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9 Dual Nature of Anticipatory Classically Conditioned Reactions

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ABSTRACT

In this chapter I argue that classically conditioned behaviors occurring between the onset of the conditioned stimulus (CS) and the onset of the unconditioned stimulus (US) may be divided into two categories of responses, on the basis of their temporal proximity and their degree of dependence on one or another of these stimuli. Responses of the first category appear as backward-directed (BD): They are primarily elicited by the CS, which is endowed with additional properties as a result of its pairing with the US. BD responses tend to emerge early in the conditioning process and are not highly sensitive to the accurate timing of events. Conceivably, their occurrence is linked to the transfer to the CS, either of the significant value (inducing an enhancement of the orienting reaction to the CS), or of the hedonic or affective value, of the US.

Responses of the second category appear as anticipatory and forward-directed (FD) in nature. FD responses occur late in the conditioning process, and their occurrence is subordinate to specified values of the CS-US intervals. They require cognitive-analytic activities and seem closely linked to the expectancy of the impending US.

An integrative and functional analysis of both types of responses is proposed in which it is suggested that only FD responses subserve a preparatory function for the receipt of the US by the organism.

1. INTRODUCTION

It is customary to illustrate the phenomenon of classical conditioning by referring to the prototypical Pavlovian reflex, namely dog's salivation. From this perspec-

tive, the nature and function of the conditioned reaction (CR) appear straightforward: The CRs are anticipatory unconditioned reactions (UR), and their function is to provide a preparation to receive the unconditioned stimulus (US). Thus conditioned salivation is essentially an anticipatory unconditioned salivation, which allows either the food to be more palatable or the acid more dilute.

Today, however, the validity of any inference about conditioning drawn exclusively from the Pavlovian model appears severely limited. Theorizing in classical conditioning has been marked during the last two decades by some drastic changes in orientation.

The principal change has been the shift from the stimulus-response framework to a conceptualization which is more cognitive in nature. Conditioned behavior in animals is now conceived as the best available indicator of a hypothetical internal variable, which may be defined as a representation or knowledge that an organism has built up about the relationships between events in its environment. In this framework, *any* behavior that may be attributed to the contiguity or contingency of two stimuli may be used as an indicator of the animal's knowledge about this relationship. The fact that the dog either salivates or wags its tail in response to the CS shows equally that it knows the relation between the CS and the food. The traditional criteria required by S-R theory for conditioned responding, limiting, for example, the choice of CR to responses previously elicited by the US, or to responses exhibiting some improvement with the succession of trials, are no longer considered justified (but see Gormezano & Kehoe, 1975).

At the same time, and partially in reaction to ethologically informed criticisms that emphasized the artificiality of classical conditioning situations, several laboratories have devised experimental procedures that more closely approximate natural situations. These new procedures allow for the observation of more diversified responses. For example, the elimination of the harnesses and headholders in which Pavlov confined his laboratory animals has led to the description of locomotor and manipulative behaviors that were previously unobservable.

Thus, as a result of developments stemming from both the cognitive approach, which justifies theorically the use of any behavioral change as an indicator of conditioned responding, and the ethological approach, affording a diversification of potential behavioral changes, the concept of classical conditioning has been considerably broadened beyond the traditional Pavlovian view. This chapter is aimed at suggesting that the thus-enlarged set of behaviors now subsumed under the label of classical conditioning could be divided into two broad classes of responses, calling for different underlying processes. This proposal is introduced in section 2 through a few examples in which the dual nature of conditioned responding may be readily observed. Section 3 assess the empirical generality, and section 4, 5, and 6, the theoretical relevance, of the distinction just drawn. Section 7 is devoted to a consideration of the implications of the overall analysis with regard to the preparatory function of CRs.

2. TWO CLASSES OF CONDITIONED RESPONSES

Let us consider a first example, taken from the field of autonomic aversive conditioning in humans. When the interval between the CS and the US is long enough (8 to 10 sec) in electrodermal conditioning, it is often possible to observe two successive responses.[1] The first appears immediately after the CS onset, roughly within the latency range of the usual unconditioned electrodermal responses, whereas the second slightly anticipates the US occurrence. With a CS-US interval of 8 sec, for example, the two response components are typically scored, respectively, from 1 to 4 sec, and from 4 to 9 sec after CS onset (review in Prokasy & Kumpfer, 1973). Lockhart (1966) has designated these response components the CS response and the pre-US response, and his terminology is adopted here. A similar division may be observed in other autonomic responses. In heart rate conditioning, for example, conditioned modification can be segregated into components related to the CS onset (a fast deceleration followed by a relative acceleration) and anticipation of the US (deceleration) (Review in Bohlin & Kjellberg, 1979).

