

POST-CONSUMMATORY AROUSAL OF DRIVE AS A MECHANISM OF INCENTIVE MOTIVATION

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Abstract. A review of experimental papers on the problem of incentive motivation reveals little or no support for the hypothesis that conditioned food signals facilitate autochthonous instrumental responses (i.e., responses motivated by the same drive and rewarded by the same unconditioned stimulus). The existing data are explained most parsimoniously by assuming that reward, or its conditioned signal, inhibits the central drive process, and, that the termination of either primary (food US) or secondary (food CS) reward causes the rebound of drive which energizes instrumental behavior. This post-consummatory arousal of drive retains some specificity related to the reward and is assumed to represent a mechanism of the phenomena usually referred to as incentive motivation.

INTRODUCTION

In this paper I intend to present a short review of the concepts concerning the mutual relationship between classical consummatory food conditioned reflexes and the instrumental food conditioned responses as they developed during the scientific life of Jerzy Konorski. He was one of the main contributors to the problem of how classical, food signaling, conditioned stimuli (FCSs) influence the performance of the autochthonously motivated (i.e., based on the same drive) instrumental behavior. He also wrote (with S. Miller) the first publication in which the problem of what today is called "incentive motivation" was specifically

formulated in the framework of an interrelationship between classical conditioning and instrumental learning (Konorski and Miller 1930). Both authors were still medical students at Warsaw University when their experiments with a new "salivo-motor method" were carried out in the physiological laboratory of the Medical Faculty. The facts reported in this early study and conclusions drawn from them deserve full attention. They mark Konorski's experimental ingenuity and theoretical boldness, which remained the characteristic feature of his creative scientific life. As a point of departure, I shall describe the experiments and quote the most salient statements from their pioneer paper.

PIONEER DISCOVERIES AND FIRST IDEAS

The experiment was a prototype of many later studies on the classical-to-instrumental transfer of control or transfer of learning. The dogs were initially trained in a Pavlovian paradigm: an auditory CS (metronome 120 beats per minute) was reinforced with food and became a positive food conditioned stimulus (FCS^+); another auditory CS (metronome 200 beats per minute) was never paired with food and when the conditioned salivation (due to generalization from the metronome 120/min) had extinguished, it became an inhibitory food conditioned

THE LIST OF ABBREVIATIONS

CNS	central nervous system
CS	conditioned stimulus, classically conditioned stimulus
CR	conditioned response
US	unconditioned response
FCS	food conditioned stimulus
FCS^+	positive food conditioned stimulus
FCS^-	inhibitory food conditioned stimulus, differential stimulus
FUS	unconditioned food stimulus
ITR	intertrial response
SD	positive discriminative stimulus, positive instrumental conditioned stimulus
S^d	inhibitory discriminative stimulus, instrumental differential stimulus
FR	fixed ratio (response to reward)
VI	variable interval (between rewards or between CS onset and US)
r_G	antedating goal response, conditioned consummatory response
s_G	stimuli generated by the r_G
$rs_G = r_G - s_G$	behavioral sequence of r_G generating s_G
S_D	drive stimulus
D	primary drive
R_G	goal response, unconditioned consummatory response
K	incentive variable

stimulus (FCS⁻) or simply inhibitor, as the authors called it. The excitatory or inhibitory nature of the stimuli was assessed by the magnitude of conditioned salivary responses elicited by the stimuli. After the dogs learned to differentiate the stimuli, the instrumental leg lifting response was trained in the presence of light. Before the discriminative instrumental behavior was learned, the dogs performed many intertrial instrumental responses (ITRs) which the authors described as "spontaneous movements". These free nonrewarded and gradually disappearing movements were recorded together with the rate of salivary secretion. The effect of FCS⁺ and FCS⁻, as well as of the food unconditioned stimulus (FUS) were tested in two stages of the training:

- (1) When the ITRs were still quite frequent, and
- (2) when these ITRs became inhibited.

The results of the influence of the FCS⁺, FCS⁻ and FUS upon the instrumental ITRs were described in the following statements.

"The unconditioned stimulus (food) inhibits fully the (instrumental) movements of the paw for a period of its duration". (Konorski and Miller 1930, p. 912).

"Similarly, the conditioned stimulus of the alimentary reflex inhibits the movements of the paw for the period of its duration". (ibid. p. 912).

"The inhibitor (the FCS⁻) of the conditioned reflex does not exert any influence upon the conditioned reflex type II (i.e., the instrumental response). It is, however, possible that it accelerates the rate of the movements". (ibid. p. 912).

After the ITRs have been extinguished the same stimuli produced the following effects.

"During its action the unconditioned food stimulus does not influence the inhibited motor response. But, at the time of its termination (when the dog stops eating), the motor (instrumental) reflex becomes disinhibited and the lifting of the paw reappears. It is probably that this phenomenon is a result of the process of inhibition which appears in the alimentary center at the moment of cessation of eating" (ibid. p. 912).

"Conditioned stimulus does not affect the inhibited reflexes type II". (ibid. p. 913).

"The inhibitor of the simple (i.e., classical) conditioned reflex causes disinhibition of the conditioned reflex type II, i.e., it elicits (il provoquer) a motor response. That phenomenon (of disinhibition of the ITRs) appears only at a certain stage of the (development of the) inhibitor, namely, when it is relatively recently trained". (ibid. p. 913). Then, considering the effect of prolonged presentation of FCS⁺, Konorski and Miller

noted: "If the application of the conditioned stimulus is prolonged (while) the presentation of food delayed, the motor (instrumental) response occurs when the inhibition (of salivary CR) develops." (ibid. p. 913).

Finally, summarizing the results in the spirit of Pavlovian speculative neurophysiology, the authors concluded: "... the process of excitation which passes through cortical cells connected through conditioning to the (cells of) alimentary reaction, causes the inhibition of the conditioned response type II (i.e., instrumentally) established by the alimentary reinforcement. On the contrary, the process of inhibition passing through these cells possesses the faculty of eliciting this (instrumental) response in the same way as the stimuli which were established to (control) this response". (ibid. p. 913).

It is remarkable how many relationships between consummatory and instrumental responses were observed in these first "salivo-motor" experiments. We shall return to them in the following pages.

The acceptance of a Pavlovian concept of a unitary "alimentary center" with its taste afferents and consummatory (salivary, etc.) efferents forced the authors to assume that it is the inhibition of this center that "provokes" the execution of the instrumental food response. The interaction between classical and instrumental food responses was conceived as *reciprocally inhibitory*. It was the inhibition of the alimentary center that elicited the instrumental response whereas the excitation of this center caused suppression of instrumental behavior. The stimulus eliciting a discriminated instrumental response (we shall refer to it as S^D using Skinner's symbol) was assumed to be inhibitory in relation to an alimentary response (Miller and Konorski 1928); similarly, the proprioceptive feedback from the instrumental movement was assumed to have the same inhibitory properties because neither S^D nor the instrumental response-generated stimuli were separately paired with food. It was only the compound stimulus consisting of S^D together with the feedback stimuli from the instrumental movement that was assumed to be a positive FCS⁺.

