Journal of Computer Assisted Learning (2000) **16**, 358-365

An activity-based analysis of hands-on practice methods

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Abstract The success of exploration-based training is likely to be strongly influenced by what activities the learner undertakes during training. This paper presents a study of the activities undertaken during training by 51 experienced computer users learning to use an application package through exercises, exploration or a combined approach to training. Results suggest that exploration learners practice procedures selectively, fail to consolidate skills through repetition, and do not devise activities which extend their knowledge beyond the scope of the training materials. It is argued that these characteristics may lead to subsequent difficulties in performance.

Keywords: Application software; Exploration; Exercises; Minimalist training; Training; Undergraduate

Introduction

The minimal training paradigm, documented in *The Nurnberg Funnel* (Carroll, 1990), is largely concerned with learner motivation. A major thrust of the training approach is to evoke and maintain positive motivation toward learning a computer application (Carroll, 1998). The central principle supporting learner motivation in minimalism is task orientation. Other principles support task orientation or follow from it (Carroll & Van der Meij, 1998): an action-oriented approach, support for error recognition and recovery, and support for reading-to-do, study and locate (Van der Meij & Carroll, 1998). This study looked at exploration learning which is part of minimalism's action-orientation. Research evaluating exploration-based training for end-user applications has yielded mixed results (e.g. Carroll *et al*., 1987; Charney *et al.* 1990; Lazonder & Van der Meij, 1993; Wiedenbeck & Zila, 1997). The success or failure of exploration-based training is most likely to be determined by what activities the learner actually undertakes during training. However, studies often report performance outcomes without reporting the activities of the learners during training. This research reports on a study of the training activities of learners using exploration, exercises, or a combined approach to training for an application package. The objective was to determine the *contents* of the groups' hands-on practice and to examine their possible implications for training.

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Exploration-based learning

Within the computer training domain, several studies of exploration-based practice methods vs. other kinds of hands-on practice have been carried out. Charney *et al.* (1988) showed that problem solving practice is superior to typing worked-out tutorial examples and also found (Charney *et al.*, 1990) that learners experience difficulties in acquiring basic computer commands by exploration. In previous work by the authors (Wiedenbeck & Zila, 1997),it was found that experienced computer users learning a new computer application were more successful when they carried out specific exercises given in the manual than when they carried out more open-ended exploration practice. It was also found that individuals who did the exercises and then went on to do further exploration practice were not more successful than those who did the exercises alone.

Anderson's (1993) work provides a possible explanation for learners' difficulties with exploration. In ACT-R theory, Anderson describes learning as the process of acquiring production rules that represent a skill. Productions are initially formed, strengthened, and discriminated through problem solving. Therefore, learning must be active. In Anderson's theory, the practice method used to acquire productions is only of concern insofar as learners may acquire productions more quickly with some methods than others. Anderson argues that exploratory learning is inefficient because learners fail to systematically explore the procedures needed to gain basic productions. Moreover, they tend to get caught up in errors that are time-consuming and do not advance their knowledge of needed productions. Minimalist training acknowledges the risk of error tangles and emphasises the provision of error recovery information (Carroll & Van der Meij, 1998). It also acknowledges the risk of degenerating into trial-and-error. Carroll & Van der Meij (1998) emphasise the importance of providing learners with the *right* knowledge to support useful goals and activities.

While some potential difficulties with exploration have been observed, there is a need for more detailed knowledge about the sources of such difficulties, for example, how systematically do learners explore, do they experience their greatest problems with setting goals, with developing and applying procedures, or with error handling? Pinpointing the main sources of difficulty is necessary if designers of training materials are to provide just the right hands-on activities to support learning. To this end, the activities during training of individuals learning with exploration, exercises, or a combination of exercises and exploration were investigated.

The research study

Methodology

Experimenter notes and videotaped activity protocols of participants learning to use a software package with exercise, exploration, or combined approaches were used to study the hands-on training activities of learners. These data were collected as part of a larger study investigating learners' performance with exercise, exploration, and combined training (Wiedenbeck & Zila, 1997).

Participants

The participants were 51 advanced students in business, science, and technology who had high computer experience, and almost all had some programming exper-

ience. Eighty percent of the participants were male and 20% female. Their average age was 28. They were selected from a course in which they needed to learn a tool to use in prototyping user interfaces. The participants were randomly assigned to the exploration, exercise, or combined condition. Each condition had 17 participants.