A second example may be drawn from situations of autoshaping[2] and more particularly from experiments dealing with the appetitive conditioning of motor reactions in animals. If one exposes a pigeon to a procedure in which the brief illumination of a pecking key reliably precedes the delivery of food, the pigeon will start pecking at the lighted key. Then, at the end of the CS-US interval, although admittedly with less frequency, the pigeon will begin pecking at the food magazine. The terms sign tracking and goal tracking have been employed to designate these components of behavior (e.g., Boakes, 1977). The dual orientation observed in pigeons appears to be a general feature of responses observed under conditions of appetitive reinforcement. Holland, for example, in a series of recent studies on appetitive conditioning in rats (e.g., Holland, 1977, 1980) distinguishes the components of approach to and contact with the CS, which occur mainly during the first half of the CS-US interval, from another set of behaviors generated by, and appropriate to, the US, which occur mainly during the last half of the CS-US interval. This kind of distinction is not really a new one. According to Boakes (1979) and Davey, Cleland, and Oakley (1982), Konorsky's (1967) distinction between "preparatory" and "consumatory" CRs

[1] A third conditioned component is often recorded, which appears after the temporal location of the US onset when the US is not presented. This component is beyond the scope of the present discussion which is devoted to anticipatory responding, that is to responses occurring between CS onset and US onset.

[2] The term autoshaping (Brown & Jenkins, 1968) tends to cover all the classical conditioning procedures in which the dependent variable is a locomotor or manipulative behavior. The term is misleading in that it tends to evoke the instrumental origin to the observed phenomena, which is today almost universally rejected.

corresponds closely to the contemporary distinction between the sign tracking and goal tracking components of conditioned behavior.

The areas of research from which the two types of examples cited are extracted have apparently been the object of independent series of studies, at least judging from the lack of reciprocal references in the literature. In this context, it is of interest to note the striking similarity of the distinction made in both cases between the two classes of conditioned behavior. The first class of responses appears as responses to a CS having acquired some new properties by pairing with a US. It may be shown that these responses are tied more to the specific characteristics of the CS (nature, intensity, localizability) than to the features of the US, which has an influence only through its general properties. Accordingly, these responses may be termed "backward-directed" responses. The second class of CRs slightly anticipates the US onset. Being closely tied to the characteristics of the impending US (nature, intensity, probability), they may be termed "forward-directed" responses.

3. THE EMPIRICAL GENERALITY OF THE DISTINCTION BETWEEN BACKWARD-DIRECTED (BD) AND FORWARD-DIRECTED (FD) CONDITIONED RESPONSES

At first glance, the distinction between BD and FD behaviors may appear highly specific to the just described examples. The report of two successive responses is rare in most other conditioning paradigms. Nevertheless, two possibilities must be examined.

First, a double response could occur without being reported. In eyeblink conditioning, for example, an initial reaction, the so-called alpha response, reliably appears before the response traditionally considered the CR, with the latency of the unconditioned reaction occasionally elicited by the CS before conditioning. Although dated and inadequate with respect to contemporary methodological standards, the only available evidence favors the associative status of the alpha response (e.g., Grant & Adams, 1944). In the same way, in salivary conditioning, the occurrence of an initial response, and the similarity of this response to the CS response in electrodermal conditioning, have been noted for quite some time (Iwama & Abe, 1952). However, these responses have been commonly overlooked. This practice may be dependent on several factors: methodological difficulties (e.g., in salivary conditioning, the dissociation of successive responses needs the recording of the electrical activity of the parotid gland), adoption of criteria deriving from S-R theory (e.g., improvement of responses over trials), and so forth. Whatever the reasons may be, an overall examination of effective behaviors would show perhaps that the double response phenomenon is more frequent than the current literature suggests.

Second, it is possible that when a single response is recorded, it may be considered either as BD or as FD or as a combination of these two components.

Let us examine again the paradigms described in the first section. Although the successive components are observed in most related studies, some slight parametric variations can affect the balance of BD and FD behaviors, eventually eliminating one or the other. In electrodermal conditioning, the pre-US response is less likely to be observed with a trace than a delay paradigm (Prokasy & Kumpfer, 1973) or with a noise than with an electric shock US (Dengerinck & Taylor, 1971). When the CS-US interval is too short (4 sec or less) to allow the multiple response phenomenon, the single response which appears is usually interpreted as a combination of CS response and pre-US response. In autoshaping, a very localized visual CS triggers approach, pecking, or licking (i.e., sign tracking component) to a greater extent than does a diffuse auditory stimulus (review in Wasserman, 1981). The duration of the CS-US interval is also an important parameter: The use of a short interstimulus interval tends to decrease the probability of behaviors oriented towards the food magazine (i.e., goal-tracking component; Holland, 1980). With respect to these examples, it is worth noting that the distinction between BD and FD behaviors remains pertinent when a single response is observed, or at least when one component of behavior predominates.

