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AN INVESTIGATION OF THE RELATIONS BETWEEN SALIVARY AND MOTOR RESPONSES DURING INSTRUMENTAL PERFORMANCE[1]

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The original investigations of animal learning were performed by students of either solely classical conditioning or of solely instrumental learning, this depending upon in which laboratory the scientist was working. Consequently, there was little fruitful interaction between the instrumental and classical schools of thought at this stage, particularly in the realm of theory. This is still true to some extent.

The early studies of Konorski and Miller (1930, 1933, 1936) introduced methods whereby the relations between classical and instrumental responses could be studied. While the general conclusion to be drawn from their experiments is that the salivary CR and the instrumental movement run usually *pari passu,* some of their experiments suggested that these two processes may not be isogenous.

For example, in one experiment these authors established in a dog a classical food CR to a sporadic stimulus (CS +) using a 15-second CS-US interval, while another stimulus (CS—) was differentiated by non-reinforcement. In the next stage of the experiment, CS+ and CS— were never presented while the dog was trained to lift his foreleg in order to obtain immediate food reinforcement. After this instrumental response was well established, CS+ and CS— were presented against the background of continual performance of the instrumental leg movement. The results of this procedure were that upon presentation of CS+ the

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dog immediately stopped performing the trained movement and stared intently at the food bowl, salivating copiously. On the contrary, the presentation of CS— barely affected instrumental responding, although the salivary response to it was insignificant (Fig. 1).

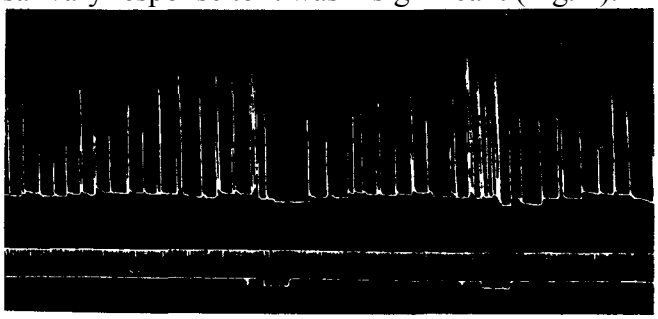

Fig. 1. The effects of a classically-trained CS+ and CS— on sporadic paw-lifting for food and on salivation. (From Konorski and Miller 1936). The markers are, from the top down: paw movements, salivation in drops, and CS. The buzzer was trained classically as CS+, and it elicits increased salivation and decreased paw movements. The metronome (M60) was classically trained as CS—, and it elicits decreased salivation and increased paw movements.

In another experiment, a dog was first classically conditioned by K on o r s k i and Miller to two stimuli, a CS+ and a CS— as in the previous case. In the second part of this experiment, this dog was trained to perform an instrumental leg-lifting response whenever a third CS, the instrumental CS, was presented. When the previously trained CS+ and CS— were presented after this training, there was no transfer of the instrumental response to CS+, but good transfer to CS—.

In later experiments by Konorski and Wyrwicka (1950), it was further established that it is extremely difficult to transform a CS which has previously been trained by classical conditioning methods into an instrumental CS. These experiments indicated that, with the same CS-US interval, the instrumental response is always stronger to an originally instrumentally-trained CS than to a CS which was originally classically reinforced and then transformed into instrumental.

On the basis of these experiments, it can be concluded that there is a certain antagonism between the classical food CS, to which the animal must simply wait for food, and the instrumental response, where he must work for food. The exact nature of this antagonism has remained obscure, however.

Opposed to the antagonism revealed in the above experiments were

the results of other experiments by Konorski and Miller (1936) where only instrumental training procedures were used with a CS-US interval long enough to allow an examination of the conditioned salivary response, using Pavlov's methods. The results of such experiments were that in a well-trained animal the salivary and motor responses ran, as a rule, pain *passu.* In general, the stronger the instrumental response, the more copious was salivation and *vice versa.* The two responses showed generally similar courses during differentiation, and tended to occur closely correlated in time.

However, a close examination of the relations between the two responses can reveal that this parallelism, although often present, is not an absolute rule. Occasionally the instrumental response is not accompanied by salivation, or salivation to the instrumental CS is not accompanied by the instrumental response. These discrepancies were clearly seen in a study by Konorski and Wyrwicka (1952), where acute extinctions of various instrumental conditioned stimuli were conducted. In these experiments, it was found that extinction of a strongly ,,motogenic" CS (i.e., one which produces an .intense instrumental response) had a strong inhibitory aftereffect upon a weakly ,,motogenic" CS, while the contrary was not true.

More recently, a number of studies have appeared in which the experimental schedules of reinforcement have been varied and the relations between salivation and the instrumental response have been further studied. It has been found, by Shapiro (1961), by Kintsch and Witte (1962), and by Ellison and Williams (1962), that when a food reward is presented under a fixed-interval schedule of reinforcement (cf. Ferster and Skinner 1957) a good temporal parallelism of the instrumental and the classical salivary response is found. With such a schedule, the first instrumental response made by the animal a fixed interval after the preceding food presentation is rewarded with food; under this schedule both salivation and instrumental responding occur nearly parallely just prior to the time of food availability, with the instrumental response perhaps slightly preceding the salivary response—a result which could be due solely to differences in recording latency between the two responses.

