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## CLASSICAL AND INSTRUMENTAL CONDITIONING: THE GENERAL LAWS OF CONNECTIONS BETWEEN "CENTERS"

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*Abstract.* This is a synopsis of the author's concept of the physiological mechanisms of classical and instrumental conditioning. In the classical conditioned reflex the connection is established between the central representations of the conditioned and unconditioned stimuli while in the instrumental reflex it is established between the representation of the former stimulus and the kinesthetic representation of the instrumental response. Drives play an important role in both types of conditioning by providing arousal in the corresponding neural centers.

### GENERAL CONCEPTS

One of the general properties of the brain, and in particular of the cerebral cortex, is the ability to establish functional connections between particular groups of neurons (denoted here as "centers"), when they are concurrently or sequentially activated. It is assumed that only those cerebral centers can become functionally connected which are linked by pre-functional (potential) connections. The formation of functional connections is thought to occur as a result of the increase of transmissibility at synapses linking the neurons belonging to each of these centers. That center which sends axons to the other is denoted as the transmitting center, and that which receives axon terminals from the transmitting center is denoted as the recipient center. In many cases connections between the pairs of centers are bidirectional (see Asratyan, this Symposium, 1).

As a rule, potential connections are formed in ontogeny between the neurons of higher levels of particular afferent systems — so called associative or gnostic areas of the cerebral cortex. In consequence, when

two stimuli belonging to two afferent systems are presented in close temporal contiguity, the functional connections are formed between the "centers" representing these stimuli. In man the formation of these connections is introspectively experienced because then the perception of one of these stimuli evokes the image of the other. In all probability the same effect occurs in higher animals, as may be judged now by EEG records (6, 7).

The essential prerequisite for the formation of functional connections between two centers is that the subject pays attention to the presented pair of stimuli. The physiological basis of attention is the arousal of perceptive fields to which the given center belongs. This arousal produces adjustment of the appropriate receptors to the optimal reception of the presented stimulus (5).

Connections which are involved in conditioning are characterized by the fact that activation of the recipient center elicits observable behavioral response (autonomic or motor). In consequence, when the connection between the transmitting center and the recipient center is formed owing to repeated pairing of corresponding stimuli, then this response is elicited by the stimulus activating the transmitting center. Thus the formation of the functional connection can be observed behaviorally.

#### UNCONDITIONED REFLEXES MEDIATED BY THE BRAIN

Higher order complex unconditioned reflexes (URs) control particular basic functions of the organism, such as alimentary function, defensive function, sexual function, etc. As it was extensively presented in the author's earlier monograph (5) these reflexes can be divided into two categories: consummatory URs mediated by the thalamo-cortical system and drive URs mediated by the hypothalamo-amygdalar system. The properties and interrelations of these two categories of reflexes are described below with regard to alimentary and defensive functions of the organism.

Concerning alimentary functions, those reflexes which deal with consumption of food (consummatory food reflexes) should be distinguished from those which deal with securing food by the animal (hunger-drive reflexes) (Fig. 1). In the consummatory UR the US (unconditioned stimulus) 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 presumably 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 (8).

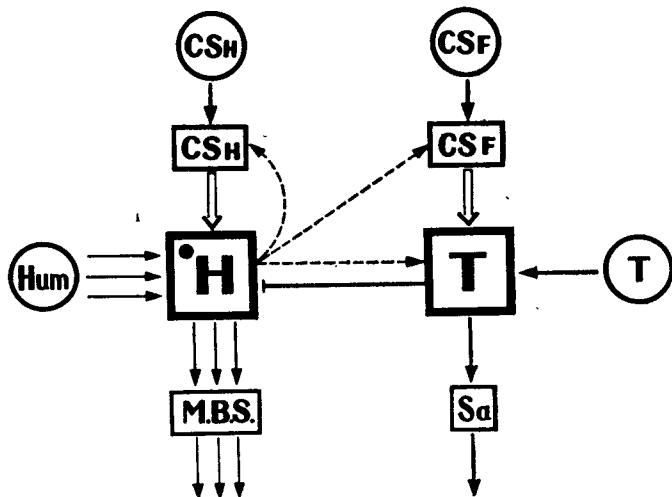


Fig. 1. Block model of hunger CR and food CR and their interrelations. Squares and quadrangles denote centers; circles denote stimuli. Continuous line arrows, inborn excitatory connections; broken line arrows, inborn facilitatory connections; double-line arrows, conditioned connections; continuous stopped 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; CSH, hunger CS. T, food gustatory system; Sa, salivation; CSF, 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 CSH and CSF. On the right, consummatory food CR is shown. Gustatory food US (T) or CSF produces salivation; both these stimuli produce inhibition of the hunger drive system. From Konorski (5).

