

On Two Types of Conditional Reflex: General Laws of Association.

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Abstract—Both types of conditioning are based on the general laws of associations-connections between the centers involved. Whereas the experimental procedures of classical conditioning expose mainly the conditioned stimulus (CS)-unconditioned stimulus (US) connection, those of instrumental conditioning expose the conditioned stimulus (CS)-response (R) connection. Thus, the main differences between the two types of conditioning are those associated with the different centers involved in each, not the associative-connective laws themselves.

Basic Notions

My present concepts concerning the physiological mechanisms of classical and instrumental conditioning are based on the one hand on the general laws of associations and on the other hand on the new ideas concerning the organization of brain controlled unconditional reflexes (URs) (Konorski, 1970). I shall discuss both these points separately.

Associative learning occurs when two stimuli are presented to a subject in close temporal contiguity. It is assumed that its physiological mechanism is based on transformation of potential connections linking the centers representing the paired stimuli into actual (or functional) connections (Konorski, 1948). This process is thought to occur as a result of the increase of transmittability of synapses linking the neurons belonging to each of these centers. The center that *sends* axons to the other center is denoted as the *transmitting* center, and that which *receives* axon terminals from the transmitting center is denoted as the *recipient* center.

The prerequisite for associative learning is that the subject must *pay attention* to the presented pair of stimuli. The physiological basis of attention is the arousal of the corresponding center, producing adaptation of receptors for optimal reception of the stimulus.

From this point of view the conditional reflex (CR) may be regarded as a special case of associative learning in which activation

of the recipient center is "labeled" by its ability to elicit an observable response. Consequently, when the functional connection between the transmitting center and the recipient center is formed, the stimulus activating the transmitting center elicits the response characteristic for the recipient center.

Let us turn now to the functional organization of brain controlled URs, *i.e.*, those reflexes which regulate particular basic functions of the organism, such as alimentary function, defensive function, sexual function, etc. These reflexes may be divided into two categories: *consummatory* URs mediated by the thalamo-cortical system and *drive* CRs mediated by the hypothalamo-amygdalar system. Below we shall describe the properties and interrelations of these two categories of reflexes with regard to alimentary and defensive functions of the organism.

Concerning alimentary functions we should distinguish those reflexes which deal with consumption of food (consummatory food reflexes) from those which deal with providing food to the animal (hunger-drive reflexes) (Fig. 1). In the consummatory UR the

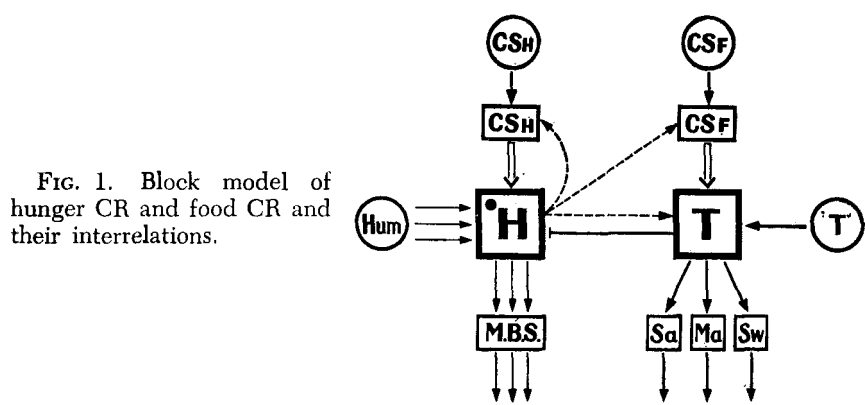


FIG. 1. Block model of hunger CR and food CR and their interrelations.

Squares and quadrangles denote centers; circles denote stimuli. Continuous line arrows, inborn excitatory connections; broken line arrows, inborn facilitatory connections; double-line arrows, conditioned connections; continuous stopped line, inborn inhibitory connection. Point inside the square denotes logical product of connections.

H, hunger system; M.B.S., motor behavioral system; Hum, humoral stimuli; CS_H, hunger CS.

