Classical Conditioning

5.1 Introduction

Classical conditioning

Classical conditioning (also **Pavlovian conditioning** or **respondent conditioning**) is a kind of learning that occurs when a conditioned stimulus (CS) is paired with an unconditioned stimulus (US). Usually, the CS is a neutral stimulus (e.g., the sound of a tuning fork), the US is biologically potent (e.g., the taste of food) and the unconditioned response (UR) to the US is an unlearned reflex response (e.g., salivation). After pairing is repeated (some learning may occur already after only one pairing), the organism exhibits a conditioned response (CR) to the CS when the CS is presented alone. The CR is usually similar to the UR (see below), but unlike the UR, it must be acquired through experience and is relatively impermanent.

Classical conditioning differs from *operant* or *instrumental* conditioning, in which a behavior is strengthened or weakened, depending on its consequences (i.e., reward or punishment).

A classic experiment by Ivan Pavlov exemplifies the standard procedure used in classical conditioning. First Pavlov observed the UR (salivation) produced when meat powder (US) was placed in the dog's mouth. He then rang a bell (CS) before giving the meat powder. After some repetitions of this pairing of bell and meat the dog salivated to the bell alone, demonstrating what Pavlov called a "conditional" response, now commonly termed "conditioned response" or CR.

In conditioning the CS is not simply connected to UR. For example, the CR usually differs in some way from the UR; sometimes it is a lot different. For this and other reasons, learning theorists commonly suggest that the CS comes to signal or predict the US, and go on to analyze the consequences of this signal. Robert A. Rescorla provided a clear summary of this change in thinking, and its implications, in his 1988 article "Pavlovian conditioning: It's not what you think it is."

Procedures

Ivan Pavlov provided the most famous example of classical conditioning, although Edwin Twitmyer published his findings a year earlier (a case of simultaneous discovery) During his research on the physiology of digestion in dogs, Pavlov developed a procedure that enabled him to study the digestive processes of animals over long periods of time. He redirected the animal's digestive fluids outside the body, where they could be measured. Pavlov noticed that the dogs in the experiment began to salivate in the presence of the technician who normally fed them, rather than simply salivating in the presence of food. Pavlov called the dogs' anticipated salivation, *psychic secretion*. From his observations he predicted that a stimulus could become associated with food and cause salivation on its own, if a particular stimulus in the dog's surroundings was present when the dog was given food. In his initial experiments, Pavlov rang a bell and then gave the dog food; after a few repetitions, the dogs started to salivate in response to the bell. Pavlov called the bell the *conditioned* (or *conditional*) *stimulus* (CS) because its effects depend on its association with food. He called the food the *unconditioned stimulus* (US) because its effects did not depend on previous experience. Likewise, the response to the CS was the *conditioned response* (CR) and that to the US was the *unconditioned response* (UR). The timing between the presentation of the CS and US affects both the learning and the performance of the conditioned response. Pavlov found that the shorter the interval between the ringing of the bell and the appearance of the food, the stronger and quicker the dog learned the conditioned response.

As noted earlier, it is often thought that the conditioned response is a replica of the unconditioned response, but Pavlov noted that saliva produced by the CS differs in composition from what is produced by the US. In fact, the CR may be any new response to the previously neutral CS that can be clearly linked to experience with the conditional relationship of CS and US. It was also thought that repeated pairings are necessary for conditioning to emerge, however many CRs can be learned with a single trial as in fear conditioning and taste aversion learning.

Forward conditioning

Learning is fastest in forward conditioning. During forward conditioning, the onset of the CS precedes the onset of the US in order to signal that the US will follow. Two common forms of forward conditioning are delay and trace conditioning.

- **Delay conditioning**: In delay conditioning the CS is presented and is overlapped by the presentation of the US.
- **Trace conditioning**: During trace conditioning the CS and US do not overlap. Instead, the CS begins and ends before the US is presented. The stimulus-free period is called the *trace interval*. It may also be called the *conditioning interval*. *For example: If you sound a buzzer for 5 seconds and then, a second later, puff air into a person's eye, the person will blink. After*

> *several pairings of the buzzer and puff the person will blink at the sound of the buzzer alone.*

The difference between trace conditioning and delay conditioning is that in the delayed procedure the CS and US overlap.

