

ON THE PECULIAR PROPERTIES  
OF THE INSTRUMENTAL CONDITIONED REFLEXES  
TO "SPECIFIC TACTILE STIMULI"

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In early papers by Konorski and Miller (1933, 1936) it was shown that the type II (instrumental) conditioned reflexes (CRs) obeyed the Pavlovian rule of "strength of conditioned stimuli" (CS) in the same way as did the type I (classical) CRs. According to this rule, the CRs established to different CSi and reinforced by the same US may differ in strength, depending on the character of the CS applied. Thus, auditory CSi generally produce a stronger effect than tactile and visual stimuli, rhythmic stimuli have a stronger effect than continuous stimuli, and the stronger the intensity of the CS, the stronger, up to a certain limit, is its effect (cf. Pavlov 1927, Konorski 1948, chapt. II).

However, according to the observation made by Konorski and Wyrwicka (1950), under certain conditions stimuli of the same strength (i.e. eliciting the same classical conditioned response) may produce instrumental responses of different strength, as measured by their latent periods and/or amplitudes of movement. This used to occur when different stimuli were used in different training procedures. When the instrumental CR was trained to a given stimulus from the very beginning of its application, the motor response to it was strong, but if the instrumental CR had been transformed from the classical CR, the motor response to the CS was weak. On the basis of these findings the authors concluded that various instrumental CSi might possess various motogenic properties depending on the previous training.

The supposition was put forward that the motogenic properties of the stimuli might also depend on their intrinsic character; in particular,

it was suggested that the tactile stimulus applied to the distal part of the leg involved in the performance of the trained movement might appear to be more motogenic than other CSi.

The aim of this paper is to compare the motogenic properties of the tactile stimulus applied to the leg involved in the trained movement (henceforth called "specific tactile stimulus") with ordinary stimuli applied in instrumental conditioning.

#### METHODS

Experiments were carried out in a regular sound-proof CR chamber. Instrumental food CRs were trained to tactile and auditory stimuli. Tactile stimuli consisted of the rhythmic touching of the skin, applied once per second and delivered by a device attached to the skin (Fig. 1, Podkopaev 1952). The

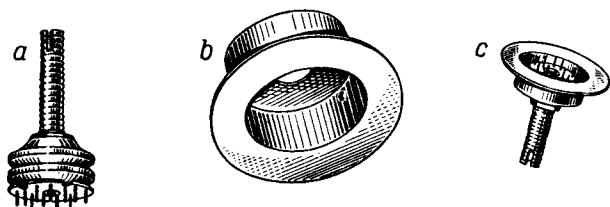


Fig. 1. The apparatus used for tactile stimulation  
 a — the rubber capsule extended by pressing the rubber bulb by the experimenter; each pressing contacts the blunt pins with the skin of the animal, b — the metal frame of the capsule attached to the skin, c — the whole apparatus

Instrumental response consisted of placing the right foreleg on the foodtray situated in front of the animal. The presentation of food (pieces of bread or minced biscuits with broth) was accomplished by moving the bowls into position one by one by an electric device controlled by the experimenter. In some animals salivation from the parotid gland through a fistula with a shortened duct (Sołtysik and Zbrożyna 1957) was recorded by Kozak's method (1950).

In the experiments in which the salivary-motor method was used the CS action was followed after 10 seconds by the presentation of food; the intertrial intervals were 3—4 minutes. In purely motor experiments the performance of the trained movement was immediately followed by food reinforcement and the intertrial intervals were about 1 min. Usually 9 trials were given in every daily session.

The first instrumental CR was trained by the Konorski and Miller's method (1933, 1936). According to this method food reinforcement followed the compound composed of a given stimulus and the passive placing the animal's leg on the foodtray, whereas the stimulus applied separately was not reinforced. In order to establish the instrumental CR to subsequent stimuli the method described by Wyrwicka was used. Wyrwicka (1952a, b) found that if an instrumental CR has been firmly established to a given stimulus, and a new stimulus is applied with immediate food reinforcement, the transfer of the instrumental response to this new stimulus occurs after a few trials.

