Durable Competence in Procedural Tasks through appropriate Instruction and Training1

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Procedural tasks tend to be learned quickly, but acquired skill deteriorates rapidly during periods of no-practice. The present study investigates how skill retention can be improved through adequate instruction and appropriate training procedures. Subjects learned four sets of procedures (14-17 steps) for directing a ship from one side of a computer-simulated lock to the other. In the learning phase, subjects first received instruction. They either simply memorized the sequences of task actions, or received additional explanations of system principles. Then they were trained until criterion according to either a mixed or a blocked practice schedule. After eight weeks, the retention test was administered. Subjects were required to practice (without prior instruction or feedback) until they had reattained criterion level. Results show that understanding the system principles facilitate learning and retention performance, but the nature of the practice schedule produced no significant effects. Conclusions for training design are presented.

1 Introduction

Procedural tasks are characterized by a well defined target situation, a clear problem structure, and a deterministic set of operations to accomplish that goal (e.g. operating tasks, like setting a VCR, or manufacturing tasks like

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assemblage). They involve few decisions and are generally performed the same way each time (Konoske and Ellis, 1986).

There is ample evidence that skill in procedural tasks deteriorates very rapidly during periods of no-practice, especially when the task consists of a large number of steps and when the relation between the constituent task actions is not immediately obvious (e.g. Christina and Bjork, 1991).

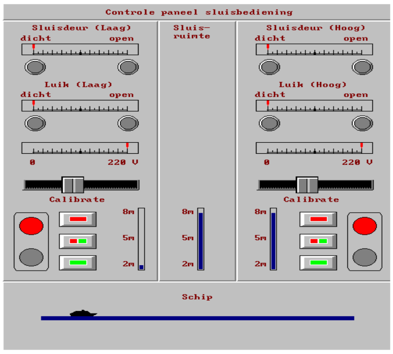
The literature reports a number of factors influencing the amount of skill loss over time. One of them is the training method used for initial learning. There are indications that the long-term retention of skill in complex procedural tasks can be improved by including functional explanations in the instruction, thus allowing students to acquire a mental model of the system and task (e.g. Catrambone, 1995; Ellis, Whitehill, and Irick, 1996; Kieras and Bovair, 1984; Mark and Greer, 1995). Another method proposed for promoting the long term retention of skill is by requiring learners to overcome high task interference during training, for instance by using random rather than blocked practice schedules (e.g. Shea, Kohl, and Indermill, 1990). The present experiment investigates the effects of both training design measures in one procedural task.

2 Method

2.1 Task

Subjects learned to direct a ship from one side of a simulated lock to the other by mouse-clicking controls on a computer monitor (see Figure 1).

Figure 1 Operating console



The ship could either go from the lower level to the higher level of the river or vice versa, and the water level in the lock could either match or be different to the ship's present water level. Combining these conditions produced four different task situations, each requiring a specific operating procedure (14-17 steps).

2.2 Subjects and design

94 subjects, recruited from the airborne troops, participated in the experiment. The following factors were manipulated:

- type of explanation (operational versus functional)
- practice schedule during training (mixed versus blocked trials)

In the learning phase, subjects learned to perform the procedures at criterion level. After eight weeks of no-practice, subjects were required to practice (without instruction or feedback) until they had reattained criterion level. To investigate whether similar or dissimilar practice schedule affects speed of re-achieving criterion performance, a third factor was introduced:

- practice schedule during retention (mixed versus blocked trials)

A (2 X 2 X 2) combination produced 8 conditions. Subjects were divided into 8 groups, matched on their 'technical insight' score (Evers and Lucassen, 1991). Groups were assigned randomly to conditions.

2.3 Procedure

2.3.1 Paper-based instruction. Subjects in the 'functional instruction' condition received a paper with a comprehensive explanation (in text and pictures) of the underlying principles governing the lock and how these relate to controls on the operating panel. Subjects in the 'operational instruction' condition received only explanation on the lay-out of the operating panel and the functions of the buttons.