This analysis suggests that in other paradigms, in which a single response is traditionally recorded, it may be relevant to consider the BD or FD character of the observed behavior. It appears, in fact, that many standard CRs may be easily classified according to their orientation. Conditioned taste aversion paradigms, for example, generate BD responses: The behavior taken into account is always oriented towards the CS, which has acquired some new value through its pairing with sickness. Conceivably, the diffuse character of the US (lithium chloride, X rays, etc.) precludes the observation of FD responses. On the other hand, eyeblink and salivary CRs usually reported are unambiguously FD in nature: They are oriented toward, and adapted to, the US. At the end of training, the CR peak latency (i.e., the temporal location of the maximum amplitude of the CR) coincides exactly with the moment of delivery of the US. If the CS-US interval is changed during the course of the experimental session, the CR already established decreases progressively, whereas another CR appears at the new temporal location of the US (review in Kimmel & Burns, 1975).

In some situations, the direction of the CR may not be easily determined. However, the potential generality, which has been occasionally noted (e.g., Buzsaki, 1982; Dykman, 1967), of the empirical distinction between BD and FD behaviors appears sufficient to justify an assessment of its theoretical relevance. The next two sections endeavor to show how this distinction may elucidate many theoretical issues in conditioing.

Prior to this examination, however, it is of interest to note that the BD-FD distinction may have potential validity in other S1-S2 paradigms. The segrega-

tion of behaviors into components related to S1 onset and to the anticipation of S2 could make sense, whatever the S2 may be. In this respect, it should be noted that EEG analyses performed during the preparatory period of an RT task exhibit a dual response component, which has some striking analogies to the distinction advanced here[3] (e.g., Loveless, 1979). Increased exchanges between researchers concerned with the different situations involving an anticipatory interval appear desirable in order to improve the understanding of these analogies.

4. INSTRUMENTAL ACCOUNTS OF CLASSICAL CONDITIONING

At least two very different instrumental interpretations of classical conditioning have been proposed (Mackintosh, 1974). It should be noted that each interpretation is principally concerned with one or the other category of CRs.

The first account considers that, with an appetitive US, the responses elicited by the CS could be adventitiously reinforced, since they are always followed by positive consequences. Brown and Jenkins (1968), for example, proposed this adventitious (or superstitious) reinforcement interpretation of the key pecking phenomenon in the autoshaping situation. BD conditioned responses are mainly concerned with this type of process: They vanish before the US occurrence (at least with a long CS-US interval), and they cannot, as a consequence, exert any direct reinforcing effect.

Conversely, the second instrumental account addresses mainly the FD responses. The positive consequences for the organism of this type of response are frequently noted. Whereas some investigators have attributed a descriptive or "derivative" status to this phenomenon, others have accorded it an explanatory status. In this latter perspective, which is based on the application of the well-known "law of effect," the CRs are simply imputable to their beneficial effects. The differences between the two traditional conditioning paradigms would, from this viewpoint, merely involve the nature of reinforcement. It would be external in the instrumental paradigm, where the responses are followed by a positive modification of the environment, and purely internal in the classical paradigm, where the responses would constitute a modification of the organism favorable to its adaptation to an unchanged environment. Under the name of "law of effect interpretation," "preparatory response theory," or "response shaping theory," this account has been cogently defended by several authors (e.g., Cantor, 1981; Hebb, 1956; Kimmel & Burns, 1975; Perkins, 1968). Pavlov himself, according to Kimmel (1976), would not have rejected it completely.

Today, however, evidence is accumulating against the explanatory power of any instrumental interpretation of classical conditioning, as illustrated by several

[3]I am grateful to M. I. Posner for this remark.

recent discussions (Coleman & Gormezano, 1979; Locurto, 1981; Mackintosh, 1974; Miller, Greco, & Vigorito, 1983). Only brief indications are given here concerning eyeblink CRs, the instrumental nature of which is often affirmed.

