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ABSTRACT

This study examined planning processes and the acquisition of expert problem solving skills among individuals of different expertise on tasks of increasing complexity. Twelve French-speaking adult students of machining (novices) and 12 French-speaking teachers of machining (experts) in Quebec (Canada) were randomly assigned to a simple or complex task. Thinking-aloud protocols were collected and analyzed according to a specific coding system in order to examine the amount of planning and other operations performed by the subjects. No significant differences were obtained for the planning variable. However, significant differences were found for the writing and evaluation variables. Also, the quality of the performance was linked to the amount of planning done by each subject. Possible explanations for the results and future directions for research are presented. One bar graph illustrates the discussion, and there is a 17-item list of references. (SLD)

Planning as a function of expertise and task difficulty in a technical domain

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This study examined planning processes among individuals of different expertise on tasks of increasing complexity. Twelve novices and twelve experts in the machining domain were assigned randomly to a simple or complex task. Think-aloud protocols were collected and analyzed according to a specific coding system in order to examine the amount of planning and other operations performed by the subjects. No significant results were obtained for the planning variable. However, significant results were found for the writing and evaluation variables. Also, quality of the performance was linked to the amount of planning done by each subject. Possible explanations for the results and future directions for research are presented.

The aim of this study was to examine the acquisition of expert problem solving strategies, more specifically the planning processes of individuals with different levels of expertise performing on tasks of distinct levels of complexity. In addition, the quality of subjects' performance was examined and linked to the amount of planning performed by each subject.

Problem solving has been studied in different domains such as physics, mathematics, and computer programming (Anderson, Greeno, Kline & Neves, 1981; Greeno, 1978; Greeno & Simon, 1987 ; Larkin, McDermott, Simon & Simon; and Newell & Simon, 1972). One issue of particular interest has been the study of strategies and how they are acquired. One may define "strategy" as a systematic process used by different individuals to solve a problem. Strategies can be either general or specific to a domain. General problem solving strategies such as planning tend to be used more frequently in unfamiliar situations and by unexperienced individuals (Anderson et al, 1981, Greeno & Simon, 1987).

Generally, planning may be defined as the anticipation and organization of several steps necessary for the solution of a problem (Breuleux, 1990; Hoc, 1987/88). Goals and plans have been used as the basis for explaining human behavior (Miller, Galanter & Pribram, 1960). Planning as a general strategy is very useful in order to cope with changing and complex situations. As a result, some researchers have investigated planning processes and the effect of expertise on planning (Goldin & Hayes-Roth , 1980; Hayes-Roth & Hayes-Roth, 1979; Davies, 1990; and Sebillotte, 1988). Goldin and Hayes-Roth (1980) found in their study on planning processes that good planners revised and assessed more often their previous decisions and were more likely to consider alternative solutions since they were more sensitive to constraints. Davies (1990) found that experts in the programming field seemed to expand their plans in a depth-first fashion, whereas other studies suggested the more frequent use of a breadth-first expansion for experts in order to be able to deal with constraints such as interactions between sub-goals (Flower & Hayes, 1980; Hoc, 1987/88; Jeffries, Turner, Polson, and Atwood, 1981). Furthermore, Hayes (1987) examined the planning strategies used by expert machinists. Results showed that experts were able to avoid constraints and were able to divide the problem into independent sub-problems, solve and merge them after.

However, relatively few studies in the problem solving literature in cognitive psychology have studied planning processes. Most studies have tended to provide either a) a detailed description of problem solving strategies using a very limited number of cases, or b) relatively superficial descriptions of problem solving strategies using statistical tests and larger number of cases. Very few studies have combined detailed analyses of planning processes with the study of the expertise/task complexity effect on planning.

The main contribution of this study was the use of detailed analyses of think-aloud protocols in order to obtain measures concerning the planning processes of individuals involved in this study. This was done in order to achieve a better understanding of planning skill acquisition as a function of expertise and task complexity.

Task analysis:

Machining tasks involve transformation operations where an initial situation (raw material and technical drawing) is presented and the machinist has to perform a sequence of actions such as applying the appropriate transformation operators on the initial state (i.e., raw metal piece) to obtain the goal state (i.e., the product). The machining curriculum developed recently by the Québec Ministry of Education identifies the construction of the "gamme d'usinage" or procedure specification as the focus of training. Such a procedure specification involves the breakdown of the task into steps, sub-steps and operations (within sub-steps). The feasibility and optimization of the order of steps, sub-steps and operations are the main concerns in the machining domain. Machinists must be able to interpret the technical drawing and establish the procedure to obtain it. They must also anticipate and identify precisely the tools required for each operation. Also, they have to represent the shape of an object at different points on the procedure specification sheets.