Simultaneous conditioning

During simultaneous conditioning, the CS and US are presented and terminated at the same time.

For example: If you ring a bell and blow a puff of air into a person's eye at the same moment, you have accomplished to coincide the CS and US.

Backward conditioning

Backward conditioning occurs when a CS immediately follows a US. Unlike the usual conditioning procedure, in which the CS precedes the US, the conditioned response given to the CS tends to be inhibitory. This presumably happens because the CS serves as a signal that the US has ended, rather than as a signal that the US is about to appear. *For example, a puff of air directed at a person's eye could be followed by the sound of a buzzer.*

Temporal conditioning

Temporal conditioning is when a US is presented at regular intervals, for instance every 10 minutes. Conditioning is said to have occurred when the CR tends to occur shortly before each US. This suggests that animals have a biological clock that can serve as a CS. This method has also been used to study timing ability in animals.

Stimulus generalization

Stimulus generalization is said to occur if, after a particular CS has come to elicit a CR, another test stimulus elicits the same CR. Usually the more similar are the CS and the test stimulus the stronger is the CR to the test stimulus. The more the test stimulus differs from the CS the more the conditioned response will differ from that previously observed. Appercepting more stimuli from the environment will cause the more widely spreadout CR in the brain cellular network, that is called GENERALIZED. WIth more in-phased braincells in chain the complete brain will show a significant reaction with the generalization on almost any CS stimulus in apperception.

Stimulus discrimination[edit]

One observes *stimulus discrimination* when one stimulus ("CS1") elicits one CR and another stimulus ("CS2") elicits either another CR or no CR at all. This can be brought about by, for example, pairing CS1 with an effective US and presenting CS2 in extinction, that is, with no US.

Conditioned suppression

This is one of the most common ways to measure the strength of learning in classical conditioning. A typical example of this procedure is as follows: a rat first learns to press a lever through operant conditioning. Then, in a series of trials, the rat is exposed to a CS, a light or a noise, followed by the US, a mild electric shock. An association between the CS and US develops, and the rat slows or stops its lever pressing when the CS comes on. The rate of pressing during the CS measures the strength of classical conditioning; that is, the slower the rat presses, the stronger the association of the CS and the US. (Slow pressing indicates a "fear" conditioned response, and it is an example of a conditioned emotional response, see section below.)

5.2 Theories

Data sources

Experiments on theoretical issues in conditioning have mostly been done on vertebrates, especially rats and pigeons. However, conditioning has also been studied in invertebrates, and very important data on the neural basis of conditioning has come from experiments on the sea slug, *Aplysia*. Most relevant experiments have used the classical conditioning procedure, although instrumental (operant) conditioning experiments have also been used, and the strength of classical conditioning is often measured through its operant effects, as in *conditioned suppressio* autoshaping .

Stimulus-substitution theory

According to Pavlov, conditioning does not involve the acquisition of any new behavior, but rather the tendency to respond in old ways to new stimuli. Thus, he theorized that the CS merely substitutes for the US in evoking the reflex response.

This explanation is called stimulus-substitution theory of conditioning. A critical problem with the stimulus-substitution theory is that there is evidence that the CR and UR are not always the same. As a rule, the conditioned response is weaker than the UR. An even more serious difficulty is the finding that the CR is sometimes the opposite of the UR.

For example: the unconditional response to electric shock is an increase in heart rate, whereas a CS that has been paired with the electric shock elicits a decrease in heart rate.

The Rescorla–Wagner model

The Rescorla–Wagner (R–W) model is a relatively simple yet powerful model of conditioning. The model predicts a number of important phenomena, but it also fails in important ways, thus leading to number modifications and alternative models. However, because much of the theoretical research on conditioning in the past 40 years has been instigated by this model or reactions to it, the R–W model deserves a brief description here.