This dichotomy between drive and consummatory response is also expressed in the defensive functions of the organism (Fig. 2). The consummatory UR consists of defensive responses to a painful or aversive stimulus (for instance, leg flexion in response to pinprick); while the fear-drive UR is manifested in the arousal of the 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 are elicited by the same aversive stimulus, and that the fear-drive reflex facilitates the consummatory reflex.

On the basis of these considerations, an attempt will now be made to analyze the mechanisms of the two main types of CRs, which Miller and I have called type I and type II which are referred to by Skinner as

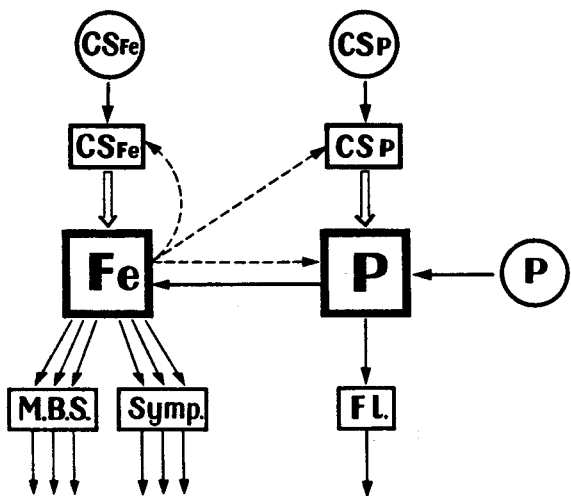


Fig. 2. Block model of fear CR and shock-to-the-paw CR. General denotations as in Fig. 1. Fe, fear system; M. B. S., motor behavioral system; Symp., sympathetic system; CS<sub>Fe</sub>, fear CS. P, nociceptive system; FL, flexion of the leg; CS<sub>P</sub>, shock CS. On the left, the fear CR is shown. 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<sub>Fe</sub> and CS<sub>P</sub>. On the right, the consummatory shock CR is shown. Nociceptive US or CS produces flexion of the leg; both of them also produce activation of the fear system. From Konorski (5).

“respondent” and “operant” and by Hilgard and Marquis as “classical” and “instrumental”.

### CLASSICAL CONDITIONING

Classical conditioned reflexes are based on connections between centers, one of which 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 this US center, the CS comes to produce the same response as that elicited by the US. Since, as noted above, the consummatory UR and the drive UR are separate reflexes, the same must be obviously true of CRs. The corresponding connections are indicated in Fig. 1 and 2 by double line arrows.

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 the drive itself; arousal of the CS center and the consummatory US center is produced by the appropriate drive (the broken-line arrows in Fig. 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.

The properties of consummatory and drive CRs are significantly different. The consummatory CRs are as a rule phasic requiring a close sequence between CS and US and are easily extinguished when the CS is not followed by the US. On the contrary, 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. In consequence, it often happens that the drive CR is present when the consummatory CR is still absent, or already extinguished (4): (Fig. 3). This phenomenon has been called by Gantt schizokinesis (3).

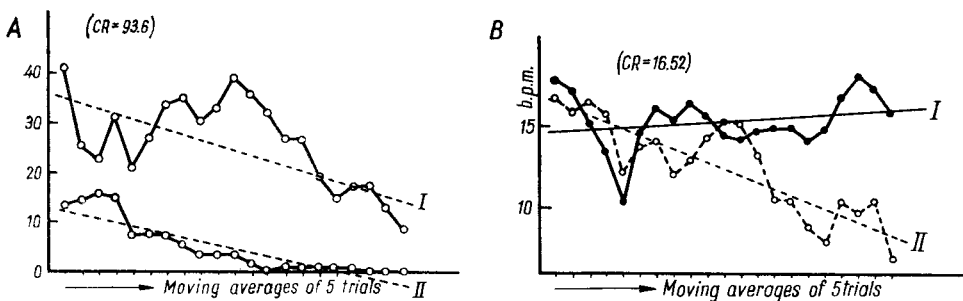


Fig. 3. Acute extinction during two consecutive days. A: Latency of the leg flexion; ordinates are calculated from the formula  $100(3-L)$  where  $L$  = latency in seconds. B: Heart rate response to CS; ordinates are differences between heart rate during CS and heart rate in the period immediately preceding the CS. I and II, the first and the second extinction session. From Jaworska et al. (4).

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 (2). If they are longer, inhibition of delay easily develops. On the contrary, in the conditional emotional response the CS-US interval lasts usually 2 or 3 min. This ostensible discrepancy between the requirements of these experimental procedures is due to the fact that brief CS-US intervals are indispensable for the consummatory CRs (blinking, leg flexion, etc.), while long CS-US intervals can be used when the drive CRs are in operation.

The relations between consummatory and drive CRs as they occur in alimentary and defensive functions can now be compared. 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 in those periods the hunger drive CR is predominant over the food CR. Salivation is usually negligible or nil, since the hunger drive as such does not elicit a salivary response.

