSFER OF A COMPLEX MOTOR TASK

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PREFACE

This report describes one of several experiments conducted in the TRAIN Cooperative Laboratory from October 1993 to March 1994. Funds for this research were provided by the U.S. Air Force Office of Scientific Research and the Armstrong Laboratory TRAIN Project, AL/HRTI, Brooks AFB, TX, Dr. West Regian, Director. A special thanks to Galaxy Scientific for data collection especially to Cathy Connolly Gomez for comments on an earlier draft of this manuscript.

SUMMARY

Research in motor skill and verbal memory suggests that random sequencing of trials results in retention and transfer that is superior to blocked presentation of trials. The contextual interference effect is based largely on relatively simple motor and verbal tasks. The present study explores the generalizability of the contextual interference effect to a complex flight simulator task. Subjects (66 males and 45 females) were assigned to three groups (i.e., whole-task, part-task blocked, and part-task sequenced) and trained on a desktop flight simulator. Part-task blocked subjects practiced 13 component tasks presented in blocks (low contextual interference), and part-task sequenced subjects practiced the same component tasks presented in a sequence that was repeated several times (high contextual interference). It was predicted that part-task sequenced subjects would show superior retention and transfer compared to blocked subjects. Results indicated that whole-task subjects showed the best retention and the two part-task groups did not differ. Additionally, all three groups showed equivalent performance on the transfer task. The results suggest that the contextual interference effect may not generalize to complex tasks.

CONTEXTUAL INTERFERENCE EFFECTS ON ACQUISITION AND TRANSFER OF A COMPLEX MOTOR TASK[1]

INTRODUCTION

Battig (1966) noted an anomaly in verbal learning experiments in which high intratask interference facilitated retention. He later termed this effect the *contextual interference effect* (Battig, 1979). Subsequent research has replicated the contextual interference effect in relatively simple tasks, such as: verbal memory (Glenberg, 1979), cognitive procedural tasks (Carlson and Yaure, 1990), and motor learning (Shea and Morgan, 1979).

Glenberg (1979) presented three experiments that support his component-levels theory of the spacing effect. He proposed that the spacing between repetitions in a random sequence produces greater storage of three types of information: contextual, structural, and descriptive. With more information stored, there would be more retrieval cues, and therefore better recall and recognition.

Carlson and Yaure (1990) present three experiments that support the idea that random practice schedules produce more extensive processing in working memory. Subjects receiving random practice on calculating Boolean functions showed greater transfer to a problem solving task than those receiving blocked practice. The same type of effect was obtained when the interval between trials was filled with other tasks that required working memory processing but not storage. They concluded that high contextual interference clears working memory and forces processes to be reloaded, thus producing efficiency in loading procedures into working memory.

Shea and Morgan (1979) demonstrated the contextual interference effect on motor learning. Their subjects learned three motor tasks under random (high interference) and blocked (low interference) presentation sequences. They found that retention and transfer were superior following random practice compared to blocked practice. Shea and Morgan interpreted their results from a levels of processing perspective and concluded that random practice leads to greater elaboration and distinctiveness of information than blocked practice.

Regardless of the underlying cognitive mechanism, these three lines of research suggest that instructors should intermix training on several skills simultaneously rather than focusing on one at a time. All three theories discussed above seem to be easily extended to complex tasks that require longer training. However, before a comparison of the theories can be made, the contextual interference effect must be obtained in more complex tasks. Thus, the goal of the present study was to demonstrate the contextual interference effect in a complex task: a desk-top flight simulator task.

One way of adapting the contextual interference phenomenon to complex tasks is through a part-task training paradigm. Complex tasks may be viewed as being composed of several component tasks. Often, complex tasks are trained by breaking the task down into its components and training the component tasks separately. This is the essence of part-task training. Contextual interference may be produced by sequencing training intervals on different component tasks so that no two consecutive intervals contain training on the same component task. This kind of schedule should produce relatively more interference than a schedule in which practice on the component tasks is blocked. If the contextual interference effect generalizes to

[1]This paper was presented at the Human Factors and Ergonomics Society 38th Annual Meeting, October 28, 1994, Nashville, TN.

complex tasks under these conditions, then a sequential presentation of different component tasks should be superior to blocked presentation for retention and transfer.