Conceivably, conditioned blinking (or the closure of the nictitating membrane) attenuates the noxiousness of the airpuff commonly used as a US. In humans, the subjective aversiveness of the airpuff is effectively reduced by the CRs (Furedy & Murray, 1976). If the beneficial effect contributes directly to the development of the response, at least two predictions may be made according to the law of effect. First, attenuating and suppressing the effects must result in the attenuation or suppression of the responses. This prediction is not supported by experimental findings. The CRs develop in the same way when the airpuff is replaced by an intense noise (e.g., Yamasaki & Miyata, 1981), a peri-orbital electric shock (Murray & Carruthers, 1974), or a mechanical shock to the glabella (Hoffman, personal communication), which are stimuli whose aversiveness cannot be attenuated by the conditioned eyeblink. Similarly, artificially increasing the intensity of an airpuff US at each occurrence of a CR does not lead to an attenuation of performance (Clark & Prokasy, 1976). Second, according to the law of effect, increasing the beneficial consequences of CRs should promote conditioning. This prediction is once again contradicted by experimental results. In the early experiments, CRs obtained from classical conditioning were compared to CRs obtained from an instrumental avoidance procedure in which the occurrence of the CR produced omission of the airpuff. Contrary to the prediction of the law of effect, the classical procedure, which only furnishes a reduction of the puff's aversiveness, led to the best performances. But this finding is ambiguous, since the partial CR-contingent omission of US weakens the CS-US contingencies, which tends to penalize the avoidance procedure. More recent experiments have either modified the avoidance procedure so that the US is not suppressed but simply reduced in intensity at the CR occurrence, or modified the classical procedure by suppressing some USs as in the instrumental procedure; each CR contingent omission of the US provoked by a subject of the instrumental group is then reproduced in a matched subject of the classical group independently of his or her behavior. Generally, under these conditions, the performances observed in the classical and avoidance procedures do not differ significantly (review in Coleman & Gormezano, 1979). All these results are inconsistent with an instrumental interpretation of eyeblink CRs.

It may not be excluded that some classical CRs can be modulated to a certain extent by instrumental actions, the reinforcement being either adventitious, essentially for BD responses, or effective, essentially for FD responses (see, for example, Locurto, 1981, note 2, about the salivary response, or Holland, 1980, about behaviors of goal tracking in autoshaping). But, by and large, classical conditioning appears to be a genuine phenomenon, which both requires and warrants its own theoretical interpretation.

5. THEORETICAL INTERPRETATIONS OF BD AND FD RESPONSES

It is argued in this section that theoretical accounts of classical conditioning, generally considered as mutually exclusive, could be relevant either to one or the other of the two components of conditioned responding distinguished here, namely BD and FD responses. Some theoretical accounts focus on the value acquired by the CS through CS-US pairing, and thus concern BD responding, while other theoretical analyses focus on the expectancy of, and preparation for, the US, and thus deal with FD responding.

BD Responses

(a) The Substitution-Transfer Account. The oldest and perhaps best known interpretation of classical conditioning postulates that the CS serves as a substitute for the US, thereby making the CR a transferred UR. This "substitution-transfer account" (Rescorla & Holland, 1982) has an attractive simplicity: Mechanistic in form, it appears at first glance easily translatable into physiological terms. The interpretation is founded on numerous examples in which the CR is identical to the UR. Among these examples are the approach or withdrawal behaviors that most animals manifest when faced with a CS positively correlated with appetitive and aversive stimuli, respectively. The autoshaped key pecking of pigeons is another available illustration. Regarding this phenomenon, Jenkins and Moore (1973) report the often cited observations showing that the resemblance between the CR and the UR can be very close. Thus, the conditioned pecking reproduces the differences in the unconditioned pecking elicited by the variations of the US: Like the corresponding UR, the conditioned key-contacts are forceful and brief when the US is grain, and weak and sustained when the US is water.

However, in many other situations, the nature of the conditioned BD behavior makes a substitution-transfer interpretation implausible. This is the case, for example, of approach and withdrawal behaviors evoked by *negative* contingencies. Animals move away from a signal negatively correlated with an appetitive US (Wasserman, Franklin, & Hearst, 1974), and approach a signal negatively correlated with a noxious US (Leclerc and Reberg, 1980). It is not possible, in these situations, to identify an unconditioned behavior which would be evoked by the nonoccurrence of the reinforcer, and which the CR could mimic. In other examples, the UR presents an identifiable pattern that the CR does not reproduce. Thus, young chicks exposed to a heat source in a refrigerated chamber adopt postures such as head raising, body lowering, and wing extension. If a lighted key signals reliably the appearance of heat, it does not evoke any of these behaviors, and elicits instead key-directed pecking (e.g., Wasserman, 1973). Conversely, the conditioned behavior may not be alimentary in nature despite the

US: Rats engage in social contact with another rat that is used as a signal for food, whereas they gnaw at a block of wood which serves the same function (Timberlake & Grant, 1975). Furthermore, all studies bearing on conditioned taste aversion poorly support a reflex transfer interpretation. Undoubtedly, it is possible to observe in these paradigms some responses to CS, retching, for example, which look like symptoms normally elicited by the US. More generally, however, the CS evokes reactions of disgust and withdrawal on the part of the animal, which are not an integral part of the UR. The nature of this reaction can depend on the intrinsic properties of the CS. Gustavson, Kelly, Sweeney, and Garcia (1976), for example, report the behavior of wolves having undergone lithium treatment after the consumption of a meal of mutton. Placed subsequently in the presence of a live sheep, these wolves tend to respond like submissive pups, exhibiting a pattern of behavior similar to the pattern normally elicited by a dominant member of their own species.