2.3.2 Computer-based instruction. Then, subjects received computer-based instruction modules and exercises. For each task situation, the computer firstly demonstrated (autonomously) correct task execution. Secondly, one trial of prompted practice was administered. Thirdly, one trial of independent practice was provided (feedback was given). The content of instruction and feedback was determined by the experimental condition.

2.3.3 Test for comprehension (I). A multiple-choice test was administered to verify whether subjects having received functional explanations had a deeper understanding of system and task than subjects having received operational explanations only.

2.3.4 Training. After the instruction and test, subjects started the training proper. Criterion performance was three errorless performances for each of the four tasks. Errors were indicated by a short beep only. Subjects in the *blocked trials schedule* groups trained one of the four tasks till criterion and then proceeded with the next. Subjects in the *mixed trials schedule* groups trained the four task situations in mixed order. Presentation order of tasks was balanced. When a subject reached criterion level for a particular task, then this task was eliminated from the sequence.

2.3.5 Retention test. Ater eight weeks, subjects returned for a retention test. The same procedure and ordering of task situations were used as during training.

2.3.6 Test for comprehension (II). To check subjects' knowledge of system principles after the retention interval, a multiple-choice test was administered.

2.4 Dependent variables

During training and retention, the following measures were recorded:

- number of trials needed to reach criterion level
- the mean number of errors per trial
- the mean time interval between successive task actions (in s)
- the mean time to complete a trial (runtime, in s)

3 Results

Subjects in the functional explanation groups did, unfortunately, not perform significantly better on the comprehension tests than subjects in the operational explanation groups, neither directly after instruction (7.3 vs. 6.8 correct answers (max=10); $F(1,92)=1.8$, $p=.19$), nor after the retention test (16.8 vs. 17.1 correct answers (max=20), $F<1$). This suggests that our efforts to create groups differing in system and task understanding by manipulating the nature of instruction has not succeeded. The question whether system and task comprehension facilitates learning and retention, is therefore addressed by performing post-hoc analyses. For these analyses, the total group of subjects is divided into 'poor' and 'good' comprehenders, by means of a median-split on the post-instruction paper-based test scores.

3.1 Learning phase

A MANOVA with Type of Explanation (2) and Training Practice Schedule (2) as between-subjects factors showed a main effect of Type of Explanation ($F(4,87)=4.9$, $p<.01$). Subjects having received functional explanations needed fewer trials to achieve criterion level (16.9 vs. 20, $F(1,90)=6.9$, $p<.01$), made fewer errors per trial (2.2. vs. 3.8, $F(1,90)=6.8$, $p<.01$), and took *more* time between successive task operations (5.8 vs 5.0 s, $F(1,90)=5.8$, $p<.05$). Furthermore, they tended to spend *more* time per trial (258 vs. 243 s, ($F(1,90)=3.0$, $p<.1$), although not statistically significant. Thus, although the results of the comprehension test suggest that subjects in the functional explanation groups did not have superior knowledge of the system principles, they nevertheless demonstrated superior performance.

3.1.1 Post-hoc analysis. A MANOVA with Level of Understanding (2) as between-subjects factor was performed. Data are displayed in Table 1.

A main effect of Level of Understanding was found ($F(4,89)=2.5$, $p<.05$). 'Good' comprehenders needed fewer trials to achieve criterion level ($F(1,92)=4.3$, $p<.05$), and made fewer errors per trial ($F(1,92)=5.7$, $p<.05$).

Table 1: Means and sd (in parenthesis) of training performance

	Level of Understanding			
	low (n=51)		high (n=43)	
n of trials	19.6	(7.3)	17.1	(3.5)
n of errors	3.7	(3.5)	2.2	(2.1)
time to action (s)	5.6	(1.8)	5.2	(1.6)
runtime trial (s)	254	(42.0)	247	(39.0)

3.2 Retention phase

After the retention interval, 84 of the original 94 subjects were still available for the retention phase of the study.