If one tried to formulate a mechanism of incentive motivation within a framework of these early views of Konorski and Miller, one would have to state, somewhat paradoxically, that it is an inhibition of the alimentary center. Obviously, one could hardly envisage a motive for action, or, using more contemporary language, a drive-like process, in the form of inhibition. Even worse, the inhibition is located in the very center which controls the consummatory behavior and the activation of this center seems logically necessary for the reward expectations inherent in a concept of incentive motivation.

However, as I shall try to persuade the Reader, the basic observa-

tions and part of the interpretation was closer to the truth than the widely accepted theory of incentive motivation developed in the following several decades.

PAVLOVIAN CONTRIBUTION

The first challenge came in a few years from the very Olympus of conditioning. Pavlov, who got interested in the experimental work of the two young Poles and invited them to work in his laboratories, disagreed with their interpretations and soon dismissed even the notion of two different kinds of conditioning. In a foreword to Konorski and Miller's monograph published in his "Transaction of Pavlov's Laboratories", he advanced a theory which linked the two kinds of conditioned reflexes into the same hypothetical "conditioned reflex arc." According to this view (Pavlov 1932, 1936) an instrumental food response is a classical alimentary reflex established by pairing of the proprioceptive stimuli generated by the instrumental movement with the food US, but "played back" in the reverse direction. When the "kinesthetic" stimuli arising during performance of a particular movement are followed, i.e., reinforced, by a palatable taste stimulus eliciting salivation, they become a FCS⁺ and acquire the power to excite the alimentary conditioned reaction. However, this newly formed connection between the kinesthetic and taste neurons (which Pavlov located in the cortical motor and gustatory analysers) is capable of conducting "excitation" in both directions. Therefore, when the animal is "alimentarily excited", excitation travels from the taste cells to the kinesthetic cells which, in turn, are connected with the corresponding motor cells and as a result, the animal performs the "so-called voluntary" movement (Pavlov's label of the instrumental response). In other words, the very same excitation of the taste analyser which leads to the classically conditioned salivation, provides an impulse or motive to execute the instrumental reaction.

It is fascinating retrospectively to realize how many elements of this explanation, so speculative in Pavlov's time, survived for decades and gained wider acceptance. The view that activation of an alimentary system facilitates instrumental and general activity is supported by many students of animal behavior (Asratyan, 1974; Beritov, 1965; Bindra, 1969; Wyrwicka, 1972). The hypothesis of two-way traffic of excitation in a center-to-center conditioned connection is presently accepted by Asratyan (1974), Beritov (1965) and even Konorski (1974), who disliked the idea of backward conditioning with which the "reverse conditioned connection" is associated. An additional hypothesis that kinesthetic cells activate the motor cells of the very movement which they represent

was reiterated in an updated terminology by Konorski in his monograph of 1967, and again in his last theoretical paper of 1974. A serious flaw in Pavlov's theory consists in not explaining why only a restricted class of unconditioned stimuli may be used as reinforcers of motor "voluntary" behavior. Why, for example, the injection of acid solution into the mouth, which as an US is also addressed to the same taste analyser and enables the formation of classical salivary CR, fails to reward the movement in the same way as food? What happens to the reverse "connection" in the case of aversive USs? Pavlov also missed the point that came clearly in the aforementioned paper of Konorski and Miller (1930). Since food as US suppresses the motor activity except for the act of eating, why doesn't the FCS⁺, which was considered by Pavlov as a food substitute, replicate this aspect of unconditioned behavior and instead, by eliciting the instrumental response, contaminates the pattern of responses belonging to alimentary category with ones that do not?

Despite these controversial points, the basics of Pavlov's idea that the instrumental movement is elicited, or at least motivationally supplemented, by alimentary excitation, meaning consummatory conditioned response or anticipation of food, has become widely accepted.

In the forties and fifties, both "uslovniks" (conditioned reflex specialists in Pavlovian jargon) and even most prominent learning theorists produced theoretical and some experimental support for this notion. Let us examine the various versions of this concept and have a careful look at the experimental evidence.

Pavlov's theory in a more elaborate form was until now supported by one of his prominent disciples and followers, Ezras A. Asratyan (1971, 1973, 1974). Outside the Pavlov's school, similar views, including the hypothesis of two-way transmission within the "conditioned reflex arc", have been expressed by I. S. Beritashvili (Beritov 1965). Factual evidence published in Asratyan's and Beritashvili's laboratories is rather unimpressive. Either the fact that dogs perform the instrumental movement *after* eating or in response to some ill-defined, as to their duration, food signals (like the sight of an empty feeder bowl (Dzhavhrishvili 1965)) are presented as proof of the "reverse" conditioned connection from the alimentary center to the motor center and the response is said to be elicited by alimentary excitation.

Further support for Pavlov was provided by one of Konorski's co-workers, Wanda Wyrwicka. In a number of studies devoted to the mechanism of instrumental food conditioning, Wyrwicka described the following observation. When the dog has been trained to perform a discriminated instrumental response rewarded by food, any new indifferent sti-

mulus paired several times with food acquires the property to elicit that response (Wyrwicka 1952). The author concluded that the new stimuli are eliciting instrumental response because, due to classical conditioning, they have acquired the capacity to activate the alimentary center. This fact was easily replicated many times by anyone who worked with food instrumental conditioned reflexes in Konorski's institute. However, a more detailed analysis proved that the interpretation might be different. In the first place, the "transfer of the instrumental movement" as this phenomenon was called in Konorski's laboratory was obtained when the newly trained FCS was presented and the delivery of the food US delayed; in other words, it was not that the instrumental response occurred automatically during the acquisition of a classical alimentary CR, but the FCS was presented and the experimenter "waited a little longer" for the instrumental response to occur. For the lack of salivary recording in Wyrwicka's experiments, there was no data as to how these first occurrences of "transferred" instrumental responses were related to the salivary CR. Unpublished experiments of Sołtysik, in which a precise salivary recording was made using a shortened Stensen's duct fistula (Sołtysik and Zbrożyna 1957) and Kozak's method of recording salivation (Kozak 1950), have shown two facts that contradicted Wyrwicka's conclusions. First, when the classical conditioning (in dogs previously trained in instrumental discriminative conditioning) was carried out systematically, starting with short CS-US intervals and gradually extending them to 10 sec, a strong conditioned consummatory response developed without any tendency to incorporate the instrumental response. This is quite a remarkable sight, when a dog, promptly pressing a lever to an old stimulus, becomes motionless to a new food CS⁺ and patiently waits for 10 sec staring at the feeder and salivating steadily. Secondly, by using a more precise method of salivary recording, it was possible to observe what happened when the duration of the food CS⁺ was extended until the dog performed the instrumental movement. The observations were exactly as those reported by Konorski and Miller in 1930: the dogs responded with bar pressing after the salivary secretion slowed down and some restlessness appeared, obviously caused by the omission of the expected food US. These facts were presented at the symposium in 1958 and a new explanation was proposed (Sołtysik 1960). The strong controversy that followed this meeting caused the author to withdraw from experiments on food conditioning for over five years, and only starting with the Sołtysik and Konorski (1966) paper on the relations between consummatory and instrumental CRs, a new series of studies was initiated.