A complex desk-top flight simulator task was divided into several component tasks. Component tasks were either presented in blocks or repeated sequences. Blocked presentation of the component tasks represents minimal contextual interference since adjacent trials are quite similar. Sequential presentation produces greater contextual interference since adjacent trials are less similar. Sequential presentation was predicted to show greater retention and transfer than blocked presentation.

METHODS

Subjects

Subjects were 66 males and 45 females recruited by local temporary employment agencies in San Antonio, Texas. Subjects were paid about $5.00 an hour for their participation. Subjects ranged in age from 18 to 30 years of age and reported spending less than 20 hours per week playing video games. All subjects had a high school diploma or GED but none had completed a two-year or a four-year college degree. Also, none of the subjects had ever flown the flight simulator. The subjects were randomly divided into three groups of 37 subjects each (22 males and 15 females). One group received whole-task training, the other two groups received part-task training on either a blocked or a sequenced schedule.

Equipment

The flight simulator, called Phoenix, was designed to train Heads-Up-Display (HUD) symbology and basic flight skills. The Phoenix display provided an out-of-cockpit view of a simulated world. The HUD shows airspeed, heading, and altitude, as well as, a climb/dive ladder that indicated pitch and roll. The data were collected in the TRAIN CoLab at Lackland AFB. This laboratory contains 30 Compaq DeskPro 486/33L computers with NEC/Multisync VGA monitors and CH Products Flight Sticks.

Tasks

Target task. The criterion flight task (i.e. whole-task) was a slalom task which required subjects to "fly" the simulator though "gates" in the sky. Subjects had to maneuver the simulator horizontally and vertically to fly through the gates. Four different courses (2 easy and 2 difficult) were used. Trials lasted 3 minutes and subjects were instructed to fly through as many gates as possible while minimizing misses.

Component tasks. Thirteen different component skills tasks previously shown to predict performance on the target task were employed (Goettl, 1993). The component tasks were designed to represent a hierarchy of tasks promoting skill development from basic "stick and rudder" skills to higher order skills of spatial orientation. Tasks used in the present study included unpitch, unroll, unpitch-roll, pitch, roll, pitch-roll, altitude, heading, altitude-heading, easy gate, tiny gate, orient plan I, and orient II (see Goettl, 1993 for a description of these component tasks).

Transfer task. The transfer task, called the strike task, required subjects to fly the simulator through the simulated environment and shoot down three targets. The stationary targets appeared as octahedrals suspended in the air at different altitudes. The targets were arranged in a straight line. Subjects were required to maneuver the simulator so that a given target was lined up with a circle in the middle of the HUD, then activate the radar and fire a missile when the target was within range. Subjects could fire a missile by either pressing the spacebar on the keyboard or by pulling the trigger on the joystick. Trials lasted 5 minutes unless all three targets were destroyed. When 5 minutes were up, or when all targets were destroyed, the trial was ended and subjects were given feedback on their performance. The next trial started automatically after subjects finished examining their feedback. The computer recorded the distance traveled, the number of kills, the total time, and the number of missiles fired.

Procedure

The study took three days to complete. On day 1, all subjects were given a brief computer based introduction to the Phoenix program to familiarize them with the displays and controls. Subjects were then given a pretest consisting of four 3-minute trials of the target task. The introduction and pretest took about 90 minutes to complete. Following the pretest, the whole-task group continued to practice on the target task for 2 1-hour blocks of 16 trials each. Each block of trials was separated by a 15-minute rest period. The two part-task groups practiced the component tasks for 2 1-hour blocks separated by a 15 minute rest. On day 2 all subjects continued their respective training for 3 1-hour blocks. Thus all three groups had five 1-hour blocks of training on their respective tasks.

During all practice blocks, subjects in the part-task blocked group received 10 consecutive trials on each of the component tasks starting with the most basic tasks (i.e., unpitch and unroll) and continuing up the component task hierarchy until all tasks had been practiced. Subjects completed tasks at their own pace, and when they had practiced all 13 component tasks, they repeated the sequence as often as needed to fill up the 5 hours allotted for training.

Subjects in the part-task sequenced group also practiced the component tasks and moved up the task hierarchy. However, these subjects had only one trial on each task in the hierarchy before moving on to the next component task. Subjects practiced at their own pace, moving up the hierarchy as many times as needed to fill the 5 hours of training.