The task of specifying a machining procedure involves several types of operations. The important ones in this study belonged to three major categories: writing operations, control and monitoring operations, and calculation operations. Writing operations were the operations used to fill in the procedure specification sheets. Control and monitoring operations corresponded to problem solving operations such as planning, evaluation, elaboration, reasoning, and clarification. Calculation operations corresponded to the subject calculating different values required by the task.

Hypotheses:

Based on the assumptions and findings stated by previous mentioned researchers, concerning the more frequent use of general problem solving strategies such as planning in novel situations and by novices compared to experts, two hypotheses were forwarded: 1) Experts will plan less than novices and; 2) both experts and novices will plan less in the simple task than in the more complex task.

Methodology

Subjects

Twelve French speaking adult students were identified as novices. The experts were twelve French speaking teachers in the machining domain teaching at the D.E.P level (diploma of professional studies). In addition, experts had industrial experience. Experts were from different regions of Québec.

Material

Two industrial drawings of increasing level of complexity were used. These drawings were provided by a consultant domain expert. The simple drawing "Drawing 1" required the subject to produce one piece. The complex drawing "Drawing 2" required the production of 100 pieces. Answer sheets were provided.

Procedure

A short description of the general goal of the study was given to each subject. Then two warm-up tasks were presented. The objective of these warm-up tasks was to encourage and ease verbalization. After the completion of the warm-up tasks, each individual was given one of the two technical drawings and answer sheets were provided as well. Subjects had to write down all the steps required in order to produce the specific machining part shown on the drawing. Subjects were asked to verbalize their thoughts throughout the task. All verbalizations were audiotaped. Once the task was finished, subjects were asked some clarifying questions concerning their procedures such as "could you explain the order of the steps involved in this task?". Answers to these questions were audiotaped.

Data analysis

All audiotaped data was transcribed. Transcripts were segmented and each segment was analyzed according to a reliable well defined coding scheme (Breuleux, 1990). Such a coding system would allow to observe: relationships between goals in plans, the amount of planning done, the amount of plan revision and the structural properties of plans constructed. In this study, only the amount of planning was considered.

Each segment (i.e., verbalization that corresponds roughly to a sentence as defined by Grevisse (1986)) was coded as belonging to a specific semantic category (i.e., Goals, Writing, Calculation, Elaboration, Statement, Clarification, Reasoning, Rereading, Evaluation, Auto-Evaluation, Incomplete, Supposition, and Repetition) and then several segments were grouped into episodes. The main types of episodes were: 1) Planning, 2) Writing, 3) Calculation, 4) Evaluation, 5) Elaboration, 6) Evaluation and Elaboration, 7) Rereading, and 8) Observation.

Furthermore, performance by each subject was rated by the expert consultant, according to the typical criteria used in technical schools. These two criteria were whether or not the procedure was feasible (i.e., logic of the ordering of steps in the subject's procedure) and optimal (i.e., whether or not the chosen procedure was the most suitable for the specific task). A procedure needs to be identified as feasible before being considered as optimal.

Design and statistical analyses

The independent variables were expertise (i.e., novice/expert) and level of complexity (i.e., "Drawing 1", simple task and "Drawing 2", more complex task). The dependent variables consisted of the proportion of segments within episodes identified as : Planning, Evaluation, Writing, Calculation, Observation, Elaboration, Evaluation and Elaboration, Rereading, and Non-Coded. Analyses of variance were performed.

Results

Planning

Experts in both task conditions seemed to plan more than novices, with experts in the more complex task condition, Drawing 2, appearing to plan the most. Novices in both task conditions seemed to plan equally. However, there was no significant task complexity effect ($F(1,20) = 0.565$, $p < 0.461$) and no significant difference (although closer to significance compared to the task complexity effect) between experts and novices in terms of the amount of planning ($F(1,20) = 0.224$, $p < 0.151$). In addition, there was no significant interaction of expertise by level of task complexity in terms of planning ($F(1,20) = 0.604$, $p < 0.446$)(see Fig.1).

