NEMO: Modeling Search Variations in ATLANTIS, a Psychodiagnostic Computer Simulation

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Introduction

ATLANTIS is a psychodiagnostic tool that confronts subjects with a computerized, game-like scenario. Its purpose is to study the plasticity of mental models and coping behavior. Subjects are in command of NAUTILUS, a small simulated submarine. The computer screen displays the state of control units and a simplified nautical chart where subjects can see the current position of the submarine. In addition, a video camera and a magnetic sonar can be activated to show visual or magnetic images of the submarine's environment.

Subjects start the game with a training task where they have to find an ore deposit in a particular area of the nautical chart. The purpose of this training is that subjects learn to operate the ATLANTIS simulation environment. They are supposed to build a mental model of the situation and to acquire a search strategy. This knowledge should then serve as a basis to solve the main task which consists in finding an airplane that crashed into the sea. Subjects get general instructions for this task and can retrieve additional hints from which they can develop an adequate search strategy to find the airplane. During their search they will be provided with information that tests their mental models and the flexibility of their chosen strategies. The subjects' behavior is logged together with comments during the task.

NEMO's Cognitive Model

We constructed an executable cognitive model, called NEMO, which is able to represent different search knowledge models that subjects acquire and use during the training phase. Variations in their search strategies can be explained by modifying this representation and their effects can be demonstrated with simulated behavior traces. Logged behavioral traces and verbal justification of several subjects formed the basis of the model. The modeling framework employed was ACT-R 3.0 (Anderson, 1993; Lebière, 1996).

NEMO's declarative knowledge contains representations of ATLANTIS's nautical chart, of objects in the environment, and of the state of the submarine NAUTILUS with its control instruments, position and depth. NEMO's procedural knowledge represents plans and actions that may be employed to achieve the main goal during the training phase: to find an ore deposit in a given area of the chart. The ensemble of selected strategies (mainly subgoaling productions) and executed actions implement a search strategy. The top-level goal is either terminated by reaching the goal-state (finding the ore deposit) or else by selecting and achieving different subgoals: (a) 'find position' (to look for ore), (b) 'move' (NAUTILUS to a position), and (c) 'explore' (a position using magnetic sonar and video camera). Subjects usually activate these plans in a cyclical manner from *a* to *c*. These subgoals will again be decomposed into various decisions and actions. The goal 'find position' can be matched by other productions which, for example, decide whether it is necessary to dive or not (diving constrains submarine movements in the simulation) or to assert the goal to move to the position of a sonar echo if NEMO's memory contains one. Other productions decide whether to take a video picture, when and how to move, whether a selected position is reached (close enough for taking images).

The order of production firings follow ACT-R's PG-C mechanism and depend on the information that NEMO's declarative model has acquired/retained and on the state and weights of its procedural knowledge (Anderson, 1993). NEMO enhances the basic ACT-R modeling tools with two extensions: (a) a simulation of the ATLANTIS environment and (b) a visualization of the environment that displays the nautical chart and NEMO's moves and scan positions.

Results and Discussion

Different search strategies emerge with the use of different paths through the procedural memory tree and with the presence or absence of different pieces of knowledge. Following the behavioral traces found in our subjects, we identified and modeled the following strategies: 'optimal', 'stupid', 'careless' and 'careful' variations of NEMO.

'Optimal' NEMO starts its search in the corner of the area that is nearest to NAUTILUS' initial position, dives, and then covers the area with sonar scans without leaving any gaps. Few subjects start with such a solution. However, almost all subjects reported that they would use exactly this strategy *after* completing the training phase. 'Stupid' NEMO does not dive (because the subject does not realize that ore deposits are always at ground level or that the range of sonar scans is limited). 'Careless' and 'careful' NEMO differ in the placement of their sonar scans.

Our main goal with this research is to establish and define the principles and knowledge that control the search behavior of human subjects and to make predictions about their behavior. The model is able to cover most search strategies shown by subjects in the main ATLANTIS task as long as their search behavior is not disturbed by other activities. We conclude that NEMO is able to represent much of the knowledge that subjects use and acquire during the training phase.

References

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Lebière, C. (1996). *ACT-R 3.0: A users manual*. Tech. Report, Carnegie Mellon University, Pittsburgh.