Before presenting the new theoretical model which was developed during the period of 1960–1973, I would like to review the related experiments and concepts proposed by experimental psychologists and learning theorists.

IN SEARCH FOR INCENTIVE MOTIVATION

In the field of experimental psychology the problem of the conditioned stimuli affecting the performance of instrumental responses (or any motor behavior, in some formulations) was probably initiated in 1941 by Clark L. Hull, when he expressed the following suggestion: "The r_G (i.e., the conditioned consummatory food response called an "antedating goal reaction" by Hull) on the other hand, and so the s_G (the stimuli produced by r_G) occurs persistently, or at least intermittently, throughout the behavior sequence. This persistence gives the s_G certain dynamic powers of controlling action resembling the S_D (i.e., the drive stimulus) which constitutes one aspect of motivation. The s_G accordingly emerges as a kind of secondary motivational mechanism". (Hull 1941).

Although the above statement is not very convincing (why the mere consistent occurrence should transform the indifferent stimuli into drive stimuli?), it influenced the development of research for over two decades. The concept of "incentive motivation", explaining of how the quantitative aspects of reward influence and motivate the instrumental performance was reformulated by Spence (1947, 1956) and particularly by Seward (1950, 1951), who proclaimed that "...an animal in a state of need is motivated not only by a primary drive (D) and drive stimulus (S_D) but by a secondary drive consisting of a set (rs_G) to make a characteristic consummatory or goal response (R_G). When a response (R) is followed by reward R_G is conditioned to concurrent stimuli. By generalization of this conditioning, stimuli accompanying R now serve to intensify rs_G this intensification (is) called tertiary motivation and it (is) endowed with the property of facilitating R , the activity in progress". (Seward 1951, p. 130).

It should be noted, however, that C. L. Hull was less enthusiastic in developing this notion, and except for inserting a formal construct of incentive motivation (K) in his system (1950), he reserved the term "secondary drive" or "secondary motivation" for indifferent stimuli paired with the evocation of drive and not the consummatory act: "When the neutral stimuli are repeatedly and consistently associated with the evocation of a primary or secondary drive and this drive undergoes an abrupt diminution, the hitherto neutral stimuli acquire the capacity to

bring about the drive stimuli (S_D) which thereby become the condition (C_D) of a secondary drive or motivation". (Hull 1950, p. 175).

However, it was difficult to ascribe to consummatory food conditioned reflexes (CS-CR) both, the properties of "secondary reward" (= conditioned drive reduction effects) and "secondary" or "tertiary" motivational function (= increment of drive), and Seward admitted it a few years later: "...I have vacillated between the two viewpoints ... between considering rewards as satisfiers and as incentives". (Seward 1956, p. 199). Mowrer (1960) after discussing the incompatibility of the two effects, (a) *token satisfaction* by CS (conditioned to a reward US), and (b) incentive-motivational increase of drive by the very same CS, tried to resolve the inconsistency by proposing that the conditioned signals of reward elicit "hope" which is both, reducing drive and prompting action: "... there is nothing paradoxical about the assumption that an organism is most likely to go into action when it is *hopeful*, which is to say, under somewhat *less* drive or tension than when *hopeless*. The point is that an anticipation of more basic satisfaction which itself is somewhat satisfying may release, organize, or focus behavior and thus give the appearance of "increased drive" when, in fact, it is just the reverse phenomenon". (Mowrer 1960, p. 272).

Although we could envisage a situation when a very intense drive elicits less "overt" activity than a moderate drive, this is not the case in a typical incentive motivational interpretation, where the drive might be weak or even nonexistent and the CSs "promising" the reward instigate the action. As it will be discussed later, we prefer to have the action correlated to one hypothetical central (CNS) process *drive* and we think that our proposed explanation of the "incentive motivation" phenomena satisfactorily resolves the inconsistencies of the above viewpoints.

EXPERIMENTAL EVIDENCE

The attempts to verify experimentally the notion that it is the conditioned consummatory response (r_G) or the stimuli generated by it (r_G-s_G) that "motivates" the animal to act appetitively (and perform instrumental responses) are relatively scarce. There are but few experiments in which the consummatory response (e.g., salivation) were studied along with the instrumental behavior. In most studies, the consummatory response was not measured and its presence was merely assumed to be a necessary outcome of the classical CS-US pairing procedure. Unfortunately, in many cases, the parameters of such implicit condi-

tioning were chosen such as to minimize rather than assure consummatory conditioning.

Instead of presenting a chronological review of published data, we shall start with a group of papers which contributed most importantly to the problem by designing experiments specifically to test the consummatory-instrumental interrelations and by employing continuous registration of both instrumental responding and salivary secretion.

I. Transfer of control experiments

In this design, instrumental and classical conditioning are carried out in the same subject in separate phases of the training, while during the testing experiments, the classical food CSs are presented in an instrumental responding situation to find out how they influence the instrumental behavior.

Shapiro and Miller (1965) classically conditioned their dogs by pairing a tone CS with a food US with a fixed CS-US interval of 5 sec. After several weeks of training when the salivary CRs were well established, the effect of the tone CS was tested in an instrumental learning situation. Bar pressing for food reward was trained prior to classical conditioning by using a conjunctive FI-2 min DRL schedule in which the dogs were taught to respond at a low rate of less than once in 2 min. This complex schedule of reward resulted in a conveniently timed behavior with a long waiting period after each response during which the classical stimuli could be applied and the salivary and instrumental responses observed. The food CSs were applied at different times during the inter-response interval to prevent any fixed time relation to the beginning and the end of the waiting period. The stimuli were presented for 10 sec without reinforcement. To prevent extinction of the consummatory CRs to the tone CS which was presented eight times in every session of 60 instrumental rewarded responses, an additional refresher session of 10 tone-food trials was run in the afternoon. The testing continued for several days. The results were presented as four examples of single test trials on which the dog (the other dog failed to acquire a consummatory CR) salivated and four examples of test trials when it did not salivate to the tone CS. Correlations were calculated from all data to show if the occurrences of salivary CRs and earlier than expected occurrences of bar presses were correlated. Similarly, as in the earlier reports (Shapiro 1960, 1961, 1962), the salivary CRs and shorter waiting times were positively correlated.

However, the figure presenting the trials on which the tone CS elicited salivation clearly shows that instrumental responses occurred *after* the termination of the tone. Even on these selected trials where

the responses were, as authors pointed out, "falsely alarmed" the response does not seem to be elicited by actual presence of the tone CS (despite its extended duration) or to be elicited by the rise or peak of the salivary response. On the trials in which the tone did not elicit salivary responses, there was also no effect on the waiting time. Interestingly enough, if a neutral stimulus (a tone never paired with food, in two other dogs) was tested in a similar way, there was an increased probability of a bar press response being performed sooner; this effect was less pronounced, however.