A MANOVA with Type of Explanation (2), Training Practice Schedule (2), and Retention Practice Schedule (2) as between-subjects factors was performed. No main or interaction effects involving Type of Explanation were found.

The two-way interaction between Training Practice Schedule and Retention Practice Schedule approached significance ($F(4,73)=2.1$, $p<.1$). Retention practice schedule had no effect on the number of errors made by subjects trained according to a mixed schedule ($F<1$). However, for subjects trained according to a blocked schedule, those receiving a mixed retention practice schedule made significantly more errors than those receiving a blocked retention practice schedule ($F(1,76)=6.3$, $p<.05$).

Table 2: Means and sd (in parenthesis) of retention performance

	Blocked Training				Mixed Training			
	Blocked Retention (n=21)		Mixed Retention (n=19)		Blocked Retention (n=22)		Mixed Retention (n=22)	
n of trials	17.8	(3.7)	21.9	(7.5)	19.0	(5.9)	19.0	(3.7)
nr of errors	4.6	(4.7)	12.7	(14.4)	7.8	(9.9)	5.1	(3.3)
time to action (s)	8.3	(2.1)	9.2	(3.5)	7.4	(1.9)	8.3	(2.1)
runtime trial (s)	246	(41)	303	(103)	242	(47)	256	(48)

3.2.1Post-hoc analysis. A MANOVA with Level of Understanding (2) as between-subjects factor was performed. Data are displayed in Table 3.

Table 3: Means and sd (in parenthesis) of retention performance

	Level of Understanding			
	low (n=42)		high (n=42)	
n of trials	21.0	(6.5)	17.7	(3.5)
n of errors	9.9	(12.1)	5.0	(4.4)
time to action (s)	8.2	(2.5)	8.3	(2.4)
runtime trial (s)	262	(77)	260	(54)

The main effect of Level of Understanding was significant ($F(4,79)=3.6$, $p<.01$), showing that subjects with a high level of understanding needed fewer practice trials to re-attain criterion performance ($F(1,82)=8.0$, $p<.01$), and made fewer errors ($F(1,82)=6.2$, $p<.05$).

4 Discussion

The present study confirmed the predicition that providing functional explanations facilitate learning a procedural task. Compared to groups receiving operational-information only, subjects provided with functional explanations achieved criterion performance with fewer trials, and made fewer errors per practice trial. The observation that they took more time between successive task operations and tended to spend more time per trial suggests that they consult a mental representation to determine the correct response, rather than mechanically reproducing the memorized action sequence.

Post hoc analyses of the retention test results revealed that subjects with a high level of system and task understanding needed less practice trials to re-attain criterion performance and made fewer errors. This is in agreement with other studies (Catrambone, 1995; Mark and Greer, 1995). The interpretation generally attributed to this outcome is that conceptual knowledge of system and task provides the framework that is necessary for reconstructing the correct action sequence which otherwise might not be remembered (Ellis, Whitehill, and Irick 1996; Kieras and Bovair, 1984). The present study does not disclose how such understanding should be achieved, as level of system understanding was not determined by the nature of the given explanations. Apparently, factors other than instruction have determined comprehension.

The nature of the training practice schedule (blocked vs. mixed) had no effect on training or retention performance. However, for subjects trained according to a blocked schedule, those receiving a mixed retention practice schedule performed worse than those receiving a blocked retention practice schedule. Thus, especially the combination "blocked-training-practice and mixed-retention-practice" is a bad choice if long-term task mastery is required.

The results warrant the following recommendations. First, if a reliable level of performance is required, even after relatively long periods of no practice, then it is important to design instruction and training in such a fashion that it allows students to acquire a thorough understanding of the system and task. Second, although the effects of using different practice schedules were not as pronounced as reported in the literature, it seems better to use mixed (or random) rather than blocked practice schedules.

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