The Rescorla- Wagner model argues that there is a limit to the amount of conditioning that can occur in the pairing of two stimuli. One determinant of this limit is the nature of the US. For example: pairing a bell with a juicy steak, is more likely to produce salivation than pairing a piece of dry bread with the ringing of a bell, and dry bread is likely to work better than a piece of cardboard. A key idea behind the R–W model is that a CS signals or predicts the US. One might say that before conditioning, the subject is surprised by the US. However, after conditioning, the subject is no longer surprised, because the CS predicts the coming of the US. (Note that the model can be described mathematically and that words like predict, surprise, and expect are only used to help explain the model.) Here the workings of the model are illustrated with brief accounts of acquisition, extinction, and blocking. The model also predicts a number of other phenomena.

Theoretical issues and alternatives to the Rescorla–Wagner model

One of the main reasons for the importance of the R–W model is that it is relatively simple and makes clear predictions. Tests of these predictions have led to a number of important new findings and a considerably increased understanding of conditioning. Some new information has supported the theory, but much has not, and it is generally agreed that the theory is, at best, too simple. However, no single model seems to account for all the phenomena that experiments have produced. Following are brief summaries of some related theoretical issues.

The content of learning

The R–W model reduces conditioning to the association of a CS and US, and measures this with a single number, the associative strength of the CS. A number of experimental findings indicate that more is learned than this. Among these are two phenomena described:

- Latent inhibition: If a subject is repeatedly exposed to the CS before conditioning starts, then conditioning takes longer. The R–W model cannot explain this because preexposure leaves the strength of the CS unchanged at zero.
- Recovery of responding after extinction: It appears that something remains after extinction has reduced associative strength to zero because several procedures cause responding to reappear without further conditioning.[2]

The role of attention in learning

Latent inhibition might happen because a subject stops focusing on a CS that is seen frequently before it is paired with a US. In fact, changes in attention to the CS are at the heart of two prominent theories that try to cope with experimental results that give the R–W model difficulty. In one of these, proposed by Nicholas Mackintosh, the speed of conditioning depends on the amount of attention devoted to the CS, and this amount of attention depends in turn on how well the CS predicts the US. Pearce and Hall proposed a related model based on a different attentional principle Although neither model explains all conditioning phenomena, the attention idea still has an important place in conditioning theory.

Context]

As stated earlier, a key idea in conditioning is that the CS signals or predicts the US (see "zero contingency procedure" above). However, the room or chamber in which conditioning takes place, also “predicts” that the US may occur. Still, it usually predicts with much less certainty than does the experimental CS itself. The role of such context is illustrated by the fact that the dogs in Pavlov's experiment would sometimes start salivating as they approached the experimental apparatus, before they saw or heard any CS.[13] Such so-called “context” stimuli are always present; they have been found to play an important role in conditioning and they help to account for some otherwise puzzling experimental findings. Context plays an important role in the *comparator* and *computational* theories outlined below.

Comparator theory

To find out what has been learned, we must somehow measure behavior ("performance") in a test situation. However, as students know all too well, performance in a test situation is not always a good measure of what has been learned. As for conditioning, there is evidence that subjects in a blocking experiment do learn something about the “blocked” CS, but fail to show this learning because of the way that they are usually tested.

“Comparator” theories of conditioning are “performance based;”, that is, they stress what is going on at the time of the test. In particular, they look at all the stimuli that are present during testing and at how the associations acquired by these stimuli may interact. To oversimplify somewhat, comparator theories assume that during conditioning the subject acquires both CS-US and context-US associations. At the time of the test, these associations are compared, and a response to the CS occurs only if the CS-US association is stronger than the context-US association. After a CS and US are repeatedly paired in simple acquisition, the CS-US association is strong and the context-US association is relatively weak. This means that the CS elicits a strong CR. In “zero contingency” (see above), the conditioned response is weak or absent because the context-US association is about as strong as the CS-US association. Blocking and other more subtle phenomena can also be explained by comparator theories, though, again, they cannot explain everything.