With another type of experimental schedule, “differential reinforcement of low rates", the animal is rewarded for low rates of responding. For example, if no instrumental responses have occurred during the previous 60 seconds, an instrumental response is followed immediately by food. However, repeating the instrumental response in less than 60 seconds is not rewarded. With such a schedule, both Shapiro (1962) and

Williams (1963) have found that the onset of the salivary CR consistently precedes the occurrence of the instrumental response. Insofar as this very complicated schedule of reinforcement fosters the development of unrecorded behavior which occurs prior to the recorded mental response, this result would not be at all incompatible with a strict parallelism between instrumental and salivary responses (see, e.g., discussion by Shapiro 1962).

In a third type of schedule („fixed ratio"), a number of consecutive instrumental responses have been required of the dog in order to obtain food. The results with this procedure have differed with different experiments. Wolf (1963) reported a strict parallelism between instrumental and salivary responding with this schedule; a small increase in salivation followed each instrumental response. Ellison and Williams (1962), on the other hand, found that after prolonged training, salivation began only after about one-half of the 33 required responses had been performed. The results of Kintsch and Witte (1962) appear to confirm this latter finding, suggesting that the salivary response and instrumental responding may be partially dissociated when a long sequence of responses is required of the animal. The differing results on fixed ratio schedules seem to depend upon differences between the experimental procedures used by the different experimenters. In the experiments performed by Wolf, the instrumental CR consisted initially of a single movement, which was immediately reinforced by food. This single movement was firmly established and only then was the number of movements required for food increased. This was done relatively rapidly, so that the animals had no opportunity to acquire a true fixed ratio CR. On the other hand, in the experiments of Ellison and Williams fixed ratio responding was trained over a long period of time.

The results of all of these investigations may be summarized as follows: it seems clear that the degree of concomitance of the classical and instrumental response in alimentary conditioning depends upon the experimental procedure. In particular, if a CS has been presented many times under the classical CR schedule, its tendency to elicit instrumental response is either little or none. On the other hand, if a CS has been presented for a long time under the instrumental CR training procedures, it elicits a strong instrumental response, while its salivary effect may be small or insignificant. The question of whether or not the instrumental response can be totally separated from the salivary response, and if so what the necessary conditions for such a separation are, has not been answered heretofore. The experiments presented in this paper were designed to elucidate this problem.

I. SEPARATION OF INSTRUMENTAL AND CLASSICAL CS

MATERIAL AND METHODS

Subjects. The subjects were naive mongrel dogs -with ages ranging from one to three years and weights from 10 to 15 kg. The instrumental training was begun on five dogs, but one of these developed strong neurotic symptoms and was discarded from the experiment proper. This dog will be reported separately. Successful experiments, then, were obtained from four dogs.

Apparatus. The method of collecting the saliva from the parotid duct was similar to that described by Sheffield (1957), involving the chronic cannulation of the intact duct with polyethylene tubing. This operation was not performed until all initial pretraining was completed and the dogs were performing well on the instrumental schedule.

The recording method involved a rigid tubing system ending with a No. 24 hypodermic needle fixed 60 cm. below the level of the conditioning stand. Drops from this needle were pierced by a second needle mounted immediately beneath the first needle, and this brief contact served to fire a thyratron tube which in turn operated the recording pen.

The experiments were carried out in the standard soundproofed Pavlovian chamber used in this laboratory. The dog, standing on the conditioning platform, could be monitored visually by E through a viewing window and could be heard or spoken to by E through a 2-way communication system. All stimuli within the chamber (lights, buzzers, and metronomes) were electrically operated by E from without. The experimental stimuli varied for different dogs, as will be described later.

The reinforcement used was a portion of boiled meat and bread cubes soaked in broth. The feeder consisted of a large disk containing a number of filled dishes which could be rapidly rotated into place by means of electrical control. The feeding schedule was arranged so that each S had a daily meal of meat and bread several hours after each daily session; as a consequence the dogs were always in good appetite during the experimental session but their normal body weight did not fall appreciably during the experimental training.

Experimental sessions were scheduled once daily six times weekly. The intervals between trials within sessions varied from one to five minutes, but usually varied only between three and four minutes.

The experimental manipulandum consisted of a clear plexiglass lever, 25 cm. wide, which projected 12 cm. through a slot cut m a clear plastic box. Depressions of this lever operated a microswitch, the output of which was used as the response criterion. The box rested on the conditioning stand floor to the right of the food tray, so that the animal was forced to turn slightly away from the food dish in order to efficiently press the lever. The normal response seen was a rapid striking of the lever with the right paw.

Pretraining. The dogs were first trained to eat from the feeder, and were then trained classically with a one-second CS-US interval to a conditioned stimulus, henceforth called classical conditioned stimulus. For dogs 1, 2, and 3, this stimulus was the sounding of door buzzer which was mounted out of sight beneath the food tray; for S 4 it was a flashing 100-watt light bulb mounted in front of the conditioning stand at approximate eye level. This stimulus always overlapped several seconds with the presentation of food.