Materials

The *Hypercard*™ program was used as the training application. None of the participants was familiar with this application or with other similar packages. Training was given on the interface toolkit but not the associated scripting language. A minimal training manual was developed for use in the experiment. The brief hardcopy manual consisted of approximately 21 pages of text and illustrations. Procedural descriptions were grouped into task-oriented topic areas. The reader was given essential procedural information but was expected to infer details of procedures. Information was given to help the reader coordinate manual and screen. Explicit error recognition and recovery information was provided. The content of the manuals was identical for the three experimental conditions.

At the end of each section of the manual an instruction was given for hands-on practice. These practice instructions differed for the three experimental conditions. The exercise group was given a specific problem related to the material contained in the current section of the manual and usually drawing on knowledge in earlier sections, as well. The exploration participants were given instructions to devise their own practice for the material presented in the section. To aid the learners in developing their own practice, the instruction suggested some general goals and asked leading questions to focus learners on important features. The combined group was first given the same problem as the exercise group, then was given an exploration instruction to devise their own further practice. There were 17 practice instructions for all groups.

Procedure

The participants were run individually in one session. The participant first filled out a demographic questionnaire, then spent up to 90 minutes reading the training manual and doing hands-on practice. An experimenter was present in the room to monitor that the participants followed the practice instructions of their assigned group, e.g. the exercise participants had to carry out the specific exercises given and were not allowed to do open-ended exploration, while the combined participants had to do the exercise before undertaking exploration. The participants were videotaped, and the experimenter also took detailed notes about the participants' activities using a form developed for this purpose. The videotapes showed the participants' actions on the screen but the participants did not think aloud.

The notes and videotapes were classified by three researchers based on the predefined categories shown in the data tables. The level of agreement was 88%. Disagreements were resolved by discussion and joint review of the data.

Results

Four kinds of observations of learner activities were made:

- the time spent on reading and practice
- the content of exercise practice of the exercise and combined groups
- the content of exploration practice of the exploration and combined groups

- innovations during exploration practice by the exploration and combined groups.

Analysis of Variance was used for statistical testing, and follow-up testing was done with Newman-Keul's test.

Table 1 shows the time spent on reading and practice during training. The exercise, exploration, and combined groups spend approximately equal time reading the training materials. The group differences in reading time were not significant. However, the groups differed significantly in time spent on hands-on practice ($F_{2,48} = 7.82$, $MSE = 165$, $p < 0.05$). The exercise group completed their hands-on practice about one-third faster then both the exploration and the combined groups. Follow-up testing showed that this difference was significant (Newman-Keul's test, $p < 0.05$). The exploration and combined groups did not differ significantly in the follow-up testing. The combined group spend 60% of their hands-on practice time doing exercises and 40% doing further exploration. In comparison to the exercise group, the combined group spent slightly less (but not significantly less) time carrying out the exercises, but substantially more time overall, including their exploration. In comparison to the exploration group, the combined group spent significantly less time in exploration than did the exploration group ($F_{1,32} = 63.29$, $MSE = 124$, $p < 0.05$), even though the overall practice time of the two groups did not differ significantly.

Table 1. Mean and standard deviation of time (minutes) spent on reading and hands-on practice during training.

	Reading	**Hands-on practice**
Exercise $n = 17$	36.2 (10.8)	31.3 (11.7)
Exploration $n = 17$	31.9 (9.2)	48.1 (11.4)
Combined $n = 17$	32.6 (11.1)	43.4 (15.05) Exercise part: 26.2 (11.6) Exploration part: 17.2 (10.8)

Table 2 shows details of the exercise practice of the exercise and combined groups. In the table, 'omission' refers to a subpart of an exercise that was not attempted, while 'mistake' refers to all other errors which remained uncorrected at the end of an exercise. The two groups were very similar in exercises attempted, exercises successfully completed, omissions, and mistakes. ANOVAs were used to compare the exercise and combined groups on these four measures, since the overall time the two groups spent in doing the exercises did not differ significantly. The ANOVAs showed

Table 2. Exercise practice results of exercise and combined groups.