Computational theory

An organism's need to predict future events is central to modern theories of conditioning. Most theories use associations between stimuli to take care of these predictions. For example: In the R–W model, the associative strength of a CS tells us how strongly that CS predicts a US. A different approach to prediction is suggested by models such as that proposed by Gallistel & Gibbon (2000, 2002). Here the response is not determined by associative strengths. Instead, the organism records the times of onset and offset of CSs and USs and uses these to calculate the probability that the US will follow the CS. A number of experiments have shown that humans and animals can learn to time events (see Animal cognition), and the Gallistel & Gibbon model yields very good quantitative fits to a variety of experimental data. However, recent studies have suggested that duration-based models cannot account for some empirical findings as well as associative models.

5.3 Applications

Neural basis of learning and memory

Pavlov proposed that conditioning involved a connection between brain centers for conditioned and unconditioned stimuli. His physiological account of conditioning has been abandoned, but classical conditioning continues to be studied in attempts to understand the neural structures and functions that underlie learning and memory. Forms of classical conditioning that are used for this purpose include, among others, fear conditioning, eyeblink conditioning, and the foot contraction conditioning of *Hermissenda crassicornis*, a sea-slug.

In their textbook on human physiology, Nikolai Agajanyan and V. Tsyrkin list five criteria for demarcation between unconditioned and conditioned reflexes. Unlike conditioned reflexes, the unconditioned reflexes are mostly stable. As described above, the conditioned reflexes are not only unstable but can be modified and extinguished. These two distinctions between the reflexes can be seen under the neural processes; A leading role in the performance of unconditioned reflexes is played by the lower divisions of the higher nervous system, the subcortical nuclei, brain stem and spinal cord. Conditioned reflexes, in contrast, are a function of the cerebral cortex and can involve the most varied stimuli applied to different receptive fields.

Behavioral therapies

Some therapies associated with classical conditioning are aversion therapy, systematic desensitization and flooding. Aversion therapy is a type of behavior therapy designed to make patients give up an undesirable habit by causing them to associate it with an unpleasant effect. Systematic desensitization is a treatment for phobias in which the patient is trained to relax while being exposed to progressively more anxiety-provoking stimuli(e.g. angry words). Flooding attempts to eliminate an unwanted CR. This type of behavior therapy is a form of desensitization for treating phobias and anxieties by repeated exposure to highly distressing stimuli until the lack of reinforcement of the anxiety response causes its extinction. It is usually with actual exposure to the stimuli, with implosion used for imagined exposure, but the two terms are sometimes used synonymously. operant conditioning.

Conditioning therapies usually take less time than humanistic therapies.

Conditioned drug response

A stimulus that is present when a drug is administered or consumed may eventually evoke a conditioned physiological response that mimics the effect of the drug. This is sometimes the case with caffeine; habitual coffee drinkers may find that the smell of coffee gives them a feeling of alertness. In other cases, the conditioned response is a compensatory reaction that tends to offset the effects of the drug. For example, if a drug causes the body to become less sensitive to pain, the compensatory conditioned reaction may be one that makes the user more sensitive to pain. This compensatory reaction may contribute to drug tolerance. If so, a drug user may increase the amount of drug consumed in order to feel its effects, and end up taking very large amounts of the drug. In this case a dangerous overdose reaction may occur if the CS happens to be absent, so that the conditioned compensatory effect fails to occur. For example, if the drug has always been administered in the same room, the stimuli provided by that room may produce a conditioned compensatory effect; then an overdose reaction may happen if the drug is administered in a different location where the conditioned stimuli are absent.

Conditioned hunger

Signals that consistently precede food intake can become conditioned stimuli for a set of bodily responses that prepares the body for food and digestion. These reflexive responses include the secretion of digestive juices into the stomach and the secretion of certain hormones into the blood stream, and they induce a state of hunger. An example of conditioned hunger is the "appetizer effect." Any signal that consistently precedes a meal, such as a clock indicating that it is time for dinner, can cause people to feel hungrier than before the signal. The lateral hypothalamus (LH) is involved in the initiation of eating. The nigrostriatal pathway, which includes the substantia nigra, the lateral hypothalamus, and the basal ganglia have been shown to be involved in hunger motivation.