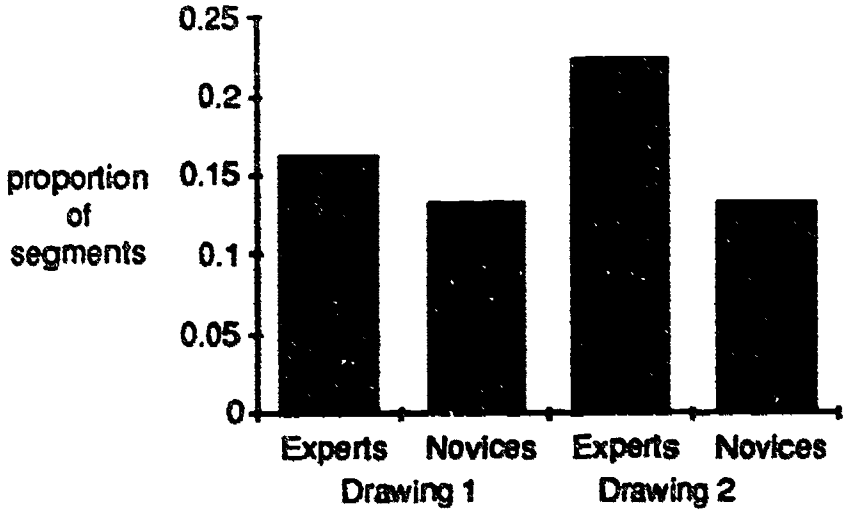

Figure 1. Mean proportion of segments in planning episodes for all conditions

Furthermore, quality of performance was linked to the amount of planning performed by each individual. No statistical analyses were done concerning the individual amount of planning, however, 1) overall experts seemed to do better than novices and; 2) the best performers in r·· experimental groups seemed to plan the least. For example, in the protocol of the expert S1'/, about 5% of the total number of segments were coded as belonging to planning episodes, and for experts S1 and S12, 16%. However for the expert S4, the amount of planning was 23%. Overall, S1 and S10 seemed to be the best two performers. They also seemed to plan the least.

Evaluation

Averages seemed to be greater for novices in both task conditions, particularly in the complex task. Also, experts seemed to evaluate equally often across both task conditions. The effect of task complexity on the amount of evaluation was close to the level of significance ($F(1,20) = 4.278$, $p < 0.052$). A significant expertise effect was found for the amount of evaluation performed by subjects ($F(1,20) = 9.308$, $p < 0.006$), with novices making evaluation statements more often than experts. However, the interaction effect of expertise by level of task complexity was not significant ($F(1,20) = 4.025$, $p < 0.06$).

Writing

The amount of writing seemed to be greater in the simple task for both experts and novices than in the complex task (Drawing 2). There was a statistically significant effect of task complexity on the amount of writing found in subjects' protocols ($F(1,20) = 4.855$, $p < 0.039$), with subjects in simple task (Drawing 1) writing more than subjects in in the complex task (Drawing 2). However there was no significant difference between the experts and the novices ($F(1,20) = 0.018$, $p < 0.894$) and the interaction effect of expertise by level of task complexity was not found to be significant ($F(1,20) = 0.586$, $p < 0.453$).

Other variables

No significant effects were found for the other variables. However, there were visible trends in the data. Experts systematically seemed to do less: 1) evaluation and elaboration, 2) elaboration, 3) observation, and 4) calculation, than novices. Experts and novices seemed to do less: 1) evaluation and elaboration, 2) elaboration, and 3) observation, in the simple task than in the complex task. Finally, experts and novices appeared to do more calculation in the simple task than in the complex task.

Discussion

Planning

Several possible explanations for the lack of differences seen between novices and experts in terms of planning can be offered such as: a ceiling effect for the novices; the selection of experts; the rigidity of the coding procedure; verbalization difficulties; and the low number of subjects per group.

One explanation relative to the between-group trend obtained in this study could be that experts needed to plan more as the level of complexity increased and that novices experienced a "ceiling" effect since their experience and knowledge are quite limited compared to the experts.

On the other hand, when looking at the quality of individual performance, one can see that within each group of expertise, there appears to be considerable variability in performance, and this could decrease the homogeneity of groups. This could account in part for the lack of significant differences between groups for planning.