After this training was completed (4—5 days with about 14 trials per day) the experimental manipulandum was installed on the conditioning stand with a small box made of wire screening and filled with meat attached to the lever. When the subjects attempted to eat this meat and were prevented from doing so by the screening, they began to paw at the screening. These paw movements were reinforced with a brief presentation of the classical conditioned stimulus followed immediately by operation of the feeder. After one or two days of such training the wire box could be removed and paw movements to the nonbaited lever reinforced.

After a few additional days of this constant reinforcement training, a second stimulus, henceforth called the instrumental CS, was introduced. Now only those lever presses which occurred in the presence of the instrumental CS were reinforced (with the classical CS, followed by food). For Ss 1, 2, and 3, the instrumental CS was the lighting of a lamp mounted inside the transparent manipulandum; for S 4 it was the sounding of a door buzzer mounted in front of the food tray. The intervals between successive presentations of the instrumental CS were subsequently slowly lengthened to several minutes as training progressed. Finally, the number of presses required to produce the classical CS, and the CS-US interval during' the classical CS, were gradually increased to *9 presses* and 8 seconds, respectively. A typical trial at the end of training would, therefore, consist of onset of the instrumental CS, 9 lever presses, offset of the instrumental *CS* and onset of the classical CS, food presentation 8 seconds after the classical CS onset, and about 5 seconds overlap of the classical CS and food. The salivation operation was performed after each individual subject was performing well on this final schedule.

RESULTS

Instrumental responding during the CS. Throughout the duration of training, there was good instrumental responding during the instrumental CS; the mean duration of the instrumental CS (including the latent period and the time required to make the 9 presses) was 6.0, 4.5, 4.0 and 6.0 seconds, respectively, for subjects 1, 2, 3, and 4 at terminal training. After the initial latent period lever pressing began at a high rate and continued with an occasional pause until 9 presses had been recorded and the classical CS was turned on. The dogs would then quickly stop responding and turn to stare at the food bowl. Occasionally, Ss 2 and 4 would become impatient while waiting for food and would change position restlessly, sometimes standing up on the foodtray. This occurred rarely, and they would never perform the instrumental response during such episodes. It should be emphasized that it was not necessary to differentially reinforce non-responding during the classical CS. At no time was reinforcement withheld or delayed because of responding during the classical CS. In other words, the classical CS reflexly elicited non-responding throughout training.

Instrumental intertrial responding. Responding in the absence of either the instrumental or the classical CS occurred to an appreciable extent early in training, but gradually declined and, while it never completely

reached zero for all of the dogs, it was clearly insignificant in comparison to the instrumental CS responding for all dogs, and was virtually non-existent in two of the dogs.

Salivation *during the classical CS.* The classical CS regularly elicited a salivary response, although the latency of this response and the total volume varied considerably from trial to trial. However, irrespective of what was the total amount secreted, the rate of salivation, being insignificant at the outset of the classical CS, increased towards the end of the CS-US interval.

Salivation during the instrumental CS. Early in training, a small salivary CR would frequently occur during the operation of the instrumental CS. This could take one of several forms: it sometimes occurred during instrumental responding, sometimes only during non-responding, and sometimes during both. As training progressed, the amplitude and frequency of these responses gradually decreased, as did intertrial salivary responding.

In two of the dogs (Ss 1 and 2), it was possible to demonstrate across one entire session during some stage of training a significant ($p < 05$) decrease in rate of salivation during the instrumental CS as compared with a control period just prior to the onset of the instrumental CS. This inhibitory effect became gradually less apparent as the intertrial salivation progressively decreased over training. Late in training, on those trials where salivation did occur just prior to the onset of a trial, this inhibitory effect could again be seen.

On some other trials, a small amount of salivation occurred during the instrumental CS, but in a manner so as to be negatively correlated with lever-pressing. On a typical trial where this effect was observed, the dog would begin to lever-press during the instrumental CS, stop after 4 or 5 presses and look toward the food bowl, only then begin to salivate, and finally return to complete the ratio with a rapid decline in salivation. This effect was quite striking to any observer accustomed to thinking of salivation as a sluggish, long-latency response, and accustomed to the usual positive correlation between salivation and instrumental responding.

A complete daily record (11 consecutive trials) of one day on which these two inhibitory phenomena were observed is presented in Figure 2 for S 1. It can be seen that on trials 2, 3, 5, and 6, lever-pressing and salivation are negatively correlated. It can also be seen that considering the session as a whole, the mean rate of salivation is less during the instrumental CS than during a comparable control period just before each trial. This effect was most noticeable in the dog shown, but was observed to some extent in other dogs.