T, food gustatory system; Sa, salivation; CS_F food CS.

On the left, hunger CR is shown. Hunger center is activated by the joint operation of humoral factors and CS. Its activation produces arousal of motor behavioral system and arousal of taste analyzer and of analyzers of CS_H and CS_F.

On the right, consummatory food CR is shown. Gustatory food US (T) or CS_F produces salivation; both these stimuli produce inhibition of the hunger drive system.

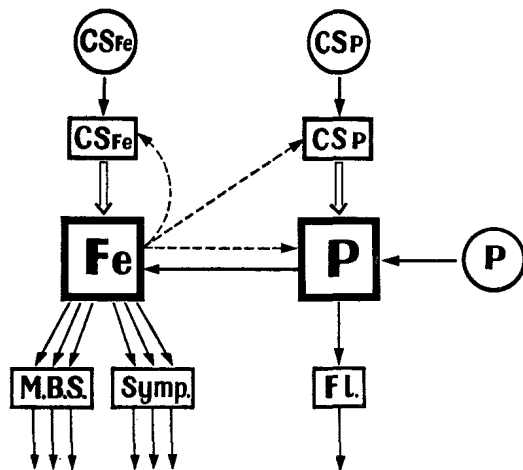


FIG. 2. Block model of fear CR and shock-to-the-paw CR.

General denotations as in Fig. 1.

Fe, fear system; M.B.S., motor behavioral system; Symp., sympathetic system; CS_{Fe} , fear CS.

P, nociceptive system; FL, flexion of the leg; CS_P , shock CS.

On the left, the fear CR is shown. Fear center is activated either by the noxious US (P) or by the CS. Its activation produces arousal of motor behavioral system, sympathetic outflow and arousal of analyzers of somesthesia (pain), of CS_{Fe} and CS_P .

On the right, the consummatory shock CR is shown. Nociceptive US or CS produces flexion of the leg; both of them produce also activation of the fear system.

US is represented by the taste of food brought to the mouth, and the response consists of salivation, mastication and swallowing. As to the hunger-drive UR, its main stimulus is the absence of nutritive substances in the blood, while its responses consist of arousal of the motor behavioral system manifested by hypermotility, increase of heart-rate, and hunger contractions of the stomach. The important peculiarity of the relations between the food UR and the hunger UR is that while the hunger drive facilitates the food reflex by producing arousal in its center, the food reflex, on the contrary, partially inhibits (appeases) hunger which reappears with increased strength (rebound) after the food is swallowed. These interrelations were first emphasized by Soltysik (1960).

Concerning the defensive functions of the organism (Fig. 2) again we deal with the consummatory UR consisting of defensive responses to a painful or aversive stimulus (for instance, leg flexion in response to a pinprick), and the fear-drive UR, consisting of the arousal of motor behavioral system, increase of heart rate and other sympathetic responses. The USs producing fear URs are the same which produce the consummatory URs, namely painful or aversive

stimuli. It may be observed that the relation between the consummatory defensive UR and the fear UR is that both of them are elicited by the same aversive stimulus, and that the fear-drive reflex facilitates the consummatory reflex.

Let us try now, on the basis of these considerations, to analyze the mechanisms of two main types of CRs, which Miller and I call type I and type II, which Skinner calls respondent and operant and which Hilgard and Marquis call classical and instrumental.

Classical Conditioning

By classical conditioning we denote the types of associations in which one of the paired stimuli elicits a brain controlled UR, manifested by an overt motor and/or autonomic response. Owing to functional connections being formed between the CS center and the US center, the CS starts to elicit the same response as that elicited by the US. Since, according to our previous considerations, we distinguish consummatory URs from drive URs, the same distinctions must be made of CRs (Figs. 1 and 2).