On day 3, all subjects were tested on three blocks of the target task and one block of the transfer task. As before, tasks were presented in 1-hour blocks of trials separated by 15-minute breaks.

RESULTS

Target Task Performance

Figure 1 shows the mean number of gates flown through per trial for the five practice blocks (whole-task training only) and three blocks of trials in the test phase. Figure 2 shows the accuracy data. In the testing phase, the average number of gates flown through for the whole-task, the part-task sequenced, and the part-task blocked groups was 18.96, 12.44, and 13.90 respectively. Accuracy showed a similar pattern: 79.4, 69.0, and 67.9 for whole-task, part-task sequenced, and part-task blocked, respectively. These data suggest that the whole-task group performed better than the two other groups on both total gates made and accuracy.

Total gates made and percent gates made were submitted to separate 3 (training condition) x 3 (test block) x 2 (gender) mixed factors ANOVAs. Training condition represented a between groups manipulation and test block was a repeated measures manipulation. These analyses revealed main effects of training condition for total gates made ($F(2,105)= 10.55, p<.001$) and for accuracy ($F(2,105)=4.98, p<.01$). Planned contrasts indicated that the whole-group differed from the blocked group ($t= 3.49, p<.001$ and $t= 2.95, p<.01$, for total gates and percent of gates respectively) but the sequenced group did not differ from the blocked group.

Figure 1 suggests a practice effect and a practice x training condition interaction. Both of these effects were supported by a significant main effect of test block (Wilks' lambda exact $F(2,104)=34.59, p<.001$) and an interaction between test block and training (Wilks' exact $F(4,208)=3.97, p<.01$) for total gates. Accuracy data (Figure 2) also showed these same effects (Wilks' exact $F(2,104)=18.90, p<.001$ for test block and $F(4,208)=4.53, p<.01$ for test block x

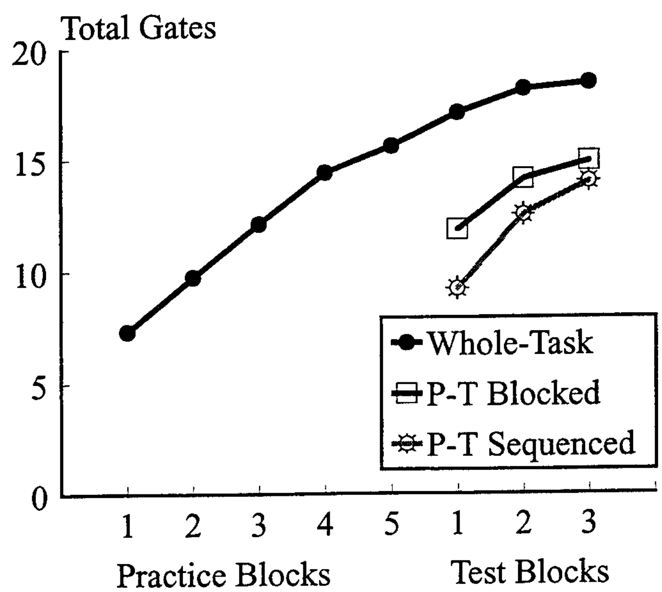

Figure 1
Mean number of gates flown though on the target task during training and retention tests

training). The test block x training interaction was tested by analyzing the simple main effect of training condition separately for each test block. For total gates made, the main effect of training condition became increasingly smaller across blocks ($F(2,105)= 17.66, p<.001$, $F(2,105)= 10.15, p<.001$, $F(2,105)= 4.27, p<.05$, for blocks 1, 2, and 3 respectively). The same pattern was obtained for accuracy with training condition failing to reach significance for block 3 ($F(2,105)= 9.12, p<.001$, $F(2,105)= 3.82, p<.05$, $F(2,105)= 1.88, p>.10$, for blocks 1, 2, and 3 respectively).

It appears that the part-task sequenced group is improving faster than the part-task blocked group (see Figure 1). This observation was not supported by analyses. None of the post hoc contrasts between the two part-task training conditions reached significance. Thus, the interaction between test block and training condition can be solely attributed to the convergence of the two part-task groups toward the whole-task group. This may suggest that the whole task group is closer to asymptotic performance than the two part-task groups.