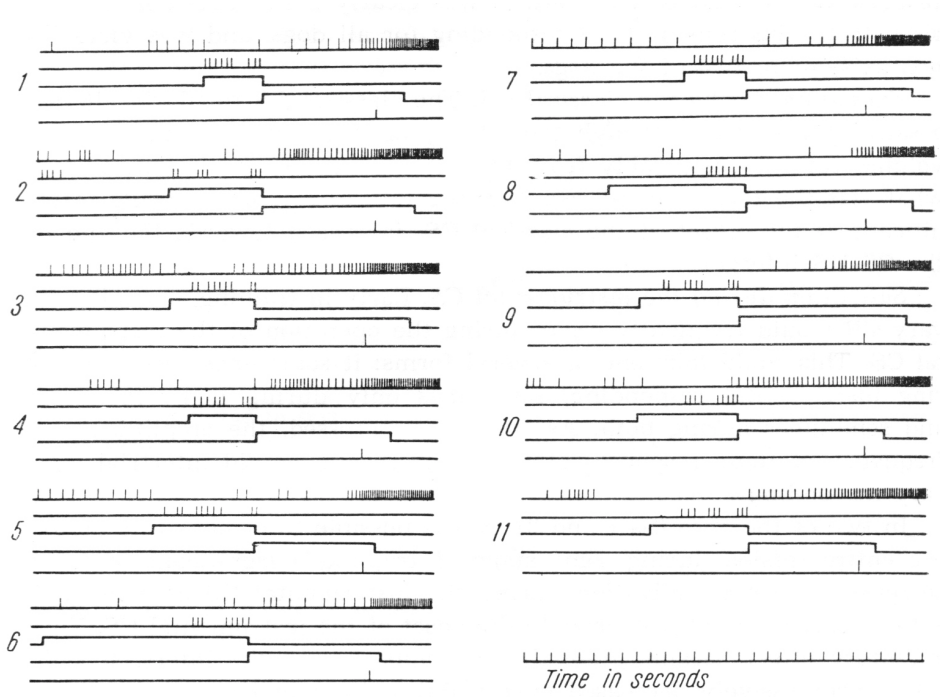

Fig. 2. A complete daily record (11 consecutive trials) of S 1 before terminal behavior had been reached. The stimulus markers are, from top down: salivary drops; lever-presses; the instrumental CS; the classical CS; food presentation. A decrease in salivary rate upon presentation of the instrumental CS can be seen on trials No. 1, 3, 4, 5, 7, 10, and 11. Salivary drops and lever presses are negatively correlate on trials No. 2, 3, 5, and 6

Typical results later in training are shown in Figure 3. This figure presents a representative series of 5 consecutive trials taken from the records of each dog at terminal performance. These records show rapid and sustained lever-pressing in each dog to the instrumental CS accompanied by low levels of salivation, and a lack of lever-pressing to the classical CS accompanied by a high rate of salivation. An averaged curve for each dog over one such terminal session is shown in Figure 4.

II. IMMEDIATE FOOD REINFORCEMENT OF THE INSTRUMENTAL CS

MATERIAL AND METHODS

After the above experiments had been completed, further training was given to Ss1 and 3. In this further training, the instrumental CS was followed immediately by food after the ratio of 9 lever-presses was performed. The classical CS