## RESULTS

### 1. Comparison of the formation of instrumental CRs to specific tactile stimulus and to other stimuli

In the first series of experiments, carried out on 6 dogs, the first instrumental CR was trained to the tactile stimulus applied to the anterior surface of the wrist of the right foreleg. As seen in Table I, the instrumental CR was formed after a few trials. When the CR was firmly

Table I

Speed of formation of instrumental CR to specific tactile stimulus and of its transfer to buzzer

Nos. of dogs	1	2	3	4	5	6
First training to specific tact. stim.	16	6	11	6	15	14
Transfer to buzzer	(56)	(66)	(61)	(22)*	(51)	25

Figures denote the numbers of trials necessary to establish the CR. Figures in brackets show that instrumental CR was not established after a given number of trials.

\*) Experiments were discontinued because of severe neurosis.

established, an auditory stimulus, the buzzer, was introduced and reinforced by food. It was applied 2 or 3 times in every session among the tactile CSi. In 5 dogs out of 6 the instrumental response failed to appear to this stimulus in spite of more than 50 applications of it with random changing the moment of reinforcement from 2 to 10 seconds or longer. The buzzer elicited merely a direct food reaction toward the food-tray and salivation. Only in one dog (No. 6) did the instrumental response occur to the buzzer after 25 trials, but its latent period was longer than to the tactile stimulus, and from time to time it failed to appear. However, no matter whether the instrumental CR to the buzzer was delayed or absent the salivary response to it was much more conspicuous than that to the specific tactile stimulus, as seen in Fig. 2.

In view of these results, in the second series of experiments, which was performed on 3 other dogs, the procedure was reversed, namely, the instrumental CR to the buzzer was established at first, and there-

after the specific tactile stimulus was introduced. As seen in Table II, the transfer of the instrumental response from the buzzer to the tactile stimulus occurred in all dogs very rapidly.

In order to see whether the lack of transfer of the instrumental CR from the touch of the leg to the buzzer is dependent on the specificity

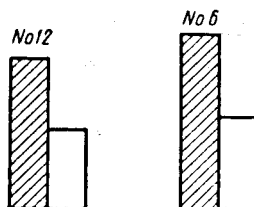


Fig. 2. The mean salivary conditioned responses in two dogs to buzzer (hatched columns) and to specific tactile stimulus (white columns). Note that salivation to tactile stimulus is much smaller than that to buzzer.

of the leg stimulation, the third series of experiments was performed on 2 dogs in which the first training of the CR was carried out to the tactile stimulus applied not to the leg but to the side of the body, and then the auditory stimulus was introduced. In this case the transfer of the CR from the first to the second stimulus occurred again quite easily (Table II).

Table II

Speed of formation of the instrumental CR to buzzer and tactile stimulus to the body and of its transfer to the specific tactile stimulus to buzzer respectively

Nos. of dogs	7	8	9		10	11
First training to buzzer	21	*)	*)	First training to tact. stim. of the body	24	31
Transfer to specific tactile stimulus	11	5	8	transfer to buzzer	6	4

Figures denote the numbers of trials necessary to establish the CR.

\*) Since the first training was accomplished not by reinforcing the passive movements, but by active manipulative movements (method not described here), the numbers of trials are not presented.

To summarize, we have found that if an instrumental CR to the specific tactile stimulus is established in the first training, it prevents a transfer of the instrumental response to other stimuli. Such a transfer is readily obtained if other stimuli (buzzer or touching the body) are used in the first CR training.

## 2. Comparison of chronic extinction and restoration of instrumental CRs to specific tactile and auditory stimuli

Experiments of this kind were performed on 4 animals. In one, the chronic extinction and restoration of CRs was carried out twice, in the others, once. The experimental procedure was the same in all series and ran as follows:

In all the dogs the instrumental CR was established to the metronome, the buzzer, and touching of the right wrist. The number of applications of the buzzer and touch was equal, and amounted up to 400. Then in the extinction series the metronome was applied with reinforcement