The quality of the verbalizations is another factor that might have limited the present study. Novices seemed to have had more difficulty verbalizing their thoughts, and these difficulties have probably affected the quantity and quality of the data on planning processes. These subjects should have been screened more carefully after the warm-up tasks.

Finally, the coding procedure for identifying episodes should be refined by taking into account the content of consecutive goal statements to be able to identify as planning episodes only the sequences of operations that represent the construction or modification of coherent plan structures (see Breuleux, 1991, 1990).

Although individual planning differences were not tested statistically, the observed trend can be described as more compatible with the first hypothesis of this study, and with the assumption that experts plan less.

Evaluation and writing

In this study, novices, particularly in the more complex task, were found to spend a greater amount of time evaluating their procedures. One possible explanation may be that in a complex task situation, novices, not possessing planning processes as elaborated as experts, may need to evaluate more often in order to correct the different operations in their procedures.

For the writing variable, subjects regardless of their level of expertise spent significantly more time writing for the simple task. One possible explanation could be that subjects did more writing in the simple task because they did not have to engage in considerable planning although this explanation has its limitations.

Directions for future research

Two types of suggestions can be offered for future research. First, longitudinal studies analyzing planning processes among individuals belonging to the same level of expertise would help clarify the acquisition of expertise. This procedure would also allow a greater homogeneity. Second, a combination of cross-sectional and longitudinal studies would be helpful since this combination would compensate for the limitations found in both types of studies.

References

Anderson, J. R., Greeno, J. G., Kline, P. J., & Neves, D. M. (1981). Acquisition of problem solving skill. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition* (pp. 191-230). Hillsdale, NJ: Erlbaum.

Breuleux, A. (1991). The analysis of writers' think-aloud protocols: developing a principled coding scheme for ill-structured tasks. In G. Denhière and J.-P. Rossi (Eds.), *Texts and text processing*. Amsterdam: North-Holland.

Breuleux, A. (1990). *L'élaboration et l'exécution de plans dans une tâche de rédaction.* Unpublished doctoral dissertation. Université de Montréal.

Davies, S. P. (1990). Plans, goals and selection rules in comprehension of computer programs. *Behaviour and Information Technology, 9*, 201-214.

Flower, L., Hayes, J. R. (1980). The dynamics of composing: Making plans and juggling constraints. In L. W. Gregg, E. R. Steinberg (Eds.), *Cognitive processes in writing* (pp. 3-30). Hillsdale, NJ: Lawrence Erlbaum.

Goldin, S. E., & Hayes-Roth, B. (1980). *Individual differences in planning processes*. (Tech. Rep. No. N-1488-ONR). Santa Monica, CA: Rand Publication.

Greeno, J. G., & Simon, H. A. (1987). Problem solving and reasoning. In R. C. Atkinson, R. Hernstein, G. Lindzey, and R. D. Luce (Eds.), *Steven's Handbook of experimental psychology* (rev. ed.) (pp. 589-672). New York: Wiley.

Greeno, J. G. (1978). Nature of problem-solving abilities. In W. K. Estes (Ed.), *Handbook of learning and cognitives: Vol. 5* (pp. 239-270). Hillsdale, NJ: Lawrence Erlbaum.

Grevisse, M. (1986). *Le bon usage* (12th rev. ed). Paris-Gembloux: Duculot.

Hayes, C. (1987). Observing Machinists' planning methods: using goal interactions to guide search. *Proceedings of Ninth Annual meeting of the Cognitive Science Society. Seattle*, WA.

Hayes-Roth, B. Hayes-Roth, F. (1979). A cognitive model of planning. *Cognitive Science, 3*, 275-310.

Hoc, J.-M., (1988). *Cognitive Psychology of Planning* (C. Greenbaum, Trans.). Grenoble: Presses Universitaires de Grenoble. (Original work published 1987).

Jeffries, R., Turner, A. A., Polson, P. G., and Atwood, M. E. (1981). The processes involved in designing software. In J. R Anderson, (Ed.), *Cognitive skills and their acquisition* (pp. 255-283). Hillsdale, NJ: Erlbaum.

Larkin, J. H., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Science, 208*, 1335-1342.

Miller, G. A., Galanter, E., Pribram, K. H. (1960). *Plans and the structure of behavior*. New York: Henry Holt.

Newell, A., Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Sebillotte, S. (1988). Hierarchical planning as method for task analysis: the example of office task analysis. *Behaviour and Information Technology, 7*, 275-293.