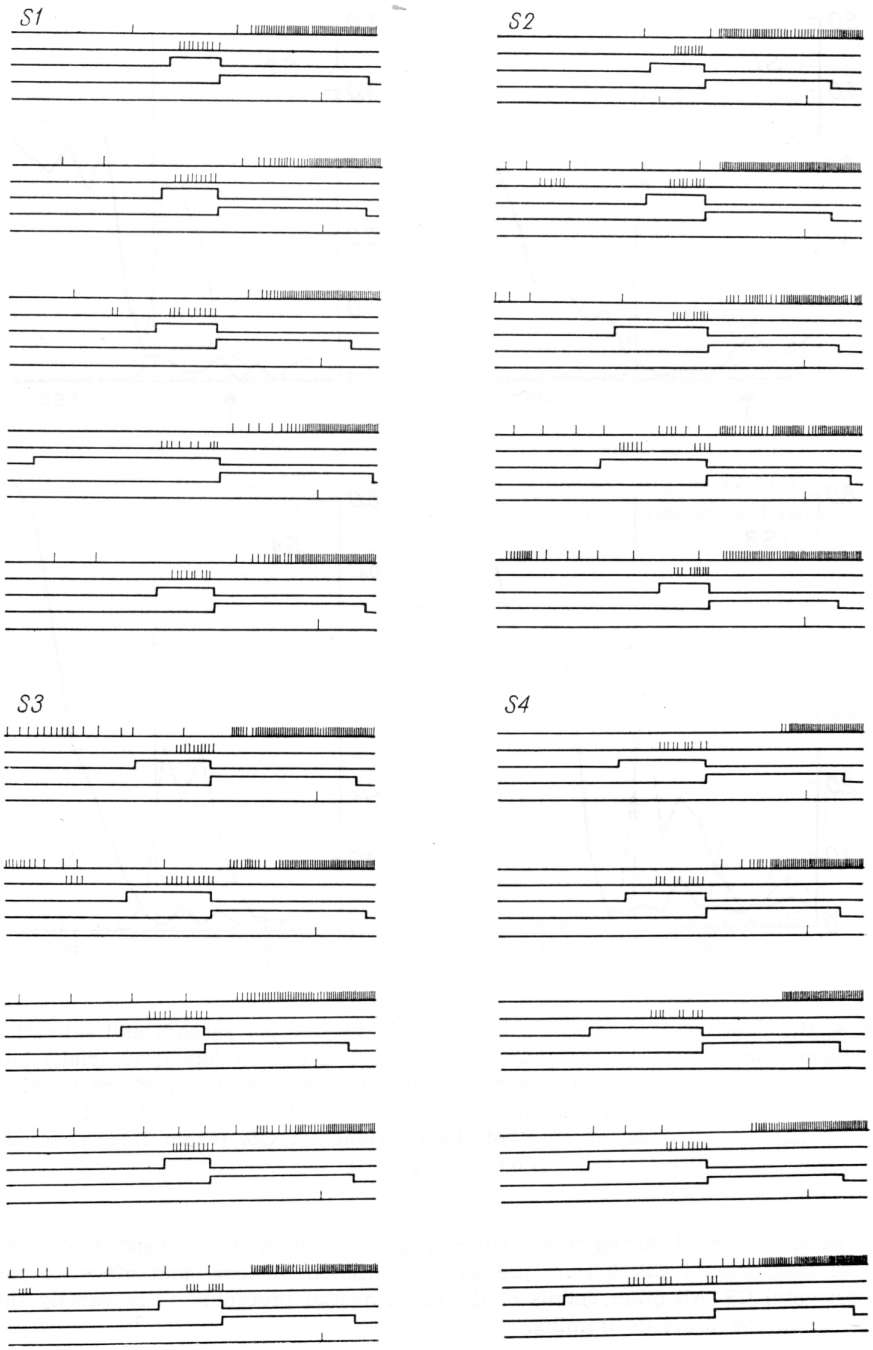

Fig.3. A representative series of 5 consecutive trials taken from each dog's records at terminal training. Stimulus markers and time marker as in Figure 2

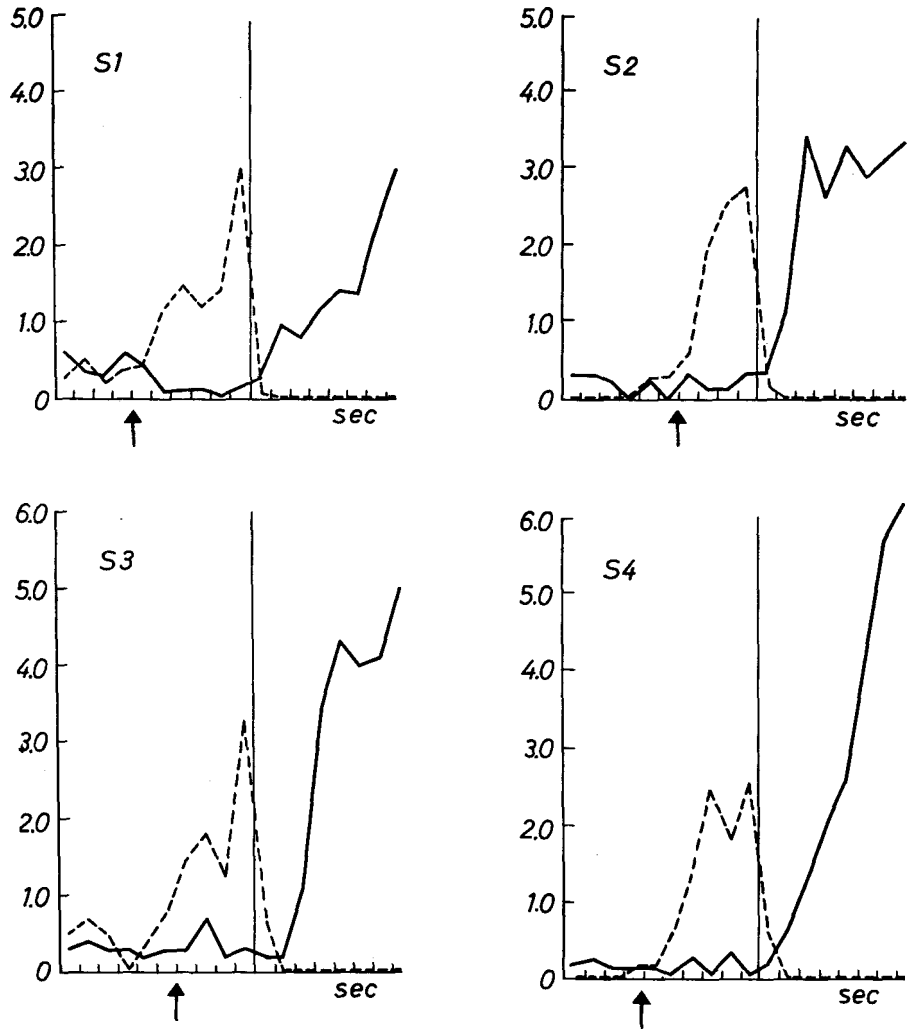

Fig. 4. Mean rate of lever-pressing (dashed line, presses per second) and salivation (continuous line, drops per second) during a typical session (about 15 trials) late in the training of each dog. The vertical line represents the onset of the classical CS, and the curves end at the time of reinforcement. The arrows indicate the median time (in seconds) of onset of the instrumental CS. (From Ellison and Konorski 1964)

the was never presented during this further training. Thus, a trial consisted of onset of the instrumental CS, 9 lever-presses, presentation of food, and offset of the instrumental CS. All other details of the experimental procedure were exactly the same as in the previous training. Thus, a trial consisted of onset presentation food, and offset of the instrumental CS. All other details of the experimental procedure were exactly the same as in the previous training.