Finally, males (17.40, 78.4%) performed better than females (11.72, 63.9%) as indicated by significant main effects of gender for total gates ($F(1,105)=22.78, p<.001$) and accuracy ($F(1,105)=15.95, p<.001$). In addition, accuracy showed significant interactions between gender and training condition ($F(1,105)=4.07, p<.05$) and gender and test block (Wilks' exact $F(2,104)=7.97, p<.001$).

Mean accuracy scores for males and females in each training condition are shown in Table 1. The gender x training condition interaction was examined more closely by testing the simple main effect of training condition for males and females separately. These tests indicated that the overall main effect of training condition, at least for accuracy, could be attributed to the females. The simple main effect of training condition was significant for females ($F(2,42)=5.17, p<.01$) but not for males ($F(2,63)=.61, p>.10$). Examination of the means in Table 1 suggests that the females in the part-task sequenced group performed better than those in the part-task blocked

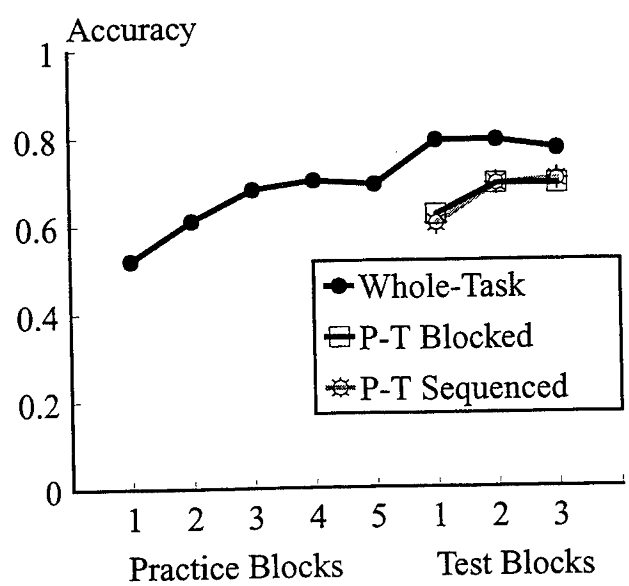

Figure 2
Accuracy on target task during training and retention tests

Table 1
Percent of gates made on target task for males and females in each training condition

Gender	Training Condition: Whole-task	Part-Task Sequenced	Part-Task Blocked
Males	80.26	75.10	79.78
Females	78.09	60.07	50.48

group. However, post hoc contrasts did not support that trend. Contrasts indicated a significant difference between whole-task and part-task blocked (t= 3.17, p<.01) but not between part-task sequenced and part-task blocked (t= 1.10, p>.10).

The interaction between gender and test block for accuracy was examined further by testing the main effect of test block for males and females separately. The block effect was stronger for females (Wilks' exact $F(2,41)=13.54$, $p<.001$) than for males (Wilks' exact $F(2,62)=4.75$, $p<.05$). The means indicated that females improved consistently over the three test blocks (56.33%, 64.95%, and 67.36% for blocks 1, 2, and 3 respectively) while males were most accurate on block 2 (77.18%, 80.25%, and 77.72% for blocks 1, 2, and 3 respectively). It is not clear whether males are showing a ceiling effect or not since, overall, they never averaged more than 81% accurate.

Transfer Task Performance

Table 2 shows the group means for distance traveled per trial, time per trial, and targets destroyed per trial on the transfer task. For these measures, proficiency on the task is indicated by relatively shorter flying distances and time per trial, and by more targets destroyed per trial. All three variables were entered into a 3 (training condition) x 2 (gender) MANOVA with the number of gates made on the pretest used as a covariate. Although the part-task blocked group showed the lowest average distance flown, the shortest time per trial, and the highest number of targets destroyed, the main effect of training condition was not significant (Wilks' exact $F(6,204)=0.19$, n.s.). There was a main effect of gender ($F(3,102)=16.18$, $p<.001$) but gender and training condition did not interact. Univariate analyses of the gender effect were significant for all three dependent measures ($F(1,104)=27.60$, $p<.001$ for distance, $F(1,104)=49.11$, $p<.001$, for time, and $F(4,208)=20.66$, $p<.001$ for targets destroyed).

