

Neurological Basis of Classical Conditioning

by Richard H. Hall, 1998

Prototype

You probably discussed **classical conditioning** in your general psychology class and the fundamental variables. For a quick review, let's consider the most frequently cited example of classical conditioning, **Pavlov's dog**. In Ivan Pavlov's prototypical classical conditioning example, a dog was trained to salivate to a bell by pairing a bell with meat powder. Meat powder was the **unconditioned stimulus (US)**, the salivation to the meat powder was the **unconditioned response (UR)**, a bell was the **conditioned stimulus (CS)**, and salivation to the bell was the **conditioned response (CR)**. This experiment is illustrated in Figure 1, and a hypothetical neural circuit is presented below it. Presumably, an instinctive connection exists between neurons that represent the experience of the meat powder and salivation, while a potential connection between sensory neurons that represent the bell and salivation, come to be developed as a result of pairing the bell with the meat powder. Note that a fundamental characteristic of classical conditioning is that an association between two stimuli (the unconditioned and conditioned stimulus) is learned, in contrast to instrumental conditioning.

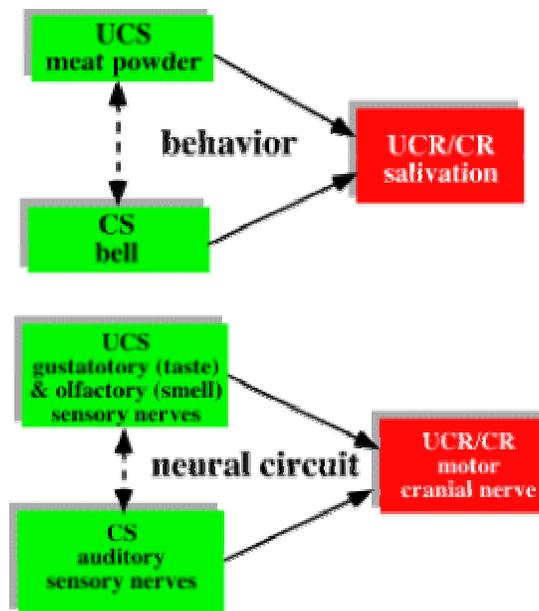


Figure 1. Pavlov's Prototypical Classical Conditioning Experiment

Classical Conditioning: Model

A model for the study of the neurological basis for classical conditioning was developed by Weinberger and colleagues in an elegant and ingenious series of experiments. These researchers used the conditioned emotional response. Some neutral (conditioned) stimulus (in this case, a tone of a given frequency) is associated with an unconditioned stimulus (in this case, foot shock), which eventually comes to elicit a conditioned response (autonomic arousal). At the level of physiological structures, the foot shock travels via a sensory pathway that runs through the

central nucleus of the amygdala to the **somatosensory cortex**. This is not surprising, given that the central nucleus plays an important role in emotion. The auditory stimulus, the tone of a given frequency, travels via a sensory pathway that passes through the **medial geniculate nucleus of the thalamus** and on to the **auditory cortex**. This model is depicted, behaviorally and neurologically, in Figure 2.

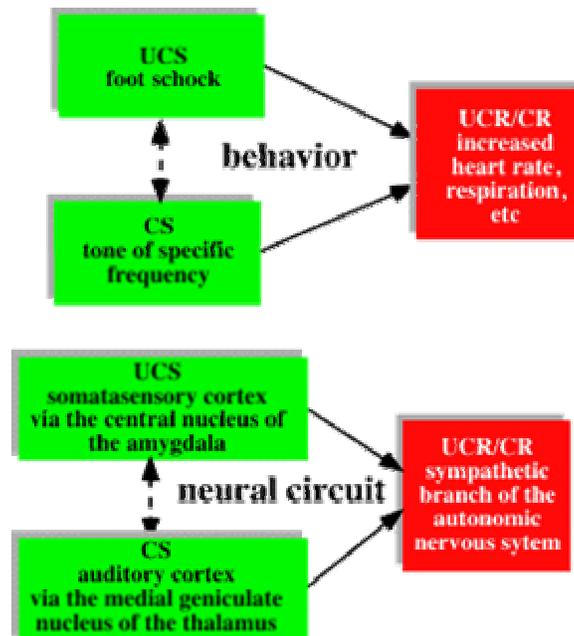


Figure 2. Behavior/Neurological Model of Conditioned Foot Shock

The question then becomes, how does the auditory and somatosensory signal come to be associated at the neurological level? The key to this involves the **nucleus basalis**, a brain structure rich in **acetylcholine (ACh)** neurons, which sends projections diffusely into the cerebral cortex. When the neural signal associated with the foot shocks reaches the central nucleus, an auxiliary pathway, which goes to the nucleus basalis, is also activated, and results in general diffuse activation of the cortex. Most importantly, for our purposes, this results in an increased level of sensitivity in the auditory cortex, so that it is now more sensitive to neural input from the medial geniculate nucleus. In this manner, via the nucleus basalis, ACh, and the auditory cortex, the unconditioned stimulus (the foot shock) and conditioned stimulus (the tone of a given frequency come to be associated.) The role of the nucleus basalis is illustrated in Figure 3.