RESULTS

For the first few days following the introduction of this immediate reinforcement, neither the salivary nor the motor behavior showed any appreciable change. The first change noted, after about 4 days and 60 trials, was that the animals began to pause more frequently in lever--pressing, turn and look at the food bowl, and salivate. This behavior had been observed occasionally during delayed reinforcement training, but the frequency of these pauses increased greatly after the immediate reinforcement training.

After a total of 8 days of immediate reinforcement training (about 120 trials) the lever-pressing behavior was quite similar to that typically found with immediate reinforcement. The first few lever-presses were often emitted before any salivary CR occurred, an effect previously reported for fixed ratio responding (Ellison and Williams 1962). Then a pause in responding would usually occur and salivation would begin, continuing to the time of reinforcement. The responses toward the end of the ratio were almost invariably accompanied by salivation. The results after at least 9 days of training are shown in Figure 5. It can be seen that anticipatory salivation and lever-pressing occur generally at the same time. While this concomitance between the two behaviors was being established, the instrumental behavior changed markedly. Whereas the be-

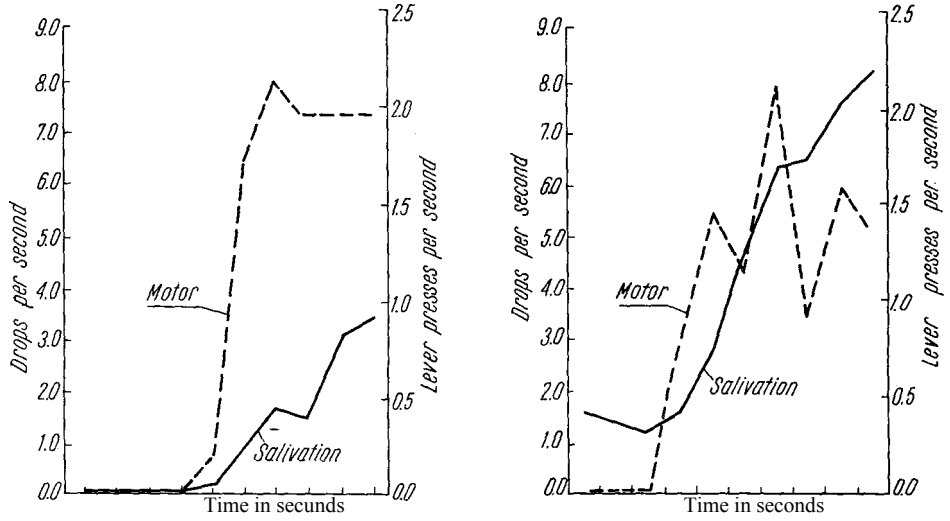

Fig. 5. Concomitance of salivation and lever-pressing after immediate reinforcement training. The curves end at the time of food delivery. On the left is the data of S 1; on the right, S 3

havior of these dogs at the termination of the original training (delayed reinforcement) usually consisted of a short pause between onset of the instrumental CS and onset of lever-pressing, and then a sustained bout of lever-pressing, the typical behavior with immediate reinforcement became one of short bouts of lever-pressing with glances at the food-bowl between each bout. In other words, the average rate of lever-pressing and the average number of presses between pauses declined. Relevant data are shown in Table I. S 1 generally had a short latency of lever-

Table I

A comparison of instrumental behavior before and after immediate reinforcement training. Means of 44 consecutive trials at the end of delayed reinforcement training and 44 consecutive trials at the end of immediate reinforcement training

Animal	Delayed	Immediate
Mean latency of first lever-press (in seconds)		
Sl S3	1.43 3.23	1.44 -2.48
Mean number of pauses (of one second or longer) per trial		
Sl S3	0.61 -0.79	2.19 1.80
Average time (in seconds) required to complete ratio of 9 presses		
Sl S3	5.32 8.00	6.31 7.95

pressing at the end of delayed reinforcement training, and this latency remained unchanged. However, the average number of pauses in lever-pressing of one second or greater greatly increased after the introduction of immediate reinforcement. The latency to first lever-press was lowered in by the introduction of immediate reinforcement, but the average number of pauses during pressing was again increased.

III. UNSUCCESSFUL EXPERIMENTS

As noted previously, the results obtained from the fifth dog were totally different from those reported above; this was connected with the experimental neurosis which developed in this animal during the course of training. A detailed description of the general behavior of this dog and its experimental data follows.

The dog was trained in the same manner as those described above**,** with buzzer as the instrumental CS and a flashing lamp as the classical

CS. The initial training was uneventful, and the behavior of the dog during pretraining was quite similar to that of the other dogs: to the instrumental CS, barking, general motor excitement, and vigorous instrumental movements were observed, while to the classical CS the dog rapidly quieted down and remained immobile, staring at the food bowl. About the time of the salivary operation this dog began to become more and more restless in the experimental chamber, and this situation progressively grew worse as further training progressed. On about half of the experimental days he completely refused to eat while in the chamber. He grew reluctant to come to the experiment, and when on the stand he struggled violently. His salivary CR became smaller and more variable even though he would continue to perform the instrumental movements correctly. After attempts to retrain this animal with a shortened CS-US interval for the classical CS failed, he was discarded. Examples of his salivary and instrumental behavior are shown in Fig. 6.