This detailed description of Shapiro and Miller's data was necessary for two reasons. First, it is technically an excellent experiment involving direct measures of the occurrence and the intensity (although the authors did not try to exploit it) of the consummatory conditioned reaction. And second, the authors' conclusions are very different from what seems to emerge from their own data. They concluded: "...the ability of a conditioned stimulus to act as a discriminative stimulus for an instrumental response is a function of the stimulus' ability to elicit the consummatory response on that particular trial". (Shapiro and Miller 1965, p. 297).

This conclusion is hardly justified. In the first place, in no dog of this study was a true discriminative stimulus (S^D) pre-trained to control the bar press performance tested in a similar way and its effect compared to the classical food signals. In the second place, the fact that a tone CS had a stronger "disinhibiting" effect on the suppressed instrumental response during the prohibited period of the DRL schedule than the indifferent tone stimulus does not mean that the food CS acts in the same way as an S^D . It might be the same effect as that of the indifferent stimulus, but quantitatively stronger. Or it might be, as will be argued later, a priming effect analogous to that of a small portion of food. Quite probably, dropping a piece of food would disrupt the response inhibition necessary to secure a 2 min waiting period, but would it mean that taste of food replicates the ability of the S^D to elicit the instrumental response? In the third place, the correlation of salivary and instrumental responses was based on the occurrences of these responses and did not take into account the temporal and the dynamic or intensity parameters. The examples presented showed that in each case, the bar press occurred not only after the cessation of the tone, but also after the salivary response was past its peak, and lasted more than the usual CS-US interval, i.e., 5 sec. For the lack of description of the dogs' behavior we would rather guess, extrapolating from countless observations of our dogs, that the bar press did not occur while the animal salivated quietly waiting for a delivery of food, but only when the food did not materialize in the expected moment and the dogs became "moved" or

restless. With our method of salivary recording the instrumental responses were clearly "correlated" with the diminution of the rate of salivation. It seems that the data of Shapiro and Miller do not contradict either Konorski and Miller's pre-war experiments or my more recent observations. The work of Shapiro and Miller also illustrates another important point. It took several weeks to establish a stable consummatory CR in dogs and even with this long and careful training, with fixed and fairly short CS-US interval and continuous reinforcement schedule (each presentation of a 5 sec tone was followed by a food US), one dog (B-65) failed to acquire the consummatory CR. In most other studies where the consummatory CRs were not directly monitored, the experimenters exhibited considerable carelessness in respect to selecting the proper parameters for classical conditioning.

Thus, Estes (1943, 1948) in his experiments on rats assumed to have conditioned a tone CS by pairing it 10 times a day for 6 days with a pellet of food using the CS-US interval of 60 sec. When the tone was consecutively administered during the extinction of bar pressing (acquired either prior to or after the classical conditioning on a "periodic reinforcement" schedule), the rate of pressing was temporarily increased. The author concluded that the "consummatory" CS was facilitating the instrumental response.

Morse and Skinner (1958) used a classical conditioning procedure in which, in pigeons, red and green lights were alternated (6-300 sec duration; mean, 120 sec) and one of them was paired with food on VI-1 min schedule. When tested later during the extinction of the instrumental key pecking (acquired on the VI-1 min reinforcement schedule), the light associated with food increased the rate of pecking.

Bower and Kaufman (1963) obtained similar results in rats using a tone and a clicker as positive and inhibitory CSs. In the phase of classical consummatory conditioning, the stimuli were alternated every 30 sec and one of them was reinforced by two pellets delivered on the 10th and 20th sec. The important difference in the consecutive testing of these stimuli during extinction of bar pressing behavior was that the instrumental response was acquired not in hungry but thirsty rats and 0.08 ml of water delivered on VI-1 min schedule was used as a reward. In 9 out of rats, the rate of pressing the bar was higher during the positive CS.

In the three above studies, the authors obviously did not optimize the conditions for the acquisition of a strong and stable consummatory CR. Although the optimum CS-US interval for food conditioning has not been unequivocally determined (Gormezano 1965), it is certain from a vast experience of Pavlov's school that it is of the order of seconds

or perhaps fraction of a second. Using CSs lasting for dozens of seconds, reinforcing them irregularly or intermittently, cannot produce any stable consummatory CRs. Therefore, of particular interest is the paper of Hyde, Trapold and Gross (1968) in which classical conditioning was carried out with very short CS-US intervals (the authors said the delivery of food was immediate) and long enough (38 daily sessions of 24 trials each) to assure considerable levels and reliability of consummatory CRs (implicit, for they have not been monitored). In addition, two CSs were used in each subject, one reinforced with 1 pellet of food, and the other with 10 pellets; in that way, the effects of two CSs eliciting (assumed) weaker and stronger consummatory CRs, could be compared. A control group had received both stimuli and both magnitudes of food USs in a random order (in Rescorla's sense (Rescorla 1967)). Following the classical training, the rats were given discriminative instrumental bar press training with discrete trials and a homelight as an S^D . The intertrial responses were extinguished by imposing a mandatory delay to the next trial after each such response. When the latencies of the responses to light were stable, the "generalization" sessions were started, in which for every 6 trials with light, one or another classically pretrained CS was presented and the latency of the bar press response recorded. The experiment was designed to test the incentive-motivation theory: positive food CSs were expected to show a better transfer of control over the instrumental response than non-paired stimuli and the CSs signalling 10 pellets were expected to elicit responses with shorter latencies than the 1 pellet signals. The results show a rather mediocre "transfer", with latencies to positive CSs shorter than to the non-paired stimuli but still much longer than to the original light S^D . The latencies (after converting them back from mean logs into seconds) ranged between 1-2 sec for the light S^D but exceeded 15 sec to positive CSs on the first day and only gradually decreased to 2.5 sec on the fourth day of testing. An even more important finding of this study was that there was no difference in the control over the bar press response between the CS paired with 10 pellets and the CS paired with only one pellet. This obviously undermines, as the authors correctly observed, the motivational explanation of the CS's control over the instrumental performance. The authors suggest that the r_G - s_G elicited by the food CSs may influence the instrumental response not by energizing in a drive-like manner, but simply as cues associated with response by virtue of concomitant occurrence. We shall later offer an alternative to this "associative" hypothesis when, after presenting our explanation of incentive-motivation, we will argue that the "cues" or S^D s are in fact also the drive CSs and that the $FCSs^+$ undergoing the extinction become, at a certain stage, also the drive CSs.

In conclusion, the Hyde et al. experiment indicated that the food CSs applied in a discriminative instrumental response situation did rather poorly in comparison with the S^D . The fact that they elicited bar presses with shorter latencies than inhibitory (or zero-correlated) stimuli could hardly be construed as an evidence for their incentive motivational role, and we concur with the authors that another explanation should be looked for.

