Learning by Observation in Complex Task Environments

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In 1986 Donald A. Norman coined the term *Cognitive Engineering*, which denotes a Cognitive Science approach within the Engineering Sciences. The research presented here follows in this tradition and exemplifies applied Cognitive Science by investigating knowledge acquisition processes in naturalistic task domains. While problem-solving research in Psychology formerly concentrated on knowledge-lean tasks like the *Tower of Hanoi*, attention shifted during the eighties to questions of knowledge acquisition, its organization and application in knowledge-rich task domains. A new paradigm, labelled *Complex Problem Solving* (see Frensch & Funke, 1995), deepened Cognitive Psychology by investigating the effects of complexity and uncertainty in dealing with computer-simulated dynamic systems.

When comparing different studies concerning complex problem solving, one central basic assumption can be found: the opportunity of active system control in an initial learning phase is regarded as a necessary precondition for the acquisition of an appropriate *Mental Model* of the system to be controlled. It is an unquestioned assumption that subjects have to be given the possibility of active exploration of a dynamic system in order to cope successfully with it. In contrast, there is a well-established trend in many engineering systems substituting supervisory control for manual control. As a consequence of the still increasing impetus for automatization, operators are removed from the manual operating loops, and their roles are redefined as system monitors.

To investigate the effects of different activity demands on system identification and system control two experiments were conducted. As a scenario for these experiments POWERPLANT, a validated and systems-theoretically well-defined model of a real coal-fired powerstation was constructed and implemented. In both experiments 40 engineering students where assigned to two experimental groups:

- while a *System Control Group* was encouraged in a knowledge acquisition phase to actively explore POWERPLANT, e.g. to freely make interventions, gather data and test hypotheses,
- the interaction of a *Monitoring Group* was restricted to the observation of a corresponding operator from the System Control Group controlling POWERPLANT.

To separate effects of active system exploration from those of pure system observation a yoked control design was used. After the knowledge acquisition phase both groups had to control PowerPlant in a knowledge application phase. To diagnose the students' knowledge about POWERPLANT several knowledge-assessment techniques (e.g. questionnaires, sorting-tasks, thinking aloud) were applied.

In sharp contrast to the prevailing assumption in the area of complex problem solving a significant superiority of the Monitoring Group with respect to system knowledge and control performance in the knowledge application phase was found. Interestingly, while there is a strong association between system knowledge and control performance in the System Control Group ($r > .75$), no correlations were found in the Monitoring Group. Analyzing the think aloud protocols revealed that students from the Monitoring Group generated significant more *self-explanations* (Sandoval, Trafton, & Reiser, 1995) about control strategies and the causal relationship of POWERPLANT'S underlying variables and their dynamics. Students of the System Control Group on the other hand mainly paraphrased the system behavior without tracing it back to physical principles.

Using the data gathered through the knowledge-assessment techniques, a cognitive simulation model on the basis of ACT-R (Anderson, 1993) was implemented and empirically evaluated. ACT-R is a cognitive architecture capable of performing and learning from the same tasks worked on by human subjects. The model not only offers a straightforward explanation of the results and a close fit to the empirical data but can also be seen as a rigorous test of the applicability of the ACT-R framework in naturalistic task domains.

References

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