	Exercises attempted (max = 17)	**Exercises successfully completed (max = 17)**	**Exercises containing uncorrected errors**	
			Omissions	**Mistakes**
Exercise $n = 17$	17.0 (0.0)	15.5 (1.7)	0.5 (0.6)	1.0 (1.3)
Combined (exercise part only) $n = 17$	16.8 (0.6)	14.5 (1.9)	0.8 (0.8)	1.4 (1.3)

(figures represent average number per participant)

no significant differences between the exercise and combined groups on these measures. Both groups were highly successful in completing the exercises, and about one-quarter to one-third of their residual errors in the exercises were omissions of part of an exercise rather than errors resulting from mistakes in execution.

Tables 3, 4, and 5 contain data about the exploration activities of the exploration and combined groups. Descriptive statistics about learners' activities are presented, but no statistical comparison between the exploration and combined groups is made. Statistical testing was not done because of the large difference in the amount of time spent in exploration by the two groups. Nevertheless, the summary of learner activities provides an observational view of how the learners used their exploration time in the two conditions.

Table 3. Exploration of features explicitly described in manual by exploration and combined groups during exploration practice.

	No exploration of features in current manual section	**Full exploration of features in current manual section**	**Partial exploration of features in current manual section**
Exploration $n = 17$	1.2 (1.1)	10.1 (2.7)	5.8 (2.0)
Combined (exploration part only) $n = 17$	5.1 (1.7)	4.2 (1.7)	7.7 (2.3)

(figures represent average number of instances per participant based on 17 practice opportunities)

Table 3 shows the coverage of the material in the manual by the exploration and combined groups. Learners' activities are classified by whether they explored in response to each exploration instruction, explored all the features described in the current manual section, or carried out partial exploration of some features described in the current section. The table indicates that the exploration group seldom skipped a practice opportunity entirely, but about one-third of the time they failed to practice all the features described in the current manual section. The combined group (which always carried out the exploration practice *after* an exercise) often skipped the exploration of a section entirely or only explored the features partially.

Table 4. Repetition and uncorrected errors of exploration and combined groups during exploration practice.

	Repeat of features in earlier manual sections	**Uncorrected errors**
Exploration $n = 17$	3.2 (1.7)	1.9 (1.6)
Combined (exploration part only) $n = 17$	1.2 (1.0)	0.2 (0.6)

(figures represent average number of instances per participant)

Table 4 reports instances in which exploration and combined learners repeated practice of features described in earlier manual sections, as well as uncorrected errors in their practice. The exploration group seldom repeated practice of features which they had encountered in earlier sections, and they left an average of approximately 2 uncorrected errors in their practice. The combined group repeated practice of features in earlier sections even more infrequently and had very low uncorrected errors at the end of practising each section.

Table 5 shows innovative activities by the exploration and combined groups during their exploration practice. Innovative activities were defined as those going beyond the features explicitly described in the manual. Innovative activities were classified as minor or major extensions beyond the manual. Minor extensions include carrying out operations described in the manual on different objects, carrying out operations only slightly different from ones described in the manual, or using tools not described in the manual but from a family of tools introduced in the manual (e.g. a drawing tool that was not explicitly described, but was similar to other drawing tools that were described). Major extensions included using tools and menu items that represented a distinct step beyond those explicitly described. The exploration group made very few minor or major extensions. The combined group made a moderate number of minor extensions but very few major extensions.

Table 5. Innovation by exploration and combined groups during exploration practice.

	Minor extensions	**Major extensions**
Exploration	1.5	1.1
$n = 17$	(1.3)	(1.0)
Combined (exploration part only) $n = 17$	5.7 (1.9)	0.6 (1.0)

(figures represent average number of instances per participant)

Discussion

The reading times of the three training groups were very similar. Time spent on hands-on practice did differ among the groups, but it seemed largely to reflect the type of practice the groups were asked to carry out. The combined group spent more time than the exercises group because they had to do both the exercise and also exploration. The exploration group also spent more time than the exercise group. This longer practice time in the exploration group may be the result of time to set goals. The exploration participants had to begin each practice episode by deciding on a meaningful practice goal, then carry it out. This contrasts with the exercise participants who were given goals in the practice instructions. It is a bit surprising that the combined group did not spend more time in hands-on practice than the exploration group, as the combined group had to do both exercises and exploration. An explanation of this may be that the exercises dominated the combined practice, reducing the time spent on exploration activities and their perceived importance.