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.

#### 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 (9) and by Sołtysik (8).

The first body of evidence 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. 4, left). The second group of

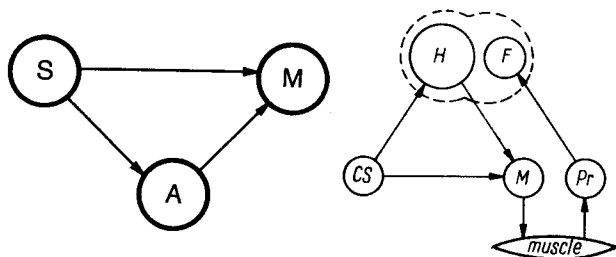


Fig. 4. Block models of alimentary instrumental CR according to Wyrwicka (left) and Sołtysik (right). Left: S, center of CS; A, alimentary center; M, motor center. Right: CS, center of CS; H, hunger center; F, food center; M, motor center; Pr, proprioceptive center. From Wyrwicka (9) and modified from Sołtysik (8).

findings was obtained by Soltyssik, 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. 4, right). My present concept concerning instrumental conditioning is basically similar to that proposed by these authors, except that it emphasizes the "direct" connections being formed between the CS center and the kinesthetic center programming the instrumental movement. The latter center is directly connected with the efferent motor centers involved in the performance of that movement. Thus it can be seen that whereas in classical conditioning there is a close temporal contiguity between the activation of the CS and US centers (regardless of whether the US is attractive or aversive), in instrumental conditioning the temporal contiguity is between the activation of the CS center and of the kinesthetic center of the instrumental movement.

The question arises as to what is the role of the drive center in instrumental conditioning.

It should be remembered that any drive, either hunger or fear, produces arousal of the motor behavioral system, manifested by the animal's performing various movements in close succession, until drive is discontinued and the animal calms down. As indicated above, each drive is easily conditionable, being elicited by signals heralding presentations of food or of a painful stimulus respectively. Conditioned hunger drive is inhibited when food is placed in the mouth, while conditioned fear drive is withdrawn when the fear producing CS is discontinued.

Both hunger and fear drives are factors permitting the formation of connections between the center of a given exteroceptive stimulus and the center of the kinesthetic stimulus generated by the performance of a given movement. When, however, the given movement is not immediately followed by the cessation of drive the subsequent movements elicited by its continuing operation exert retroactive inhibition upon the traces of the previous movement thereby forestalling formation of the above connection. Thus it can be concluded that the connection can be formed only between the CS center and the kinesthetic center of that movement which just precedes the cessation of drive. In this way that movement becomes an instrumental response and is elicited by the CS with minimal latency. The block models representing the connections involved in alimentary and defensive conditioning are presented in Fig. 5a and 5b respectively.

In sum, it can be seen that the 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 center of that movement. Drive operating in this

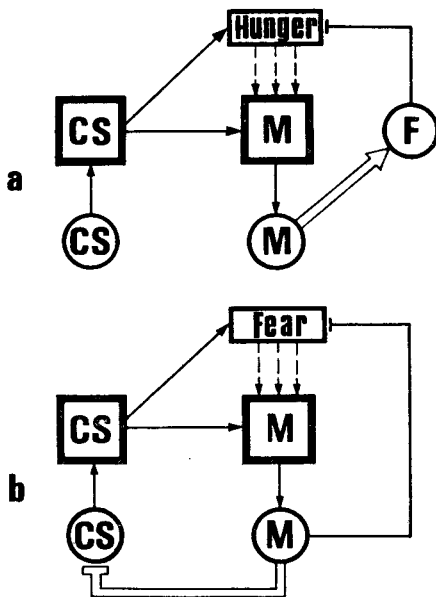


Fig. 5. Block models of instrumental alimentary (a) and defensive (b) CRs. Squares and quadrangles, centers; circles, stimuli and responses. Single arrows, excitatory connections; single stopped lines, inhibitory connections; double arrows, causal positive connection; stopped double line, causal negative connection. M, motor; F, food.

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 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.



It remains to be considered what role is played in instrumental CRs by consummatory USs, i.e., those USs which play a dominant role in classical CRs. The models of instrumental CRs presented in Fig. 5 show the USs as not directly intervening in these reflexes. In alimentary instrumental conditioning the presentation of the consummatory US (food in the mouth) plays only an indirect role, namely, by inhibition of the hunger drive it permits consolidation of the instrumental response. In defensive instrumental conditioning the role of the aversive US is quite the opposite, namely, its non-presentation leads to the consolidation of the instrumental CR.

The considerations included in this paper were also presented at the 13th meeting of the Pavlovian Society of North America held on 26-28 September 1972 in Oslo, Norway. They are published in a somewhat different version in the journal *Conditional Reflex* (1973, 8: 2-9).

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