Table 2
Three transfer task performance measures (distance, time, and number of targets destroyed) for male and female subjects in three groups

Performance Measure	Whole-task	Part-Task Sequenced	Part-Task Blocked
	Training Condition		
Distance, simulator miles			
Males	31.43	27.97	25.03
Females	43.19	42.28	46.44
Mean	36.18	33.75	33.69
Time, seconds			
Males	172.87	169.03	166.31
Females	261.53	260.24	256.79
Mean	208.81	206.01	202.99
Targets			
Males	2.66	2.61	2.86
Females	1.91	1.98	1.69
Mean	2.35	2.36	2.39

DISCUSSION

The goal of this study was to explore the contextual interference effect in a complex motor task. Contextual interference was manipulated in a part-task training paradigm. Part-task training subjects practiced several component tasks that were presented in either blocks (low contextual interference) or a repeated sequence (high contextual interference). The results for total gates made indicated that the group receiving whole-task practice showed superior retention to both part-task training groups. Moreover, the two part-task groups did not differ on retention. For accuracy scores on the target task, the effect of training condition interacted with gender. The advantage of whole-task performance was only obtained for female subjects. Results also showed that all three groups performed equally well on the transfer task.

The comparison relevant to the contextual interference effect is the comparison between the part-task blocked and the part-task sequenced groups. None of the comparisons between the two part-task groups were significant. Furthermore, though females in the sequenced group showed higher accuracy than females in the blocked group, the difference was not significant. Thus, contextual interference, as defined in the present study, did not show a strong beneficial effect. The importance of the null findings can not be overstated. It is often assumed that training approaches and recommendations based on training simple tasks will generalize to more complex tasks. This is an assumption that must be empirically tested. The present study suggests that the contextual interference effect, which has been supported by research using relatively simple tasks (Battig, 1966; 1979; Carlson and Yaure, 1990; Glenberg, 1979; Shea and Morgan, 1979) may not generalize to a more complex perceptual-motor task.

One explanation for why the contextual interference effect was not obtained is that sequential presentation produced too much interference. In teaching complex skills in general, and motor skills in particular, intuition suggests that instruction should focus on component skills sequentially, allowing the student to achieve proficiency on one skill before moving to the next skill. Shea and Morgan (1979) pointed out that many instructors adopt this procedure to avoid interference among the component skills. Consistent with this reasoning, subjects in the sequenced group may have been overwhelmed by excessive interference produced by having to perform a different task on every trial. This hypothesis predicts better retention and transfer by the blocked group than the sequenced group. However, the data do not fully support this hypothesis. Although blocked group subjects flew through more gates than the sequenced group and scored better on all measures of the transfer task, none of the differences reached statistical significance.

Another reason for the failure to obtain an effect may have to do with the relationship between component tasks and the whole-task. Whole-task performance may be partially based on component task fluency and partially based on higher-level strategies that integrate component skills (Carlson, Sullivan, and Schnieder, 1989; Lesgold, 1984). Contextual interference may serve to produce greater elaboration and distinctiveness of the components (Shea and Morgan, 1979), but not integrate them. If a task depends heavily on integration of component skills, then it may not benefit from contextual interference.

There is reason to believe that the tasks examined in this study depend heavily on component task integration. Information from several sources (e.g., altimeter, climb/dive ladder, heading indicator, the view out the window, and proprioceptive feedback) must be combined and coordinated to produce complex motor movements to maneuver the simulator through the gates, or to line up targets to be shot. Component skills in the target task may be interdependent and require integration into more complex skills. The present data do not directly address this possibility. Thus, future research comparing the contextual interference effect in tasks that differ in integration of component skills may resolve this issue.

Perhaps the most simple explanation for the null effects is that the part-task sequenced condition did not produce significantly more interference than the blocked condition. However, this possibility has implications for our implicit assumptions about training. As mentioned above, in training complex tasks, instructors often block component task training to minimize interference. Based on this reasoning, the blocked condition would be predicted to be superior to the sequenced condition. The present data challenge this hypothesis by failing to show a strong advantage for blocking component task training.

In sum, the contextual interference effect, as operationalized in the present study, does not appear to generalize to the complex tasks examined herein. Perhaps a more systematic application of contextual interference is needed. For example, tasks might be grouped into skill categories and trained under random presentation (high contextual interference) within skill categories but blocked (low contextual interference) between categories. Such an approach might take advantage of variability in acquisition while avoiding excessive interference between different classes of skills. These questions must be pursued before strong conclusions about the generalizability of the contextual interference effect can be made.

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