

Anticipatory Behavior: Exploiting Knowledge About the Future to Improve Current Behavior

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Abstract. This chapter is meant to give a concise introduction to the topic of this book. The study of anticipatory behavior is referring to behavior that is dependent on predictions, expectations, or beliefs about future states. Hereby, behavior includes actual decision making, internal decision making, internal preparatory mechanisms, as well as learning. Despite several recent theoretical approaches on this topic, until now it remains unclear in which situations anticipatory behavior is useful or even mandatory to achieve competent behavior in adaptive learning systems. This book provides a collection of articles that investigate these questions. We provide an overview for all articles relating them to each other and highlighting their significance to anticipatory behavior research in general.

1 Introduction

Intuitively, anticipations are an important and interesting concept. Looking ahead and acting according to our predictions, expectations, and aims seems helpful in many circumstances. For example, we say that we are in anticipation, we are looking forward to events, we act goal-oriented, we prepare or get ready for expected events, etc.

Several recent theoretical approaches have been put forward in an attempt to understand and formalize anticipatory mechanisms. Despite these important approaches, though, it is still hardly understood why anticipatory mechanisms are necessary, beneficial, or even mandatory in our world. Therefore, this book addresses the following questions:

- When and in which circumstances are anticipations beneficial for behavior and life?
- Which types of anticipatory behavior are important to distinguish?
- Which environmental properties or rather which fundamental characteristics of our environment make which types of anticipatory processes useful?
- How can the different anticipatory processes be modeled and implemented in artificial adaptive systems?

Over the last few decades, experimental psychology research gradually started to accept the notion of anticipations beginning with Tolman’s suggestion of “expectancies” [29, 30] due to his observation of *latent learning* in rats (learning of environmental structure despite the absence of reinforcement). More recently an outcome devaluation procedure [1, 9, 19] has been employed that provides definite evidence for anticipatory behavior in animals. Even more recently, cognitive psychology provides further evidence of distinct anticipatory mechanisms in, e.g., learning [14, 15], attentional processing [18], or object recognition tasks [22].

In theoretical biology [20, 21] and physics [21, 10] anticipations have been suggested to contribute to the essence of complexity and life itself as well as to the stabilization of chaotic control processes. Robert Rosen puts forward one of the first definitions of an anticipatory system:

[...] a system containing a predictive model of itself and/or of its environment, which allows it to change state at an instant in accord with the model’s predictions pertaining to a later instant.[20, p.339]

In Rosen’s definition a *system* might be any entity in an environment, such as an animal, a human, or any other living being as well as inanimate physical entities such as machines, robots, or even weather systems. A predictive model is a model that provides information about the possible future state(s) of the environment and/or the system. The system becomes an anticipatory one when it has such a model and when it uses the model to change behavior according to the predictions in this model. For Rosen, anticipation is the fundamental ingredient to distinguish living from non-living systems.

Several recent attempts have been made in artificial intelligence to integrate anticipatory mechanisms into artificial learning systems in the framework of reinforcement learning [27, 16], learning classifier systems (as online generalizing reinforcement learners) and related systems [24, 4, 12, 31], as well as neural networks [8, 11, 28, 2]. So far, research in artificial intelligence has included anticipatory mechanisms wrapped in model learning systems such as the model-based reinforcement learning approach. Anticipatory processes were never analyzed on their own.

This book suggests the investigation of the characteristic properties and enhanced capabilities of anticipatory behavior in a distinct framework. We are interested in when anticipatory behavior is useful, which environmental properties enable effective anticipatory behavior, what types of anticipatory behavior can be distinguished, and what are the distinct behavioral impacts of anticipatory behavior processing. This introduction takes a general approach to these questions clarifying what we mean by anticipatory behavior and related questions. More concrete treatments of the questions, as well as first implementations and application studies of anticipatory behavioral adaptive learning systems, can be found in the successive articles. The provided overview to each article is meant to give guidance to the reader and relate the articles to the big picture of anticipatory behavior put forward herein.