As noted before, the necessary condition for establishing connections between the CS center and the US center is their arousal. Arousal of the drive US center is directly produced by the arousing capacity of drive itself; arousal of the CS center and the consummatory US center is produced by the appropriate drive (the broken line arrows in Figs. 1 and 2). If the appropriate drive is for some reason not in operation (hunger is abolished by satiation, or fear is abolished by a tranquilizer), the corresponding CR cannot be established, or if already established, cannot be manifested. Let us compare now the properties of consummatory and drive CRs. The consummatory CRs are as a rule phasic; they require close sequence between CS and US and are easily extinguished when the CS is not followed by the US. In contrast, the drive CRs are usually tonic; they are commonly elicited by longlasting stimuli (often by a whole experimental situation), their formation is more rapid than that of consummatory CRs and their extinction is very protracted. Consequently, it often happens that the drive CR is present when the consummatory CR is still absent, or already extinguished. This phenomenon has been called schizokinesis by Gantt (1960).

The phasic character of the consummatory CRs and the tonic character of the drive CRs explain many facts which are incomprehensible if this division is not recognized. For instance, the authors using for their experiments consummatory defensive CRs claim that CS-US intervals should extend from a fraction of a second up

to a few seconds. If they are longer, inhibition of delay easily develops. On the contrary, in the CER method the CS-US interval usually lasts two or three minutes. This ostensible discrepancy between two experimental results is due to the fact that in the first type of experiments the consummatory responses were recorded (blinking, leg flexion, etc.), while in the second one the fear-drive response was recorded.

It is also worthwhile to compare the relations between consummatory and drive CRs as they occur in alimentary and defensive functions.

Concerning the alimentary consummatory CR, the optimal CS for its elicitation is a stimulus closely preceding the presentation of food. Since the corresponding US is a taste stimulus partially inhibiting the hunger drive, the animal in the presence of the CS calms down, looks intently at the feeder and salivates copiously. On the contrary, during the intertrial intervals most dogs, if not overtrained, exhibit hypermotility, because at those periods the hunger drive CR dominates over the food CR. Salivation is usually negligible or nil, since the hunger drive as such does not elicit salivation.

As far as the defensive CR is concerned, its fear-drive component is in operation both in the intertrial intervals (tonic phase) and in the presence of the sporadic CS closely preceding the painful US. The fear reflex to the CS is even increased because of the excitatory connections linking the CS consummatory center with the fear center (Fig. 2).

Instrumental Conditioning

Before entering into discussion of my present concept concerning the mechanism of instrumental CRs, I would like to emphasize that the development of my views upon this subject was mainly determined by experimental results and ideas advanced in our department by Wyrwicka (1952) and Soltysik (1960).

The first body of findings which influenced my concept of instrumental conditioning was obtained by Wyrwicka. She has shown that the occurrence of the alimentary instrumental CR depends on two types of connections, those linking "directly" the center of the CS with the center of movement, and those linking these two centers "indirectly" by the mediation of the alimentary center (Fig. 3a). The second group of findings was obtained by Soltysik, who has shown that the "indirect" connections of Wyrwicka were mediated by the drive or emotional center—fear center in defensive reflexes and hunger center in alimentary reflexes (Fig. 3b). My present concept concerning instrumental conditioning is essentially

similar to the concepts proposed by these authors, but it lays more stress on the "direct" connections being formed between the CS center and the kinesthetic center programming the instrumental movement, while it assumes that the drive centers play rather an auxiliary role in the formation of these connections. In this way it is possible to account for the fact that the attractive (food) and the aversive (pain) USs, which in classical conditioning play basically the same role of reinforcers, here play just the opposite roles.

In classical conditioning the connections are formed between the CS center and the US center because these centers are regularly activated in temporal contiguity. On the other hand, in instrumental conditioning temporal contiguity concerns only the activation of the CS center and the kinesthetic center programming the instrumental movement; and, therefore, connections are formed between these two centers. The irrelevance of the consummatory USs as direct components of the connections involved in instrumental conditioning is demonstrated by the fact that while in alimentary conditioning the US is indispensable for the formation of CS-M connections (M stands for kinesthetic center of movement), in defensive instrumental conditioning the absence of the US leads to consolidation of these connections. This is why the latter conditioning is usually denoted as avoidance. Therefore the question arises as to what *is* the role of USs in instrumental conditioning?