The trials shown are taken from assorted days during training, and were selected to provide a fair sample of the various types of trials which occurred. The last trial is representative of terminal performance. Du-

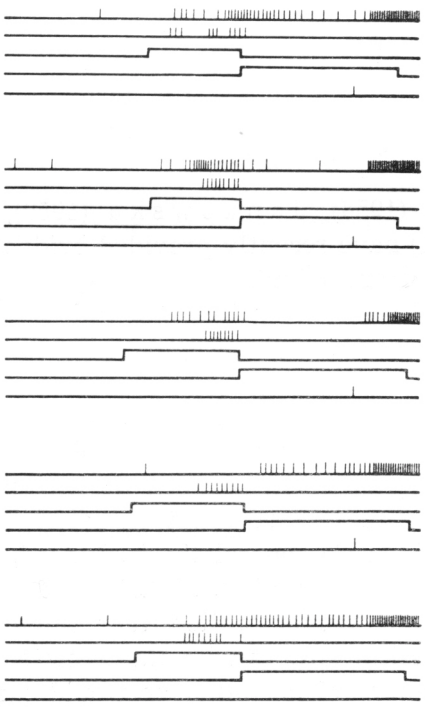

Fig. 6. Five trials representative of the general behavior of S 5. Signal markers and time scale as to in Fig. 2

ring the instrumental CS on such trials, the dog would stare at the food-dish while making paw movements with the right forepaw. Because he was not attending to the lever, about half of these movements were abortive and consisted of merely pawing the air. Upon onset of the classical CS, he would usually case lever-pressing, but would not look for food, rather moving about aimlessly, biting at his leash and his salivary recording fistula, and climbing up on the food tray. Extensive attempts to form a good classical CR to the flashing lamp failed, and this resistance to conditioning surely was the cause of the failure of the experiment.

DISCUSSION

The original hypothesis of Konorski and Miller (1933, 1936) proposed that classical and instrumental conditioned responses are in he rently linked, in that an instrumental response can be established when and only when, its proprioceptive feedback becomes a classical food CS. It was similarly proposed that extinction of this classical CR to the proprioceptive feedback should lead to the extinction of the instrumental response.

This hypothesis implies that (1) proprioceptive feedback from a trained movement is indispensable for the formation of an instrumental CR, and (2) that the performance of an instrumental movement should invariably be followed by salivation.

Knapp et. al. (1958), Jankowska (1959), and Górska and Jankowska (1961) have recently provided evidence showing that proprioceptive feedback from a limb is not indispensable for the preservation, or even establishment, of an instrumental CR. This evidence would constitute a refutation of the above hypothesis unless it were assumed that intercentral feedback could be substituted for the peripheral feed-back (cf. Konorski 1962). However, the finding that in instrumental conditioning salivation does not necessarily follow the instrumental movement and that the parallelism between the two responses is often far from being precise seems to cast doubt on even this weaker version of Konorski and Miller's general thesis. Indeed, unless it is assumed that systems of classically conditioned CR's other than that mean by salivation exist, the demonstration that salivation, the traditional exemplar of the classical CR, can be uncorrelated or even negatively correlated with instrumental performance would cast doubt on any theory which attempted to correlate the two types of responses (e.g, Mowrer 1960).

Sołtysik (1960), on the basis of Konorski and Mi1ler's earlier studies of alimentary CR's, has proposed that while a classical CR based on the consummatory feeding act may be considered as a consummatory CR, instrumental responding is the effect of an entirely different CR—the drive CR. The present data are in agreement with this separation of the drive CR on the one hand and the consummatory CR on the other, and allow us to clarify in more detail the particular effects of each of these CR's.

In the investigations of instrumental performance carried out by the behavioristic school, instrumental responding has usually been considered as being energized by the drive state of the animal (Hull 1943, Miller 1951, Sheffield unpublished, and Spence 1956). This drive can be classically conditioned, and results in motor arousal (Sheffield and Campbell 1954). Many neurophysiological studies, such as the studies of the effects of hypothalamic stimulation in waking animals initiated by Hess (1949) and the later ablation studies, such as that of Anand and Brobeck (1951) have provided a precise physiological meaning of the term „drive". Later studies by Miller (1957) and by Wyrwicka et. al. (1959) have shown that the instrumental food response can be indeed faithfully driven by the hunger drive produced artificially by stimulation of the lateral hypothalamus. Thus, the evidence for a drive CR seems adequate.