The data show that exercise practice was productive. Learners attempted and successfully completed a very high proportion of the exercises. While they did make errors, they recognised the difference between the goals they were given and their outcomes, and corrected the errors. They left very few uncorrected errors. Furthermore, over one-fourth of the uncorrected errors were omissions of subgoals. These omissions appeared to be merely failures to reread the exercises at the end to verify that all the requirements had been fulfilled. The exercises were carefully designed to cover all of the procedures described in the corresponding section of the manual and also to require learners to revisit essential procedures from earlier in the manual as they carried out later exercises. It appears that the exercises channelled learners toward full practice of the material in the manual.

The data on activities during exploration practice show a different picture. The exploration participants were not given goals. They had to create their own goals by reading a manual section and thinking about how they could use the procedures in it. The practice of basic procedures described in the training materials was not highly systematic in the exploration group. Exploration learners carried out exploration in response to 94% of the practice instructions, but 62% of the time they did not practice *all* the features described in the manual section. They rarely repeated practice of features that had been introduced in earlier sections. From the videotapes, it appeared that they set their goals based on the contents of the current manual section and did not consider how the current material fit into the context of other procedures that they had encountered. As a result, their goals were specific to the current section. There were few uncorrected errors in their practice, indicating that they were able to carry out the goals they set. Their exploration almost never extended beyond procedures described explicitly in the manual, even in minor ways

For the combined group, the exercise portion of the practice was very similar to that of the exercise group: a high proportion of exercises attempted and completed, along with few uncorrected errors. On the other hand, the combined group's exploration activities were in some respects different from the activities of the exploration group. Most notable is that the combined group explored rather briefly. Having done the corresponding exercise before exploring a topic, the combined group's exploration of the basics was much more selective and they were even less likely than the exploration group to repeat practice of features from earlier manual sections. They were slightly more innovative than the exploration group, but the extensions beyond the training materials were minor. It may be that their prior exercise practice gave them a better basis, and perhaps better motivation, for attempting at least minor innovations.

Learning begins with initial study and practice. Subsequently skills are improved through two means: repetition and innovation (Lesgold, 1984). According to Lesgold's framework, repetition consolidates skills and makes them more automatic. Innovation, on the other hand, expands skills to cope with new situations. The training observations are summarised in terms of initial practice, repetition, and innovation. The exercise group received solid initial practice and also repetition of important skills through the structuring of the exercises given in the training manual. This group did not attempt any extensions or innovations (in fact, extensions and innovations were not allowed in the design of their training). Thus, it seems that these learners should be equipped for carrying out similar tasks and perhaps limited extensions of them but not for dealing with new situations that differ significantly from those they have encountered in training. The exploration group's initial practice was less thorough because they practised some, but not all, of the procedures in the training manual. The exploration practice they devised rarely repeated procedures learned earlier, nor did it attempt significant innovations. As a result, it is suggested that these learners would be likely to have difficulty carrying out both similar task and dealing with new situations. The combined group gained solid initial practice through the exercises and the repetition of important procedures embedded in the set of exercises. Their exploration provided additional repetition, which should have aided in the consolidated the basic skills. The innovation was minor. Thus, it seems that this group, like the exercise group, should be prepared for tasks similar to the training tasks, but not for new and distinctly different situations.

Conclusion

This experiment investigated learner activities during training to determine how learners using exercise, exploration, and combined practice methods behave during their training. The study is largely observational, so definitive conclusions cannot be drawn. Nevertheless, the observations suggest that learners using exploration practice may have neglected to practice all the basics, to consolidate their knowledge through repetition, and to innovate beyond the basics of the training materials. While exploration offers the potential for innovation by the learner, it opens the danger of insufficient initial practice and repetition.

Some past studies have found poor performance at test of learners trained to use software using relatively open-ended exploration (Charney *et al.* 1990; Wiedenbeck & Zila, 1997). The current study concentrates on the training period itself and suggests that exploration-based learners may fail to be systematic in exploration of the basics of a system and may fail to explore beyond the basics. While it seems likely that the nature of the activities during training influences performance, to date that link has not been shown in exploration-based training. Further experimental research is needed to determine whether differences in exploration activities can be shown to have a direct effect on performance.

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