We should remind the reader that any drive, both hunger and fear, produces arousal of the motor behavioral system, manifested by the animal's performing in close succession various movements until the moment when drive is discontinued. If, in the presence of some longlasting or sporadic drive producing CS, a movement is performed which is regularly followed by the cessation of drive, the CS center becomes connected with the kinesthetic center of that movement. If the given movement is not followed by the cessation of drive, the CS-M connections cannot be formed because

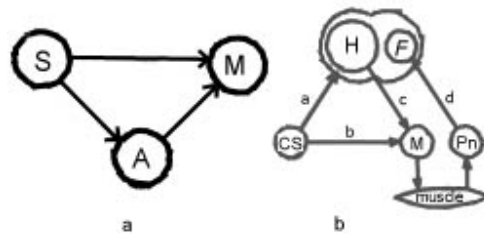


FIG. 3. Block models of alimentary instrumental CR according to Wyrwicka (a) and Soltysik (b).

a: S, center of CS; A, alimentary center; M, motor center. b: CS, center of CS; H, hunger center; F, food center; M, motor center; Pr, proprioceptive center.

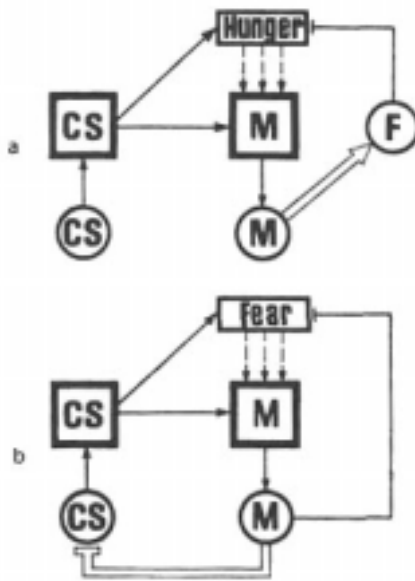


FIG. 4. Block models of instrumental alimentary (a) and defensive (b) CRs.

Squares and quadrangles, centers; circles, stimuli and responses. Single arrows, excitatory connections; single stopped lines, inhibitory connections; double arrows, positive causal connection; stopped double line, causal negative connection. M, motor; F, food.

this movement is subjected to retroactive inhibition produced by the performance of subsequent movements.

In instrumental alimentary conditioning the instrumental movement performed in the presence of the hunger CS is immediately followed by presentation of food, which exerts an inhibitory effect upon the hunger-drive center (Fig. 4a). On the contrary, in avoidance conditioning the instrumental movement performed in the presence of the fear CS is immediately followed by the cessation of this CS, and this cessation leads to the reduction of fear drive (Fig. 4b).

In summation, we see that the only difference between classical and instrumental conditioning lies in a different circuitry of connections formed between particular centers, due to different experimental procedures. In classical conditioning the CS regularly precedes *the US*; and therefore, the connections are formed between the CS center and the US center under the influence of drive, which produces arousal of these centers. In instrumental conditioning the CS regularly precedes the *given movement*, and therefore the

connections are formed between the CS center and the kinesthetic of that movement center. Drive operating in this procedure plays a dual role in the formation of the instrumental CR. On the one hand, it produces arousal both in the CS center and the kinesthetic center, arousal which is indispensable for establishing connections between them. In this respect the role of drive is exactly the same as in classical conditioning, except that instead of CS-US connections, CS-M connections are formed. On the other hand, *the cessation* of drive after the performance of the given movement causes the CS-M connections to be consolidated because, if the drive did not cease, the continuing motor excitement would retroactively inhibit that movement. The cessation of hunger drive in alimentary instrumental CRs is due to its inhibition by a taste stimulus; the cessation of fear drive in avoidance CRs is due to the cessation of the CS eliciting this drive. Since the operation of drive may be regarded as a Thorndike'ian "annoying state of affairs," and appeasement of drive, as a "satisfying state of affairs," there is no essential difference between the old concept of Thorndike concerning habit formation and the concept of the mechanism of instrumental conditioning advanced in this paper.

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