All these facts suggest that the US does not simply substitute for the CS: The CR may not be conceived as merely a replica or subset of the UR. It remains possible that the CS acquires some general value as a consequence of its pairing with the US, the observed response depending on the nature of the CS and on the other characteristics of the situation. This additional value may be conceived either as cognitive or as affective in nature, thus determining two principal interpretations which are now briefly examined.

(b) The Enhancement of Orienting Reactions (OR). In the field of human autonomic conditioning, the interpretation of CS responses in terms of OR has given rise to an abundant literature (e.g., Maltzman, 1979; Ohman, 1983). In a general way, according to this interpretation, the CS response constitutes an OR ascribable to the subject's discovery of the signal value of the CS. Supporting this view, there is a large amount of evidence that during the course of an experimental session, the CS response coincides with the awareness of the CS-US relationships. On the other hand, it is recognized by most authors that the repetition of a physically unchanging stimulus can engender a new OR if the significance of the stimulus changes for the subject.

This interpretation is able to account for a number of experimental findings, notably the particular evolution of the CS responses with the repetition of paired trials. In the course of electrodermal conditioning experiments, the CS responses reach a maximum very quickly, then diminish in amplitude. Such an evolution confers an inverted U form and often even a decreasing monotonic trend to the learning curve. This type of evolution may be explained by considering that the simplicity of the usual procedures makes almost immediate the discovery of the CS-US relationships in adult humans. The OR, therefore, occurs early in the session, then habituates (as all ORs do).

Independently of the previously mentioned works, apparently, Holland (1977) has also proposed an interpretation in terms of OR, of certain BD motor

CRs which appear in animals during appetitive conditioning. Several subsequent studies tend to corroborate this position (Holland, 1979, 1980). Here, the interpretation is principally suggested by the resemblance between the form of BD CR and that of the OR evoked by the CS before pairing. Differences in unconditioned behavior elicited by various CSs are enhanced by the pairing of these CSs with an US. Buzsaki (1982) has presented convincing arguments in favor of this general position, based on a comparative analysis of the OR-related and autoshaping-related literature.

Despite their terminological identity, it is not certain that the interpretations proposed for the autonomic responses in humans and for the motor behaviors in animals involve exactly the same processes. However, the reference to the concept of OR seems to imply a common functional interpretation of these behaviors. It has been traditional since Sokolov, (1963) to tie the OR to the enhancement of information processing in the central nervous system. This enhancement may be conceived as the result of a switching of attention, which allows controlled processing of the stimuli (Kahneman, 1973). OR-related conditioned behavior could reflect the increased attention of the subject to the conditioning situation.

(c) The Transfer of Hedonic Value. To elicit an enhancement of the OR, the only imperative condition concerning the US is that it be, in some sense, significant for the subject. In fact, for humans, a US that does not have any reinforcing properties (positive or aversive) may suffice to evoke BD CR if a meaning is arbitrarily conferred to it (e.g., the US as an imperative signal in an RT task: Pendery & Maltzman, 1977). It appears, however, that the simple fact that the US is a stimulus endowed with significance for the subject is not sufficient to account for all the BD CRs. To consider only one example, an animal's disgust for, and withdrawal from, food whose flavor has been previously associated with gastro-intestinal troubles in the taste aversion conditioning paradigm cannot be interpreted as an enhancement of the attention directed to this stimulus: The aversive properties of the US contribute to determine the form and direction of the response. This imprint of the specific properties of the US has been formulated as the product of the transfer to the CS of the hedonic or affective value of the US. Most experimental examples mentioned above as not reducible to the substitution-transfer account are consistent with this interpretation. Additional support is provided by studies reporting that the CS can become the reinforcer of an operant response. Thus Hyde (1976), after exposing rats to tone-food associations, observed that these animals learn to perform a lever-press response designed to produce the tone: the stimulus has acquired attractive properties through its pairing with food. When the tone was *negatively* paired with food, the rate of lever-pressing was markedly lower than that of a control group; in this latter case, the tone must have acquired the aversive properties of food deprivation.

The relevance of the process of hedonic transfer with respect to human conditioning may be questioned. It would seem that in our species, BD behavior is essentially accounted for by an OR focused interpretation. But this may not be the case. The restrictions in the choice of independent variables (e.g., lower motivational value of the US) and dependent variables (e.g., lack of manipulative and locomotor indicators) in human experimentation must be considered. A brief look outside the laboratory suggests that hedonic transfer can affect humans. A limited amount of experimental evidence may be adduced in support of this view.