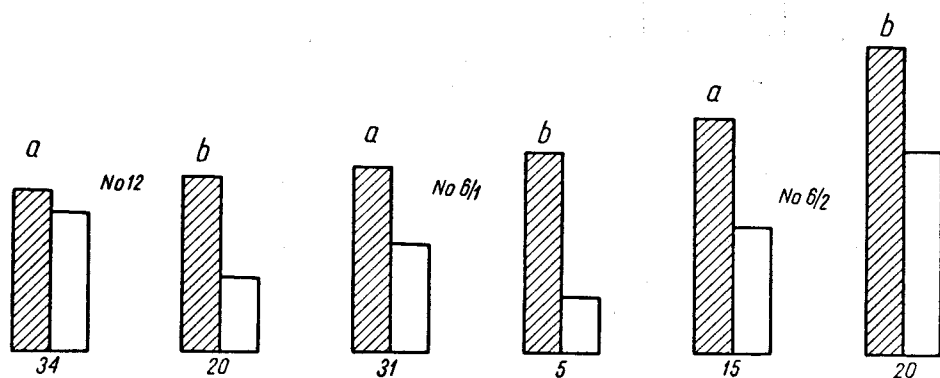


Fig. 3. Mean salivary conditioned responses to buzzer (hatched columns) and specific tactile stimulus (white columns) during chronic extinction (a) and restoration (b) of CR. Nos. of dogs and number of trials in extinction and restoration series are indicated. Note that both in extinction and restoration series the salivary responses to buzzer are larger than to tactile stimuli

7 times in a session, while the buzzer and the tactile stimulus were applied only once per session without reinforcement, in the 3rd or 4th trial, and in the 6th or 7th trial. Their sequence alternated from day to day, so that if in a given session the buzzer came first and the touch second, in the next session their order was reversed.

After the extinction of the instrumental CRs to both stimuli was completed, a restoration series followed with reinforcing the extinguished CSi by food. As known from Wyrwick's studies (1952a, b) the re-reinforcement of an extinguished instrumental CS by food leads to the re-establishment of the instrumental response to it.

As seen in Table III, the results obtained in all the extinction series were the same. The resistance to extinction of the instrumental CR to the specific tactile stimulus was much stronger than that to the buzzer.

