Chapter 5
Empirical Issues and Theoretical Mechanisms of Pavlovian Conditioning

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ABSTRACT

Pavlovian conditioning is a very simple and universal form of learning that has the benefit of a long and rich tradition of experimental work and quantitative theorization. With the development of interdisciplinary efforts, behavioral data and quantitative theories of conditioning have become progressively more important not just for experimental psychologists but also for broader audiences such as neurobiologists, computational neuroscientists and artificial intelligence workers. In order to provide interdisciplinary users with an overview of the state of affairs of theoretically oriented research in this field, this chapter reviews a few key mechanisms that are currently deemed necessary for explaining several critical phenomena of Pavlovian conditioning. The chapter is divided into several sections; each referring to a particular theoretical mechanism and to the type of phenomena that it has been designed to account. The progression of the sections reveals phenomena and mechanisms of increasing complexity, which is an indication of the theoretical sophistication that has been reached in this domain. Since there is not a single theory containing all mechanisms, they are described separately from their originating theories, emphasizing thus the fact that they might be used in almost any theoretical implementation.

INTRODUCTION

Pavlovian conditioning is one of the most basic and well-studied varieties of learning. In its simplest form, a target stimulus, designated as conditioned stimulus (CS), is repeatedly paired with a reflex-eliciting stimulus, designated as unconditioned stimulus (US), resulting in a progressive change in the response to the CS, designated as conditioned response (CR). The classic example is dogs learning to salivate in the presence of a bell that has been paired with food (Pavlov, 1927), but several other more efficient procedures have been developed, such as eyeblink conditioning in

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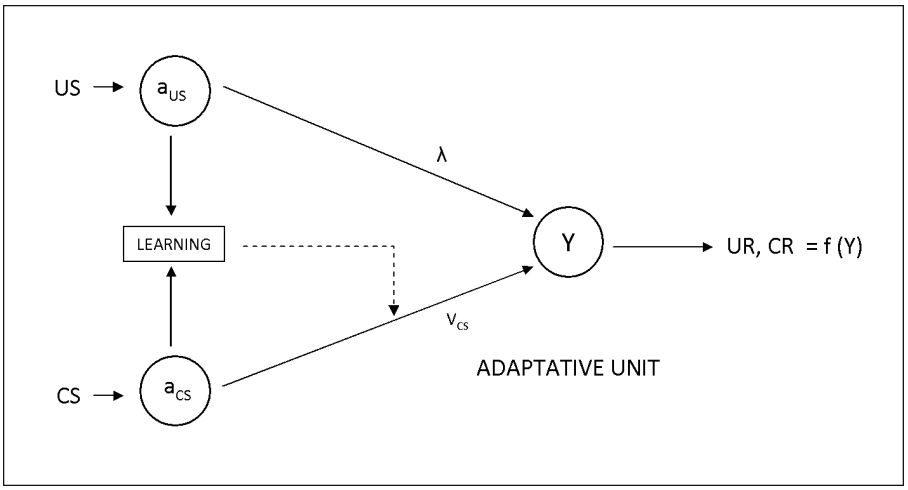
Figure 1. Basic connectionist representation of Pavlovian conditioning. Presentation of the US and the CS provokes the activation of their respective units, a_{US} and a_{CS}. The adaptive unit represents the output responsible for the generation of the CR and is unconditionally activated by the US, via λ, and conditionally by the CS via V_{CS}. The link between the CS and the adaptive unit can be modified by learning, which depends on concurrent CS-US processing.



humans (Hilgard & Campbell, 1936) and rabbits (Gormezano, Schneiderman, Deux & Fuentes, 1962), fear conditioning in rats (Estes & Skinner, 1941), pigeon autoshaping (Brown & Jenkings, 1968), and taste aversion in rats (Garcia & Koelling, 1966).

The fundamentals of the process of CR acquisition, as well as of its natural counterpart, extinction, along with several other related phenomena, have been intensively studied since the pioneering work of Pavlov (1927). After more than a century of research, a great deal of empirical work has been cumulated and the theoretical interpretations are still subjected to intense theoretical debate (Wagner & Vogel, 2009).

One of the hallmarks of Pavlovian conditioning theories is their marked preference for associative explanations and quantitative formulations, where learning is viewed as changes in CS-US associations. The goal of quantitative theoreticians is to develop algorithms to describe the dynamics of these changes (learning rules) and to conceive theoretical structures in which they take place (stimulus representation and association between the representations).

Given that the predominant outcome of CS-US pairings is the development of a CR that resembles some aspects of the unconditioned response (UR) elicited by the US, several authors have adopted the simple schema outlined in Figure 1, in which the CS and the US are connected to a common response unit or adaptive unit (Sutton & Barto, 1981; Vogel, Castro & Saavedra, 2004). It is assumed that the CS and the US activate their respective representational units, which in turn influence the activity of the adaptive unit in proportion to their associative links, V and λ. The CS link is assumed to be modifiable, starting with a value of zero prior to conditioning but with the possibility of developing positive (excitatory links) or negative (inhibitory links) values after CS-US pairings. The US link, λ, is assumed to be non modifiable and capable of producing substantial activation of the response unit. Learning is normally assumed to be Hebbian; that is as a function of simultaneous CS and US processing.