On the one hand, some experimenters use either an extremely anxiety-arousing US (Campbell, Sanderson, & Laverty, 1964) or a CS and a US whose association is "prepared;" that is an association which, through genetic prewiring or early influence, is learned in a particularly rapid and stable fashion; for example, in a series of studies, Ohman and his co-workers (e.g., Ohman, Eriksson, & Olofsson, 1975) have associated images of snakes and spiders (CS) with a moderately aversive electric shock (US). Under both these conditions, the electrodermal CS responses follow particular laws: Established after a single trial, they do not habituate and are therefore not reducible to an OR interpretation. They are, moreover, largely insensitive to cognitive factors and persist after the subject has been informed of the absence of subsequent US. Conceivably, these responses could constitute manifestations of a transfer to the CS of the emotional value of the US.

On the other hand, a body of research, breaking away from the constraints tied to the utilization of motor or autonomic indicators of conditioning in humans, addresses the possibility of verbalizing the subjectively appraised affective value of a stimulus. In one of the earliest studies of this type, Razran (1940) showed that sociopolitical slogans, presented to subjects while they were eating a free lunch or inhaling putrid odors, were respectively more positively evaluated or more negatively evaluated, as compared to pretreatment ratings. Later experiments diversified the stimuli used and refined the methodology. Some sophisticated techniques have been developed, such as the semantic differential or the Kelly grid, which allow a reliable and valid measurement of subjective evaluative behavior. As a general result, it appears that the subjective evaluation of the CS, in terms of dimensions such as pleasant/unpleasant, like/dislike, safe/dangerous, and so forth, changes with the CS-US pairing as a function of the affective value of the US employed. This change could be partially independent of the cognitive activity of the subject (review in Martin & Levey, 1978). This field of research provides a rarely noticed support for an interpretation of conditioned BD responses in terms of transfer of hedonic value.

FD Responses

Both the timing and the orientation of FD responses appear compatible with an interpretation focusing on the *expectancy* of the US. This concept has received

repeated mention in the field of conditioning since the well-known works of Tolman (1932). Even though the specific details of Tolman's analysis are generally overlooked, the expectancy theory of conditioning is today widely accepted. According to this theory, exposure to the CS-US contingencies creates in the subject an expectancy of the US just prior to its occurrence. This expectancy is in itself the source of various behaviors. Unfortunately, the manner in which these behaviors are generated has not been specified. Bolles, for example, maintains that "an expectancy explains movements because it is postulated to do so" (Bolles, 1972, p. 404). This uncertainty as to the process by which expectancies generate behaviors does not permit the explication of rules for predicting the CR form.

A few experiments directly support an expectancy theory. For example, Williams and Prokasy (1977) compare the electrodermal CR after a reinforced and an unreinforced run of trials in a procedure of human aversive conditioning. If the responses are due to the expectancy of the US, they should more likely occur after a set of unreinforced trials as a function of a tendency to alternate, a phenomenon usually observed in probability learning studies, and commonly called the "gambler-fallacy." Such is, in effect, the result observed. The frequency of the pre-US responses increases with the number of unreinforced trials and decreases with the number of reinforced trials. The opposite result would be congruent with numerous interpretations, including cognitively oriented interpretations. Thus, if the responses were due simply to an image of the US (King, 1979) without reference to the probability of its real occurrence, the effect of the reinforced trial runs would have been to consolidate this image and to facilitate the CR.

However, in general, direct tests of expectancy theory are rare. Its principal support comes from the general correspondence between the nature of the observed CR and what a line of reasoning that is largely based on intuition and introspection permits to attribute to the expectancy of an impending US. Thus the temporal course of the responses matches the temporal course of the expectancy: Conceivably, expectancy increases as the time interval to the occurrence of the US decreases. The diversity of the observed responses, and in particular the dissimilarity sometimes observed between the CR and the UR, is also easily taken into account. The behaviors connected to the anticipation of a stimulus are not necessarily identical to the behaviors elicited by this stimulus. For example, the FD component of the conditioned modification of heart rate is a deceleration, whereas the UR is an acceleration. This deceleration, it may be noted, is also observed in other S1-S2 paradigms, such as reaction times with a warning signal, where its interpretation in terms of expectancy has been well documented (review in Bohlin & Kjellberg, 1979). A direct transposition of this interpretation to the conditioning paradigm seems possible. Certain CRs observed in animals have been described as reproductions of action patterns naturally accompanying the anticipation of the US (such as food-procuring activities with a food US; review

in Rescorla & Holland, 1982). It is also possible that an expectancy of the US underlies these responses. The form of the relationship observed in humans between the FD CR and cognitive activity also supports an expectancy theory. The attention given to the stimuli, and the verbalizable awareness of the CS-US relationships seem to be necessary conditions for the appearance of the FD CRs, whether they be autonomic or motor in nature (review in Perruchet, 1979, 1980). The degree of correspondence, during an experimental session, between the onset of awareness and the first occurrence of the CR is, however, much smaller than for the OR related BD CRs. The FD CRs always appear later than the onset of awareness, as if they required a finer analysis of the situation than that which permits the verbalization of the simple existence of a contingency. This required supplementary analysis could address the accurate timing of the events necessary to the formation of an expectancy.