Several recent papers published in the *Journal of Experimental Analysis of Behavior* found a clear-cut suppression of lever pressings by a consummatory food CS. Azrin and Hake (1969) observed a decrease of rate of bar pressing in rats trained on VI-1 min for a food or water reward during the presentation of a pure 500-Hz tone reinforced by the same food or water US. The amount of noncontingent reinforcer (i.e., the free US following a CS) was much larger than a reward for bar pressing and the authors speculated that the facilitatory effects observed by other authors may be related to the similarity, qualitative and quantitative, of reward and US in their experiments.

Kelly (1973) found suppression of bar pressing (VI-1min) in monkeys by the food CSs, tone and light, trained for several months with 1 and 3 min CS-US interval. With repeated testing the suppression tended to appear at the end of this longlasting CS.

The following two papers brought forth a very important parametric exploration. Namely, FCSs paired with a short CS-US interval were compared with the FCS reinforced after a long CS-US interval for their effects on instrumental bar pressing. The FCSs of short duration suppressed instrumental performance (in rats and monkeys) while the longlasting FCS either facilitated bar pressing (Meltzer and Brahlek 1970) or did not affect it (Miczek and Grossman 1971).

II. Transfer of learning experiments

For another group of experiments, a different design was used in testing the relationship of a classical positive and inhibitory CS to the homogeneous instrumental response. Instead of testing the effect of an established food CS on the already established instrumental performance, the transfer of learning design consisted of applying the food CS as a potential S^D during the acquisition of a new, for the animal, instrumental response. The rate of acquisition of the discriminated instrumental response was compared for three classes of stimuli neutral, classically pretrained positive food CS and classically pretrained inhibitory CS¹.

¹ We excluded from this discussion of three other classes of stimuli: S^D and S^I for different instrumental responses autochthonously motivated (e.g., Trapold and Fairlie 1965), S^D and S^I trained with allochthonous drive, and heterogeneous classical CSs, as irrelevant to our subject.

Similar to the transfer of control design, the experiments in which the consummatory CRs were directly monitored are almost nonexistent. The only study in which salivary secretion to well established food CSs was continuously recorded was published by Konorski and Wyrwicka in 1950. In three dogs, classical conditioned consummatory reflexes were trained for several months and good salivary responses were established to light, bell and metronome CSs. Neither the CS-US intervals nor any other numerical data were specified (the size of salivary reflexes during transfer training, latency of motor responses, etc.), which considerably lowers the interpretative value of the paper. A few points, however, have come clear from this publication. The classical CS never, even after prolonged training, acquired the same capacity to elicit the instrumental movement as an original S^D (a bubbling sound) or other new stimuli introduced after the food CSs were "transformed" into S^D s. The dogs could wait and salivate for 20 sec without performing any instrumental movement. When the dogs were forced to respond to the food CSs by being rewarded only when they lifted the leg, the latencies of the instrumental responses were long, and amplitudes of movements low. The negative transfer that was found in this experiment was interpreted by the authors as a result of antagonism between two different motor reactions: instrumental leg lifting and that of "waiting" for food. Thus, in contrast to Konorski and Miller's early studies (1930, 1933, 1936) where the differences between classically trained food CSs and instrumentally trained S^D s were described in terms of different central processes, in 1950, the difference was assumed to consist of eliciting different motor responses².

In other reports, the consummatory conditioning was not monitored and its reliability is doubtful because the length of training and the CS-US temporal parameters were usually far from optimal.

Bower and Grusec (1964) used rats and in the classical conditioning phase of their experiment alternated tone and clicker every 30 sec reinforcing them irregularly with water. Even the magnitude of the water US was not constant but varied from 0.08 to 3 ml. The training continued for 10 sessions of 30 min each. Either tone or clicker was paired with water while the other stimulus was not. Later, both stimuli were used as S^D and S^I in the instrumental discrimination training. When water positive CS was S^D and water inhibitory CS served as an S^I the acquisition was faster than with the reverse use of both stimuli. The results were interpreted in terms of the positive water CS⁺ being the source of incentive motivation (hope, joy), while the negative water CS⁻ eliciting depression or frustration.

² However, the allowance should be made that in this period, Konorski was under the pressure not to disagree overtly with orthodox Pavlovian interpretation.

Bacon and Bindra (1967) classically conditioned rats using tone as a CS and water as a US for 12 days; they used a VI-2 min schedule. After the conditioning phase was completed, instrumental learning in an alleyway was run with a 15 sec confinement in the start box. Either with or without the water CS, the rats were released and the running times and starting times compared in three subgroups: with the same motivation, with food reward and with shock avoidance. No differences between groups were found and only the negative effects were significant: i.e., if in the classical phase, the tone was used as a random stimulus or if the control group with tone only (habituation) pretraining was subsequently trained to run in an alleyway, the performance was poorer than in other groups.

Bindra (1968) proposed a new interpretation of drive and incentive motivation in which food is said to elicit a "Central Motivational State" (CMS) activated by incentive (e.g., food) in the presence of drive. To explain the above results, the CMS was considered less specific than is usually believed. In his following paper (1969), the separate central representation of drive disappeared and the food US was assumed to activate consummatory response by contact stimuli and elicit a CMS by remote stimuli.

Trapold and Winokur (1967) preconditioned the rats with tone, light and clicker as positive and inhibitory FCSs; the US was food and the duration of stimuli was 3 sec and the entire training was very short (five sessions) considering differential conditioning. The tone was always a positive stimulus (except for the control group with none of the stimuli paired with food) and in the other groups, either light or clicker were paired while the other stimulus was the differential CS.

In the instrumental phase, the tone CS was transformed into an S^D controlling a bar press response, and following the establishment of the discriminated instrumental behavior, light and clicker were introduced as generalization test stimuli every 10th trial. Only light, pretrained as a positive FCS, had a greater tendency to elicit the bar press response. On the other hand, the inhibitory CSs, after having been transformed into S^D s, could be extinguished more easily than the S^D s pretrained as positive FCSs.

Even more damaging to the incentive motivation theory was the next paper of Trapold and his colleagues (Trapold et al. 1968). In the classical conditioning phase, a 3 sec tone and clicker were used as positive and inhibitory FCSs in 8 daily sessions. In a control group, the same stimuli were randomly presented together with random delivery of food pellets, however, they were never paired in closer succession than 7.5

sec, so they were, in fact, negatively correlated with food. In the instrumental learning (to press a bar) both FCS^+ and FCS^- were used as either S^D or S . The results from the 6 days of discrete trial differential instrumental training were the following. Responses to S^D , whether it was pretrained as FCS^+ , FCS^- or from the control group, were the same. On the other hand, the S s were affected by the pretraining, although the effect lasted only during the first 3 days. The rats reached the asymptote on the 2nd day if the S was pretrained as FCS^- . It required 4 days of training to reach asymptote if it was used as a random stimulus in the control group, and 6 days if it was a food CS^+ .

