

## Procedural Learning in the Control of a Dynamic System

Danilo Fum and Andrea Stocco  
University of Trieste

One of the interesting phenomena that occur when people interact with a dynamic system is an increase in their capacity to control it without any concomitant, apparent consciousness, i.e. without being able to report how the system really works. While this dissociation has been first explained by supposing the existence of a separate implicit learning capacity, many scholars now agree that most aspects of the behavior could be caught by supposing that people act on the basis of previously memorized instances of their interaction with the system.

We challenged this explanation by working with one of the most famous dynamic systems, known as "Sugar Factory" (Berry and Broadbent, 1984). In this task, participants are required to control the production of a simulated sugar factory by varying the amount of workers allocated to the job. Sugar production should be consistently maintained at a target level, and its value is related to the number of workers by a mathematical expression that is both counterintuitive and stochastic, to prevent participants to discover it too easily.

Two major computational, instance-based models have been developed to account for the participants behavior in Sugar Factory: one by Dienes and Fahey (1995), the other by Wallach and coworkers (Lebiere, Wallach & Taatgen, 1998; Taatgen and Wallach, 2002). Both models show quite a good fit with experimental data, with no model being clearly superior. The second model, however, because it relies on the mechanisms provided by the ACT-R cognitive architecture and requires fewer additional assumptions, seems preferable on the basis of criteria of parsimony and generality.

The evidence in favor of the models, however, is not so strong as it seems, and it does not exclude possible alternatives.

In this work we first present two experiments designed to explicitly falsify some foundational assumptions of the hypothesis of instance-based learning in the context of the Sugar Factory paradigm. The results of the experiments did not allow to reject the hypothesis, that therefore came out corroborated. By comparing the results of the two experiments, we discovered an effect, previously never reported in the literature, concerning the influence of the production target value on the participants performance. A third experiment, designed to test the effect, brought positive results. This new finding allows to discriminate between the two instance-based explanations because it could be produced by the model of Wallach but not by that of Dienes and Fahey.

Finally, we set up a critical experiment involving a shift in the target value between the first and the second phase of the interaction with the system. Differently from what one could predict on the basis of instance-based theories, people acquire implicit knowledge that can be successfully transferred to different situations, a result that none of the models was able to reproduce.

We developed a new ACT-R model, entirely procedural and not implying the acquisition of any new symbolic knowledge, that could replicate the previous experimental findings. In the model different intuitive strategies are embedded in different production rules that compete with each other. In this case, learning resolves in a refinement of the expected utilities of the different productions. We conclude with some speculations about the ACT-R reward mechanism that is entailed in the production parameter learning.

### References

- Berry, D. & Broadbent, D.A. (1984) On the relationship between task performance and associated verbalizable knowledge. *The Quarterly Journal of Experimental Psychology*, 36A, 209-231.
- Dienes, Z. & Fahey, R. (1995) Role of specific instances in controlling a dynamic system. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 21 (4), 848-862.
- Lebiere, C., Wallach, D. & Taatgen N. (1988) Implicit and explicit learning in ACT-R. In Frank Ritter & Richard Young (eds.), *Proceedings of the Second European Conference on Cognitive Modelling*. Nottingham, UK: Nottingham University Press.
- Taatgen, N.A. & Wallach, D. (2002). Whether skill acquisition is rule or instance based is determined by the structure of the task. *Cognitive Science Quarterly*, 2(2), 163-204.