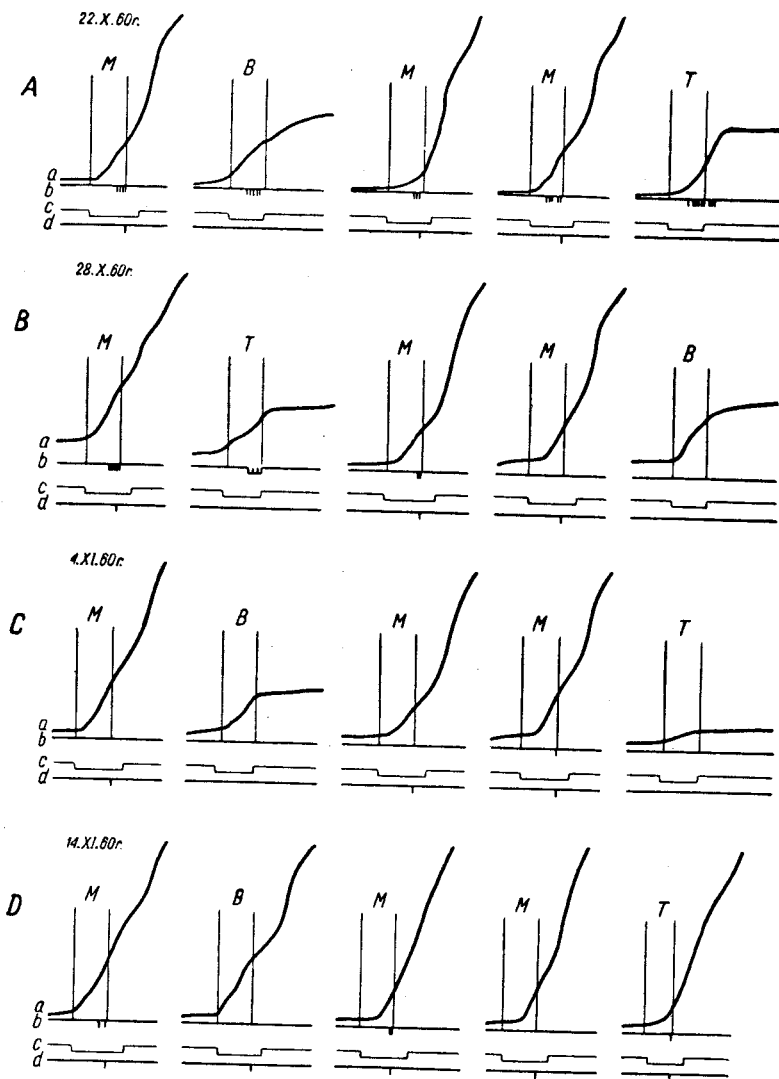


Fig. 4. The fragments of records of experimental sessions in the second extinction-restoration series in dog No. 6

A — 2nd session of the extinction series, B — 7th session of extinction series, C — 12th session of extinction series, D — 5th session of restoration series.

In each record only five successive trials are presented including two extinction trials. a — cumulative curve of salivation; perpendicular lines denote the outset of CS and presentation of food respectively; b — putting the right foreleg on the foodtray; c — CS; M — metronome, B — buzzer, T — specific tactile stimulus; d — presentation of food.

In A, both buzzer and tactile stimulus elicit strong motor and salivary reaction. In B, tactile stimulus still elicits motor response, while buzzer fails to do so. In C, both buzzer and tactile stimulus do not produce motor response; note the considerable salivation to B. In D, on 5th day of restoration tactile stimulus produces motor response, while buzzer does not. Note the gradual decrease of motor responses to metronome in the course of extinction series

Table III

Speed of extinction and restoration of instrumental CRs to buzzer and specific tactile stimulus

Nos. of dogs	12		6/1		6/2		9		8	
Extinction to buzzer	7	7	3	7	6	6	8	8	5	8
Extinction to specific tact. stimulus	27	31	8	22	11	11	31	32	10	13
Restoration to buzzer	(20)	(20)	(5)	(5)	(20)	(20)	7	9	—	—
Restoration to specific tact. stim.	2	2	2	2	2	2	2	2	—	—

The first column for each dog denotes the first trial in which the instrumental response was absent in the extinction series, or the first trial in which the instrumental response reappeared in the restoration series. The second column denotes the same for three consecutive trials. The figures in brackets denote that after a given number of trials the instrumental response did not reappear.

On the contrary, in the restoration series, the reappearance of the instrumental movement in response to the touch occurred already after a few reinforcements, while to the buzzer it occurred much later, or even failed to appear.

The extinction and restoration of the salivary reflex took a quite opposite course, namely, its resistance to extinction and promptness of restoration was greater to the buzzer than to the touch (Fig. 3).

In Fig. 4 representative fragments of records of the second extinction-restoration series in dog No. 6 are shown. It is seen that the motor reaction to the buzzer disappears sooner than that to the tactile stimulus, while the salivary reaction drops earlier to the latter stimulus. It is also seen that during the extinction series there is some impairment of the instrumental CR to the positive CS (metronome), which either elicits a less vigorous motor response, or even fails to elicit it.

#### DISCUSSION

Our results demonstrate that the association between the CS and the instrumental response is particularly strong when the CS is represented by a tactile stimulus applied to the distal part of the leg involved in

this response. These results are supported by other tests, such as acute extinction of the CR or satiation of the animal, as reported in another paper (Wyrwicka and Dobrzecka 1960). Here, also, the instrumental response to the touch of the leg was much more persistent than the same response elicited by either the auditory stimuli, or tactile stimuli applied to other parts of the body. Similar results were obtained independently by Zewald (1959).

Thus, the old and well documented Pavlovian principle of the dependence of the CR strength on the CS strength should be reformulated by stating that for different types of CRs there exists a different hierarchy of strength. According to our present evidence, for the classical salivary CR the auditory CSi are stronger than the tactile CS applied to the leg, whereas for the instrumental CR the opposite is true. Thus a noticeable discrepancy exists between the type I salivary CR and type II motor CR, which is seen even in regular CR experiments, and may be even more clearly manifested by special tests, such as satiation of the animal, acute or chronic extinction, etc.