To conclude this review, we have found very little if any evidence for the incentive motivation concept in the Hull-Spence-Seward version. In most studies, the FCSs were obviously not well established consummatory CSs, but rather, as it will be argued later, appetitive drive-inducing CSs. In the studies in which procedures were either enabled to measure the consummatory responses or in which the length of training and the short CS-US intervals could promote the formation of real consummatory CRs, the results were against the incentive motivation concept.

The last experiment we would like to mention belongs to the first group, that is, the pretrained positive and inhibitory food CSs were tested in a situation of already well established instrumental responding (S. Sołtysik, J. Konorski, A. Hołownia and T. Rentoul, in preparation). The experiment was designed in such a way as to avoid the shortcomings of almost all the aforementioned studies. Thus, (a) salivary response were registered and measured to ascertain that the consummatory CRs were indeed established and also to estimate the relative strength of the salivary CR to different CSs. (b) The recording of conditioned salivation enabled us to ascertain that the inhibitory CSs were well differentiated from the positive food CSs. (c) Heart rate recording was also used to compare the degree of arousal elicited by the positive and inhibitory food CSs. (d) Classical pretraining was long (6 months) and systematic, starting with the short CS-US intervals (2 sec) and extending them very gradually to 20 sec. (e) The instrumental response was a multiple bar press to a tactile S^D (experiment I) or a multiple bar press without any discriminative stimulus (free instrumental response in experiment II) so that not only the latency of the first bar press, but also the rate of the instrumental responses could be measured. (f) The duration of the positive and inhibitory CSs during the testing of their effect on the instrumental performance *did not* exceed the duration of the CS-US interval during the classical conditioning (i.e., 20 sec) so that no extinction of the

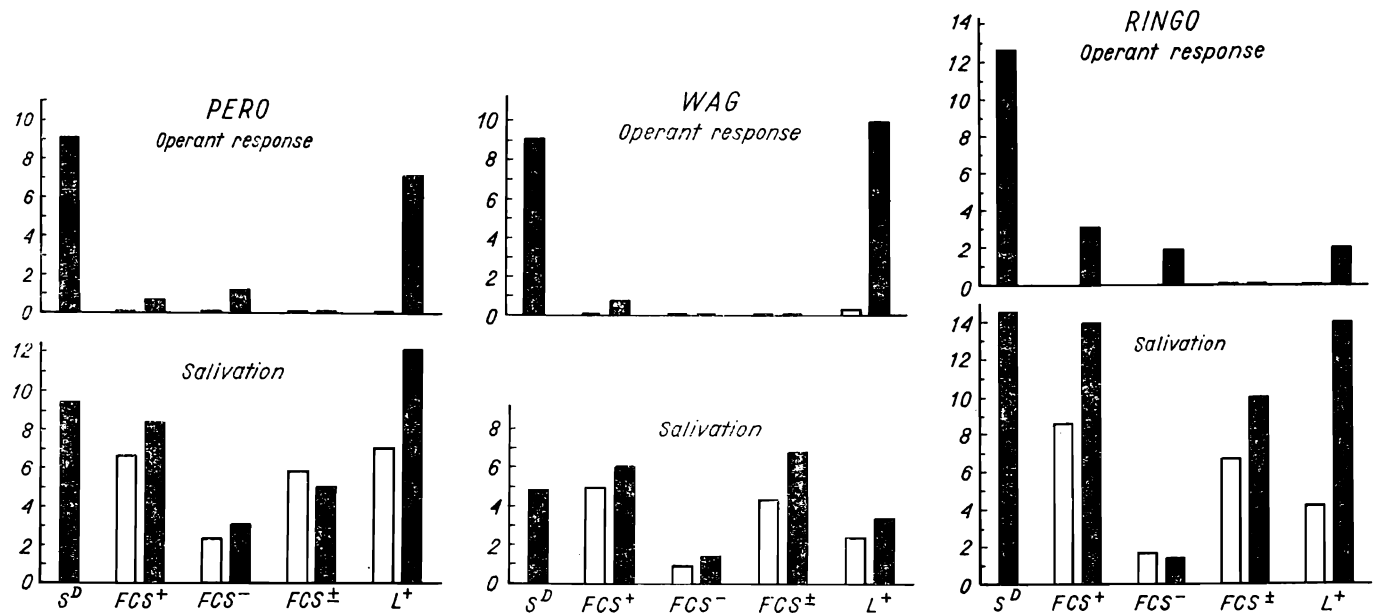


Fig. 1. The rate of bar presses and the rate of salivation is compared to different conditioned stimuli. Abscissae: The number of bar presses and drops of saliva in 10 sec period. Ordinates: S^D , a tactile stimulus eliciting a multiple (10 bar presses) instrumental response. FCS^+ , a positive consummatory food CS; left white bar, instrumental and salivary responses to the FCS^+ presented alone; right black bar, instrumental and salivary responses to the same FCS^+ presented together with the tactile S^D . FCS^- , inhibitory food CS; left white bar, responses to the FCS^- presented alone; right black bar, responses to the simultaneous presentation of FCS^- and S^D . $FCS^\pm$, a food CS alternately reinforced and nonreinforced (FR 0.5). L^+ , a weak CS (40 w electric light bulb) which often was giving inconsistent results as if the dogs did not always notice its presence. Note the intense inhibition of the instrumental performance when FCS^+ were presented together with the S^D and possibly a facilitation of salivary responses to the same combination of stimuli,

consummatory reflexes could occur and confound the interpretation. The results of this study were absolutely incompatible with the incentive-motivation hypothesis of the conditioned consummatory CR being facilitatory in relation to the autochthonously motivated instrumental responses. Positive food CSs profoundly inhibited the instrumental responses while eliciting undiminished salivary CRs. This is an important condition for the assumption of the *unilateral* inhibitory effect: simultaneous presentation of FCS^+ and S^D resulting in a full salivary CR and very profound suppression of instrumental activity (Fig. 1). Actually, salivary responses to the compound of FCS^+ and S^D were larger than to the FCS^+ alone (but not larger than to the S^D + instrumental activity, which consisted of 10 consecutive bar presses). If the salivary CRs were also diminished, then the only safe conclusion would be that the simultaneous presentation of FCS^+ and S^D elicited an orienting response (to a surprise combination of stimuli never compounded together) and this caused a mutual suppression of both consummatory and instrumental responses. But the actual results would warrant rather a conclusion that S^D facilitated the salivary response to the FCS^+ , while the FCS^+ inhibited the instrumental response to the S^D . These results are even more significant if one realizes that in order to get rewarded the dogs needed less than 10 sec of bar pressing to S^D , while the same food US was delivered only after 20 sec waiting to the FCS^+ . So, when both the stimuli were presented simultaneously, the dogs were "choosing", by not responding to the S^D , a longer waiting for food. The inhibitory effect of FCS^+ s upon the instrumental response did not depend on which response, consummatory CR or instrumental CR, started first. The inhibitory FCS^- s clashed with the S^D , and caused the suppression of both instrumental responses and salivary CR.