The vagueness of the predictions deriving from expectancy theory generally undermines its explanatory value. It seems however that expectancy theory opens the most potentially fruitful avenue of research for the exploration of FD conditioned behaviors.

6. TOWARD A TENTATIVE SYNTHESIS

According to the preceding section, BD CRs may be attributed to the acquisition by the CS, either of the significant value of the US (thus inducing an enhancement of the OR to the CS), or of the hedonic or motivational value of the US; FD CRs would be dependent on the accurately timed expectancy of the US. In this perspective, to claim the independence of the *responses* elicited by the three postulated processes would be clearly mistaken. Trivial considerations about the eventual reciprocal inhibition, or all other kinds of interactions, between the peripheral effectors can only lead to the conclusion that the observed behavioral modifications are not, in the general case, the product of a single process. However, it is of interest to question the functional independence of the very *processes*. These latter could be also partially linked. There is some evidence that the OR to the CS is intimately related to the FD component of the CR, so as to form a single functional unit that is under the control of cognitive-analytic activities. BD CRs connected to the hedonic transfer would form, according to this line of reasoning, an independent functional unit.

Cognitive-Analytic CRs

The establishment of FD behaviors appears to be based on a fine analysis of the CS-US relationships which may require all the attentional resources of the organism. The initial OR may express the availability of these resources.

The hypothesis of a functional correspondence between the OR and the development of the FD CRs is congruent with the temporal course of these phenomena. In a general way, the OR occur earlier than the FD CRs and could therefore prepare the conditions for their development. In a study of eyeblink conditioning in humans, Putnam, Ross, and Graham (1974) observed that the heart rate OR increased until the establishment of conditioned eyeblinks, then decreased in amplitude. The same study furnishes additional evidence of a functional relationship between OR and eyeblinks by showing that the subjects having the strongest ORs to the reinforced CSs were also those for whom the best eyeblink conditioning was obtained.

It should be noted that the proposed analysis relies on a particular conception of the OR. It is in effect possible to imagine that the supplementary processing capacity accompanying the OR is allocated either to the eliciting stimulus or to the events which follow it. If it is postulated that the OR must be linked to a more efficient analysis of the CS-US contingencies, then the second alternative must be chosen. The available literature on the OR offers little relevant information permitting a decision to be made on this point. However, some experimental findings lend credence to the hypothesis that the OR expresses an alerting of an organism whose attention is oriented towards future incoming information (Siddle & Spinks, 1979). Thus, the integration of the OR and the FD components of the CR into a common functional unit devoted to the analysis of an existing situation as well as the deployment of behaviors designed to cope with the US, is consonant with the observed findings.

Hedonic Transfer CRs

The responses connected to the transfer of the hedonic value of the US appear entirely different in nature and could be the product of an independent process. These responses appear to be based on an association of the CS with the US that is direct and immediate, although much less precisely defined. The responses are at least partially independent of the cognitive activity of the subject. While the CS-US interval seems to be a determining parameter for the occurrence of the FD CRs, the BD CRs which are linked to the transfer of the hedonic value may be less sensitive to the temporal relationships between stimuli. This is illustrated for example, by the ready development of conditioned taste aversions with the very long CS-US intervals, or conversely with an inversion of the habitual order of the CS and the US.

The distinction to which this analysis leads rejoins Garcia, Rusiniak, and Brett's (1977) distinction between the behavior of rats that prepare to cope with a painful US signaled by an auditory stimulus, and the behavior of rats that acquire an aversion to a flavor previously associated with sickness. In the discussion following Garcia's paper, Seligman (p. 315) distinguishes explicitly the learning of an "if-then" relationship from the acquisition of a hedonic shift; these two

processes, even though very different, are both engendered, according to Seligman, by Pavlovian situations. However, to the best of my knowledge, this kind of development, which is closely related to the preceding analysis, has never been systematized, and its full implications have never been drawn.

Before examining, in the last section, how these developments partially modifies the traditional formulations of the preparatory function of classically conditioned responses, some brief comments are in order regarding the dominant contemporary conception of conditioning, in which it is claimed that the CR in animals is the best available indicator of the knowledge of the CS-US relationships. This conception postulated that a single intervening variable serves as a junction between the law of learning and the law of performance. A certain number of authors have recently underlined the necessity of analyzing the laws of performance, for the most part neglected to the advantage of the laws of learning (e.g., Wasserman, 1981). But it is perhaps more urgent, in the framework of the present analysis, to re-examine this complete dissociation between learning and performance. Even within the same classical conditioning paradigm, CRs may result from at least two very different processes, that refer to different laws of learning. To conserve the single label of "knowledge" to designate the source of all observed conditioned behaviors confers such a level of generality to this concept that its heuristic value tends to be severely strained.