The problem arises what is the explanation of this peculiar motogenic potency of the specific tactile stimulus in comparison with other stimuli to which an instrumental CR is established.

In an attempt to approach the physiological mechanisms of CRs and their properties discovered by the Pavlov school Konorski has suggested that in the course of conditioning "actual" connections are formed between the respective centres on the basis of "potential" connections developed in ontogeny (cf. Konorski 1948, chapt. IV). Thus, the maximal strength of the given CR and its relative resistance to extinction depends on how powerful are the innate connections between the given centres.

On the basis of an ample experimental evidence, Wyrwicka (1952a, b) has shown that the "arc" of an instrumental food CR consists of two components. The connections between the centre of the CS and the centre of the instrumental response run both through the feeding centre\*, and directly (Fig. 5a). The first connections ( $S \rightarrow F \rightarrow R$ ) are responsible for the fact that the instrumental food response is "driven" by the excitation of the feeding centre, and is reduced or abolished by satiation. The direct connections ( $S \rightarrow R$ ) are responsible for the selection by the animal of the appropriate instrumental response out of many in dependence of which CS is operating in a given moment.

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\* In this paper, we understand by "feeding centre" the whole system of "centres" situated in the diencephalon and telencephalon related to food intake without going into its anatomical substrate and functional organization.



Now, one may suppose that the exceedingly strong motogenic potency of the specific tactile stimulus is due to the powerful direct connections existing between the centre of this stimulus and the relevant motor centre (Fig. 5b). The presence of such connections is manifested, among other things, by the innate cortical placing reaction to the touch applied

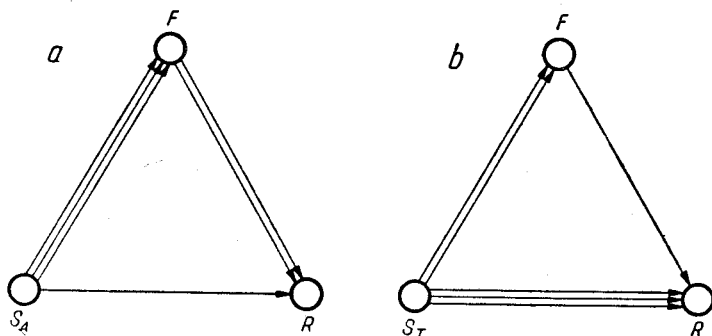


Fig. 5. Schematic representation of the instrumental CR arc to the auditory stimulus (a) and to the specific tactile stimulus (b)

$S_A$  — centre of auditory stimulus,  $S_T$  — centre of specific tactile stimulus,  $F$  — feeding centre,  $R$  — centre of instrumental response. The number of lines between centres denote the strength of particular connections

to the anterior aspect of the wrist. These very connections are "utilized" in the formation of the instrumental CR involving the movement of the touched leg.

This hypothesis seems to explain all properties of the instrumental CR to the specific tactile stimulus described in this paper.

First, as seen in Table I and II, and as confirmed by many other experiments not described in this paper, the instrumental CR to the specific tactile stimulus is established with great speed, and sometimes even after a few trials. It happens that in response to the first touch applied to the rostral side of the leg the animal raises this leg, and if this movement is reinforced by food, the instrumental CR is formed almost immediately. This result is self-evident in view of our previous considerations.

The finding indicating that the instrumental CR to the specific tactile CS is stronger than the CR to other stimuli is also obvious.

In addition, we have found that if the given instrumental CR is formed at first to the specific tactile stimulus, the transfer of this reflex to other stimuli is very slow or even impossible. This fact may be explained by the preponderance of the  $S \rightarrow R$  connections over  $F \rightarrow R$

connections in the structure of the respective CR arc (cf. Fig. 5b). In consequence, when a new stimulus, "neutral" in this respect, is introduced and reinforced by food, it cannot utilize the direct pathway  $S \rightarrow R$ , while the established pathway  $F \rightarrow R$  may be too weak to secure a proper transfer. Since the new stimulus is simply reinforced by food without the performance of the learnt movement, the classical food CR is readily formed to this stimulus, as evidenced by the conditioned salivary response elicited by it. According to the ample experimental evidence provided by Konorski and Miller (1930, 1933, 1936) and Konorski and Wyrwicka (1950), the classical food conditioned response established to a given stimulus inhibits the instrumental response. This makes the transfer of this response to a new stimulus even more difficult.