SEPARATE DRIVE AND CONSUMMATORY CRs AND THE DRIVE REBOUND

After this review of experimental data related to the problem of the relationship between conditioned consummatory food CSs and instrumental behavior rewarded by food, we would like to present the hypothesis of the organization of the part of CNS controlling the food oriented behavior, which could reconcile all the conflicting data.

As stated over 15 years ago (Sol'tysik 1960) two basic subsystems within the "alimentary brain" are distinguished, one for hunger drive and another for consummatory behavior. Both appetitive, hunger driven, food seeking behavior and consummatory, elicited by the palatable tastes,

activity were assumed to be classically conditionable. It was pointed out, however, (Soltysik and Konorski 1966, Konorski 1967) that the parameters of optimal conditioning of drive and consummatory behaviors were not the same. Conditioning of drives was believed faster and less dependent on a short CS-US interval. Precisely timed and coordinated consummatory acts, with their brisk onset and high degree of "reflexness" or "stimulus boundness", require short CS-US intervals ranging from a fraction of a second to a few seconds. The slowly developing and long-lasting drive "reflex" can tolerate long CS-US intervals of dozens of seconds and minutes. We are tempted to speculate, that it is not necessarily a dichotomy between consummatory and drive responses, but between organismic reactions possessing a different "time base". The reactions with a very long time base, such as Garcia's bait shyness, were found to be conditionable even with CS-US intervals of several hours (Revuski and Garcia 1970).

Therefore, using variable CS-US intervals should be much more detrimental for the consummatory conditioning than for the appetitive conditioning. Also, since faster extinction characterizes the consummatory CRs, the partial reinforcement³ schedules should more severely handicap the consummatory than drive CRs. This distinction between fast, stimulus-bound consummatory reflexes, on the one hand, and sluggish, long-lasting hunger drive activity, on the other, is essential for explaining why in some studies, assumed to involve consummatory conditioning, a facilitatory effect of classical CSs upon the instrumental activity was observed. The Reader should be reminded, that in all, without an exception, studies discussed in this paper, no "true" classical food conditioning was used. The CSs were always followed not by the taste US, but by the food object *made available* — so that the CSs were paired with, however short, appetitive behavior and only after approaching and seizing the food, the taste US and consummatory response was initiated. As found in one of our studies (Kieryłowicz et al. 1968), pairing the CS with a US, delivered directly to the mouth (eliminating thus the appetitive food approach behavior) resulted in a superior conditioning of consummatory responses. In "normal" food conditioning experiments, the CS is paired with both appetitive behavior (i.e., with a drive-instigated activity) and with consummatory response.

In the Soltysik-Konorski model, the hunger drive was the motivational, eliciting force of instrumental behavior and of the consummatory

³ In classical (respondent) conditioning, the schedules of reinforcement refer to the contingencies between occurrences of CS and US and not to the contingencies between the responses and rewards.

act of eating. The consummatory reflexes, at least those elicited by palatable taste stimuli, were assumed to exert some inhibitory effect upon the hunger drive. The need for this hypothetical inhibitory control of drive by a taste US was derived from the following considerations.

(a) First, the eating animal must discontinue the activities belonging to the category of "appetitive" behavior, e.g., searching for food, performing the instrumental learned responses, etc.

(b) A temporary and at least partial inhibition of drive has to occur if we accept the drive reduction theory of reward; the ingestion of food does not instantly reduce the hunger state of the organism, and the immediate, though transient, inhibition of drive by a taste US explains satisfactorily the rewarding property of food. If this inhibition could exert some cumulative effect, it might help the hungry animal to learn when to stop the eating which, as a matter of fact, should occur long before the state of hunger is replaced by the state of satiation.

(c) This inhibitory effect of consummatory stimuli on the drive is conditionable to positive consummatory food CSs. However, neither unconditioned or conditioned drive-inhibitory effect cannot be complete because it would stop the consummatory act which depends on drive. Therefore, it is possible to phase the instrumental and consummatory

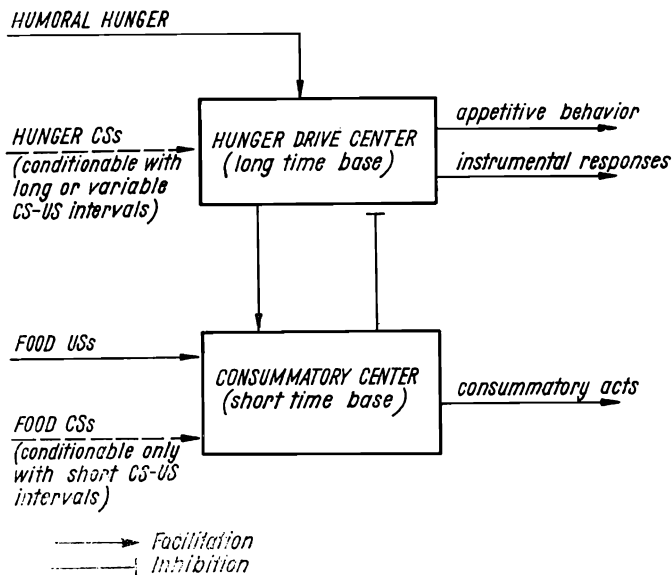


Fig. 2. Hypothetical network of the central alimentary system with its two subdivisions: taste-consummatory and hunger drive-appetitive. Note that consummatory "center" is facilitated by hunger "center" but the reverse connection is inhibitory.

behavior in such a way that they coexist and animals seem to simultaneously perform both instrumental repetitive movements and consummatory reactions.

From the model, in which the mutual influences between drive and consummatory behaviors (or "neural centers", Fig. 2) are asymmetric, drive $\rightarrow$ consummatory being facilitatory, and consummatory $\nrightarrow$ drive being inhibitory, the following important predictions can be made:

1. The strong consummatory positive food CSs should inhibit the instrumental responses trained with the same reinforcing US.

2. The hunger conditioned CS should facilitate the conditioned consummatory CRs. Also, the discriminative stimuli of instrumental response S^D s, being associated with both the instrumental response and the hunger center (Soltysik 1960), should facilitate the consummatory CRs.

3. The cessation of either the consummatory US (palatable taste stimulus) or FCS^+ should result, due to removal of the inhibitory effect, in a rebound of the drive excitation and of the appetitive and instrumental behavior controlled by this drive.