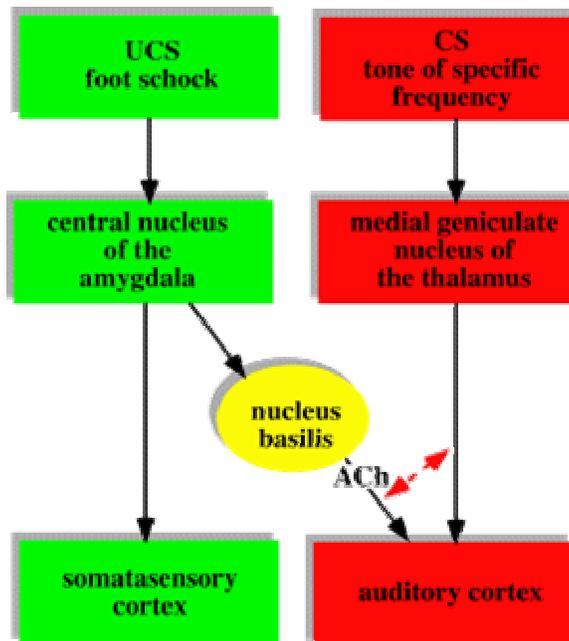


Figure 3. The Role of the Nucleus Basalis in Conditioned Foot Shock Response

Supporting Evidence

In order to test the viability of the neurological model presented above, Weinberger and colleagues began by establishing the **tonotopic frequency** of a set of neurons within the auditory system, in particular the auditory cortex. Many cells in the auditory system are "tuned" to a given frequency, that is, they fire at a maximum rate to a certain pitch or tone. (In terms of sound waves, the wave frequency varies as a function of the pitch of the sound). They then conditioned guinea pigs by pairing the foot shock with a tone of a specific frequency, after which, they retested the tonotopic frequency of the same neurons. They found that these neurons had, in effect, "learned", they had been conditioned to be sensitive to the frequency of the tone that signaled the foot shock. The cells' "favorite frequencies" had changed. The guinea pigs' auditory cortexes had become sensitized to this frequency, so that next time it occurred it would result in increased attention and autonomic arousal on the part of the guinea pig.

In order to establish the importance of the nucleus basalis and ACh in this conditioning, these researchers performed the same experiment, except now they stimulated the nucleus basalis in place of the electric shock. The tone of a given frequency was now paired with electrical stimulation of the nucleus. If the model is accurate this would represent an internal, a "virtual", unconditioned stimulus, inside the rats head, and this, in turn, should result in the same change in the tonotopic frequency of the target neurons. In fact, this is exactly what they found. (This "virtual" classical conditioning is represented in Figure 4.)

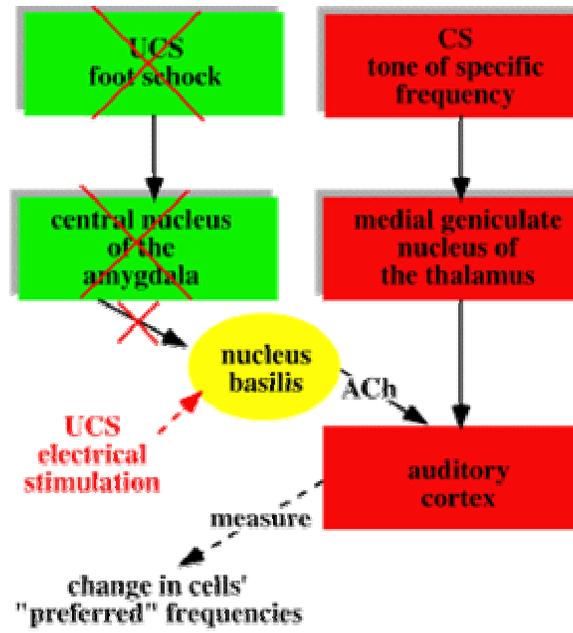


Figure 4. “Virtual” classical conditioning of neurons conditioned to change preferred tonotopic frequencies