If the hyperactivity representative of the pure drive CR is adaptive for seeking food, quietness when food is very close at hand is also adaptive for the hunting carnivore. Just such behavior was observed during the classical CS. The existence of a consummatory CR, as distinct from the drive CR, can be inferred from several different observations. The main effect was, of course, the conditioned salivary response. A second effect was the inhibition of both lever-pressing and general activity which occurred upon presentation of the classical CS. This inhibition was correlated with an intense staring at the food bowl, and was similar to that reported originally by Konorski and Miller. The classically conditioned consummatory reflex must be very well established in order to observe this effect. In several experiments (Shapiro and Miller 1963, Bower and Grusec 1964) where presentation of a positively reinforced CS resulted in an increase in instrumental responding, the consummatory CR was probably not so strongly established.

Heretofore, the question of whether or not the conditioned hunger drive directly elicits salivation had remained unanswered. The results reported above definitely indicate that salivation does not belong to the repertory of the direct effects of the conditioned hunger drive.

The question of why a clear separation of the hunger CR and the consummatory CR was possible in our experimental situation arises. Although a complete answer to this question requires further experimentation, the following factors seem to be relevant:

(1) The lever which the animals were required to press was situated on the right side of the feeder, so that the dog had to turn about 45 degrees in order to perform the trained movement. The question is open as to whether a similar lack of salivation during the instrumental responding would have been obtained if the movement had not implied turning away from the feeder, as is the case when the trained movement entails placing the foreleg on the food-tray or lifting the hindleg. It seems quite likely that the clear-cut antagonism (as distinct from the separation) between instrumental responding and salivation seen in at least two of our dogs is attributable to this factor. Just as turning toward the food bowl is certainly and important component (both proprioceptive and visual) of the compound classical CS, turning away from the bowl must make the CS compound less potent.

(2) Spatial contiguity between the classical CS and the place of feeding may contribute to the purity of the classical CR and the lack of its contamination by the instrumental CR.

(3) However, while the two preceding factors might have played an auxiliary role in the success of our experiment, the decisive role was certainly played by the two-segment character of our procedure: the instrumental CS was separated from the time of food presentation by the firmly established classical CS. The decisive character of this factor is clearly shown by the demonstration that when the instrumental CS was immediately followed by food, the salivary and instrumental responses occurred in parallel. The normal process of inhibition of delay in salivary conditioning was heightened in our experiments by the sequential nature of our CS'i (the so-called „masking" 'of the first stimulus by the second). This was crucial for a full separation of the two responses in our experiments.

Previous investigations of the interrelations between the salivary CI and instrumental responding have indicated a complex relationship between these two responses. The reasons for this become clearer when viewed in the light of our experiments. While the hunger CR, which is responsible for instrumental performance, and the consummatory CR which is responsible for the salivary response, can be produced by different stimuli, as was the case in our experimental procedure they can also be elicited by the same stimulus, as is the case in the majority of earlier experiments. In fact, when the instrumental CS is

and closely followed by food, it becomes ipso facto a signal of food—i.e., a classical CS. The more classical its character, the more copious is the salivary response, and the poorer may be its motogenic power; on the other hand, the stronger its instrumental character, the stronger is its motogenic capacity and the poorer the salivary response (cf. E11ison and Konorski, in press). It should be recalled that if the food reinforcement closely follows the performance of the trained movement, the proprioceptive feedback from this movement will certainly become a classical food CS, as is shown by the experiments using the salivary-motor experimental procedure. Although this effect is a usual by-product of instrumental learning, it does not seem to be an indispensable condition for the formation of the instrumental response.

Finally, the contradictory results obtained from our fifth dog need some comment. From the description of this dog's behavior it seems clear that the dog developed a heavy experimental neurosis, with all of the typical symptoms described long ago by Pavlov and confirmed by many others. In this category belong such symptoms as: motor excitement, a tendency to escape from the stand, erratic and unpredictable CR's, and frequent refusals to eat food in the experimental chamber. The fact that the neurotic behavior developed immediately after the insertion of the polyethylene tube into his salivary duct suggests that this operation produced some discomfort to which the animal could not habituate. On the other hand, it should be noted that the instrumental CS often produced not only the instrumental response but also salivation in this dog. Since the instrumental CS for this dog was a buzzer (a strong stimulus) and the classical CS was a lamp (a weak stimulus), it seems likely that both the drive CR and the consummatory CR were conditioned to the first simulus. Thus, the animal expected food immediately after the buzzer, and the additional stimulus interspersed between the buzzer and food may have become the cause of the neurotic symptoms.

SUMMARY

1. Dogs were trained on an experimental schedule with the following final result: to a stimulus called the instrumental CS, the animal was required to perform 9 lever-presses, whereupon the stimulus was turned off and another stimulus, called the classical CS, was presented. Eight seconds after the onset of the classical CS the dog was given food.

2. With this schedule the instrumental and classical conditioned responses appeared to be virtually completely seperated. The animals performed the trained movement without salivation in response to the

first segment, and salivated without performing the movement in sponse to the second segment.

3. In some dogs a clear antagonism between the classical and the instrumental conditioned response was observed. The lever-pressing coincided with the cessation of salivation and salivation coincided with the cessation of motor responding.

4. When further training was given with the instrumental CS reinforced immediately by food, the salivary and motor response began occur parallely, as is the case in the typical salivary-motor training procedure.

5. The significance of these results for the interpretation of the relationship between classical and instrumental CRs is discussed.

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