This last prediction is most crucial for our further consideration, so it should be explained in more detail. The drive activity, or the activity of the drive center(s) is initiated and maintained by the shifts in the organism's chemistry due to depletion of certain materials, both in the gastrointestinal tract and in the tissues and body fluids⁴. This state of need is not changed immediately by the taste US and even less so by the food CSs. But the activity of the hunger drive is temporarily inhibited by those consummatory stimuli. Therefore, the termination of the US, or CS or even, as shown by Konorski and Miller (1930) long ago, by the acute continuous extinction of the FCS^+ (i.e., when the duration of the CS is extended until the salivation discontinues) results in releasing the hunger center from the inhibitory bombardment and the rebound phenomenon occurs. An excellent point was made by Sheffield when, referring to his "drive-induction" hypothesis (Sheffield et al. 1954), he described the behavior of the animal at the moment of not receiving the expected food US as: "a special sort of excitement induced, not by the animal's deprivation state, but rather by the stimulation of a consummatory response under circumstances in which the (unconditioned) consummatory response cannot occur". (Sheffield 1965, p. 318). This is certainly a departure from the straightforward Hull-Spence-Sew-

⁴ No attempt was made to incorporate in this article the abundant data on the peripheral, central and humoral mechanisms of hunger. For the purpose of this paper it is sufficient to assume that some part of the CNS responds to the signals of body hunger with activation and that some "drive" neurons project their activation to the "motor behavioral system".

ard notion that it is the r_G , the conditioned consummatory response (or its sensory feedback s_G) which facilitates the instrumental response. Sheffield's point is reminiscent of Konorski and Miller's view that it is the unfulfilled consummatory act or partly extinguished alimentary CR (as they called it) that makes the animal restless and prompts the execution of the instrumental response. Sheffield also states that this "unconsummated consummatory arousal" (Sheffield 1965, p. 319) "feeds primarily into skeletal behavior rather than energizing all response mechanisms indiscriminately" (ibid., p. 319). We think that this excitement is even more specific and that not all motor acts are equally facilitated; for instance, there is no facilitation upon the startle reflex by food CSs (Trapold 1962, Armus and Snaidowski-Dolinsky 1966). Our model prompts us to make two additional corrections to Sheffield's view. First, in keeping with our model and data, we would rather call this arousal "post-consummatory". Second, while agreeing with the notion of some specificity of the post-consummatory excitement in respect of where it is "fed into" (see Konorski's concept of drive UR with its "arousal of motor behavioral system" (Konorski 1967, p. 23)), we would like to stress a highly specific "input component" inherent for our model. Assuming that the hypothetical hunger neurons are of variegated nature (for specific deficits) and that the known variety of gustatory stimuli, or rather their perceptual units (Konorski 1967) within the taste analyser are specifically connected with the corresponding classes of drive neurons, the following hypothetical situation is deduced. Each consummatory food CS eliciting a specific gustatory expectation also elicits a specific pattern of inhibitory effects in the drive center. Therefore, the post-consummatory rebound is not general or random within the hunger center, but retains a specificity; it might be called a specific appetite.

The above considerations bring us to the reformulation of the concept of the incentive motivation. In our model, incentive motivation is a drive process, endowed with considerable specificity related to the sensory quality of the rewarding US, and this drive process is induced in several ways:

1. As a rebound exaltation of drive due to diminishing consummatory excitation. This post-consummatory arousal within the drive system may be called an unconditioned primary appetite when it appears after eating (after food US), or unconditioned secondary appetite when it arises at the termination of the conditioned consummatory reaction (either when the food CS^+ is terminated or the food CR discontinues due to extinction process).

2. As a conditioned appetite elicited by "hunger" CSs which have

been paired with the appetitive behavior or with the post-consummatory arousal. To this class of CSs belong, in the first place, discriminative stimuli *S*_Ps which precede instrumental response, and also classical consummatory CSs undergoing the process of extinction, because they are paired with the incidents of drive-rebounds after "unconsummated conditioned consummatory responses". Most importantly, however, here would belong the CSs paired with the food US using long and variable CS-US intervals, or partial reinforcement schedules, so as to minimize the consummatory conditioning and leave the pairing of CS with appetitive behavior as the main learning event.

3. Some authors (Konorski 1967, Bindra 1969) assume that there are unconditioned stimuli directly addressed to the hunger (Konorski) or appetitive (Bindra) centers which at the same time carry enough specific information about the consummatory stimulus to be considered a sort of unconditioned incentive stimulus. For example, a smell or sight of food would belong to this category. And any indifferent stimuli paired with these incentive USs should become:

4. Conditioned incentive stimuli. We would not be so certain that olfactory and visual stimuli are really unconditioned and do not derive their appetite-inducing ability from inevitable lifelong conditioning. Which, in fact, may give them a status of practically unconditioned stimuli. And by conditioning, I do not mean consummatory short CS-US interval type conditioning, but the natural irregular type of pairing in which a sight and smell of food, not always immediately available, often requiring both time and (instrumental) effort before the act of consumption could be initiated, become strong signals not so much of the palatable taste US, but of the presence of a palatable food object in the not too remote distance.

Thus, the dilemma of the incentive motivational process being specifically tied to a reward and at the same time possessing drive properties is resolved by our hypothetical neural mechanism in which the drive (hunger) and consummatory (taste) subsystems are interconnected to form a regulatory feedback loop with the drive facilitating the consummatory and consummatory inhibiting the drive subsystems. This concept handles the existing behavioral data better than the previous theories. It explains both successes and failures to finding the facilitatory effects of CS stimuli paired with food, by pointing to the fact that such pairings may result in mixed conditioned responses with varying proportions of consummatory and drive conditioned components, depending on the temporal and quantitative parameters of the conditioning procedure.

In the past decade, an accumulation of numerous data on the firing patterns related to food oriented behavior was started. It is our hope that the new concept of the appetitive-consummatory relationship and the mechanism of incentive motivation will help to organize the existing data and lead to new experiments specifically designed to verify the proposed model.

SUMMARY

The concept of incentive motivation traditionally ascribes a drive property to the consummatory conditioned stimuli. The purpose of this paper is to advance a hypothesis that it is not the reward heralding, consummatory CSs but their aftereffects that correlate with increased instrumental activity. A review of literature is presented to show that no convincing evidence is available to support the traditional concept of incentive motivation. Whenever a carefully conditioned consummatory stimulus was tested against the background of instrumental, autochthonously motivated (i.e., by the same drive) activity, either no effect or inhibition was observed. On the other hand, CSs paired with food with long CS-US intervals, or with variable interval or partial reinforcement schedule, have been shown to facilitate instrumental behavior.

To explain these facts, a neurophysiological speculative hypothesis is proposed in which a consummatory "center" inhibits the drive "center" and the termination of consummatory reflexes, conditioned or unconditioned, is assumed to bring about a rebound-like arousal of the drive center. Both consummatory reflexes and drive state are classically conditionable, but their different "time bases" call for different CS-US intervals. Consummatory reflexes depend on short CS-US interval and high reliability of reinforcement. Drive state can be conditioned with long and variable CS-US interval and under partial reinforcement schedules. Therefore, the CSs acquire different properties when conditioned with short and long CS-US intervals.

Particular attention is paid to contributions of Konorski, who first observed in 1930, both: (a) inhibition of instrumental behavior by conditioned and unconditioned consummatory stimuli, and (b) post-consummatory facilitation of instrumental responses.

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