7. CLASSICAL CONDITIONING AND PREPARATION

If the foregoing analysis is correct, it would hardly be conceivable that all CRs might share the same adaptive function.

First, let us consider the cognitive-analytic CRs. In the previous section, it was observed that the OR related responses are intimately interconnected with the FD CRs, so that the present discussion may focus on these latter responses. As mentioned above, many of these responses appear to subserve an obvious preparatory function oriented toward the receipt of the US by the organism. However, the apparent lack of sensitivity of these responses with respect to their immediate consequence, as documented in section 4 in relation to eyeblink conditioning, has recently lead some authors to express strong doubts on this point. For example, Dickinson (1981) denies the preparatory value of CRs by arguing that the CRs whose preparatory function seems obvious, persist in instrumental procedures in which the occurrence of these CRs involves negative consequences. Miller and his co-workers (e.g., Miller & Balaz, 1981) have also cast doubt on the preparatory function of conditioned responding. They base their views on the fact that in their experimental design, where rats received electric shocks from electrodes fixed to their tails, CRs occured in spite of a total absence of favorable effects. In both of the cases just cited, the necessary criteria for recognizing the preparatory value of the CRs seem to be that the CRs have

positive consequences in *all* situations. The introduction of this requirement, however, may amount to a confusion of the ontogenetic and phylogentic levels of analysis, when interpreting the assertion that CRs occur in order to prepare for the receipt of the US. This assertion appears to be mistaken at the ontogenetic level, where the local effect of an individual reaction is considered. It may be true, however, if one considers that the mechanisms underlying conditioning have persisted in phylogenetic evolution because of their *generally* adaptive value. According to this point of view, the preparatory value of individual CRs is without an intrinsic relationship to the immediate determinants of the responses, thereby making predictable the adaptive failure of some CRs in some situations (Coleman and Gormezano, 1979; Hollis, 1982). This does not mean that classical conditioning is a completely blind mechanism, suitable for all systems and for all occasions, irregardless of the consequences of the CRs. For example, it is possible that different systems might show a differential sensitivity to classical conditioning as a function of the average utility that conditioning represents for them. Thus, Gantt (1973) reports repeated failures to develop renal secretory CRs. He attributes these failures to the fact that a renal CR that anticipates the ingestion of food will be useless to the organisms because of the timing of the events, and even detrimental if the food does not occur: Unlike salivary secretions which are reabsorbed into the system, kidney secretions are irrevocably lost to the organism.

To a certain extent, BD responses linked to the transfer of hedonic value suggest the same kind of remarks as do FD responses: Their lack of sensitivity to their consequences leads to a search for their adaptive value beyond the level of an isolated reaction within a particular situation. But the problem appears more complex: unlike FD responses, hedonic transfer CRs usually do not overlap the US; consequently, they cannot fulfill any preparatory function with respect to the US occurrence, even when it is derivative in relation to their actual causes. They could be judged irrational. In orienting behavior towards the CS, the transfer process can only logically "disturb" the organism and prevent it from adopting a coping behavior with regard to a biologically significant stimulus: the US. This irrationality, however, corresponds to an absence of adaptive value only when the CS and the US are causally independent as in the previously described cases. If, for example, the withdrawal of the CS produces the absence of the US, as in the instrumental avoidance paradigm, the adaptive significance of BD behavior appears manifest. Yet, it is evident that in the natural environment, CS and US are most often intimately interconnected. As Wasserman (1981, p. 41) asserts: "signals of reward and punishers are usually located at the source of reward and punishment." The form and the sound of a predator, for example, are spatially indissociable from the predator itself and from the danger it constitutes for the prey; consequently, a behavior oriented by visual and sound signals appears fully justified. Similarly, it is probable that the disaffection of the animal with respect to the food associated with sickness, irrational in the laboratory since the sickness is not linked to the food, becomes adaptive in natural conditions. Along the same lines, Hollis (1982) has cogently argued, in an extensive review of the literature, for the adaptive significance of various conditioned BD behaviors.

As a concluding comment, it may be worth noting the complementary nature of the functions proposed for the two categories of CRs. The BD CRs associated with a hedonic shift seem principally oriented toward a modification of the *environment* through approach and withdrawal behaviors. Rapidly established and not very sensitive to the timing of events, they could have an immediate survival value. The FD CRs seem oriented towards a modification of the *organism,* in order to cope with a predictable environment, and are apparently more "optional" for survival. Their establishment, generally long in duration, would depend on a finer analysis of the situation and on more strictly defined conditions.

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