Now, we have to explain the increased resistance to extinction of the instrumental CR to the specific tactile stimulus and its prompt restoration in comparison with the CR to other stimuli.

Extinction of the instrumental CR may theoretically occur along two pathways. First, the inhibitory process may affect the pathway  $S \rightarrow F$  owing to the fact that the CS is not reinforced by food; since centre F is no longer stimulated by the CS, the connections  $F \rightarrow R$  are not put into action. The evidence of the operation of this mechanism is provided by the fact that usually the extinction of the instrumental response occurs *pari passu* with the diminution of the salivary response to the CS (Konorski and Miller 1936, Konorski and Wyrwicka 1952). Secondly, inhibition may also occur along the pathway  $S \rightarrow R$ , i.e. the movement R, no longer leading to food reinforcement, is "stamped out". The fact that the extinguished instrumental response immediately reappears as soon as the stimulus is again reinforced by food (Wyrwicka 1952a, b), provided that extinction was not overtrained, (Szwejkowska 1959) shows that the first and not the second of these two mechanisms is actually in operation, since otherwise the re-reinforcement of the CS should lead to the formation of the classical and not instrumental CR to this stimulus.

In view of these considerations we may assume that extinction of the instrumental response to ordinary CS<sub>i</sub> occurs as soon as conditioned excitation in centre F becomes too weak to produce a superthreshold excitation in centre R. On the other hand, the instrumental response to the specific tactile stimulus still persists, since it is facilitated by powerful connections existing between S and R.

However, this does not fully explain all the events observed in the course of extinction-restoration experiments. We noticed that in the course of extinction the positive CS (metronome) also became less moto-

genic than it was before, and often failed to elicit the trained movement. It was also observed that the restoration of the extinguished instrumental response to the auditory CS was strongly defective (see Table III) in spite of the fact that the restoration of the salivary conditioned response was prompt and complete (cf. Fig. 4d). One should stress that these effects have never been observed in any other chronic extinction-restoration experiments performed in our laboratory, and they are certainly connected with the general weakness of the instrumental CRs to the auditory stimuli trained side by side with those to the specific tactile stimulus. The evidence supporting this view will be provided in the next paper of this series. Anyhow, the deterioration of the instrumental CR to the positive CS in the extinction series, as well as a defective restoration of the instrumental response to the extinguished auditory stimulus, would suggest that in the course of extinction the direct pathway  $S \rightarrow R$  has also been partially affected by inhibition. This inhibition could easily attenuate the instrumental CR to the auditory stimuli, leaving their salivary effects undisturbed.

In another paper, which is now in preparation, we shall provide evidence showing that the physiological connections dealt with in this paper have in fact a definite anatomical basis. It will be shown that by cutting the fibers connecting the sensory and motor cortex of the contralateral hemisphere all the extraordinary properties of the specific tactile stimulus are abolished and this stimulus does not differ from other instrumental CSi.

#### SUMMARY

- 1) Instrumental food CRs consisting in placing the right foreleg on the platform situated before the dog were trained to various stimuli, and among them to the tactile stimulus applied to the anterior side of the wrist (specific tactile stimulus).
- 2) If the instrumental CR is trained first to the specific tactile stimulus, its transfer to auditory stimuli is prevented. If, however, the tactile stimulus applied to the body is first used in the instrumental CR training, the transfer to other stimuli occurs without difficulty.
- 3) The instrumental response to the specific tactile CS is stronger than that to the auditory CS, while the salivary conditioned response is stronger to the auditory CS.
- 4) When the specific tactile CS and the auditory CS cease to be reinforced by food, the resistance to extinction of the instrumental response to the former stimulus is much greater than to the latter, while in respect to the salivary response the reverse is true. The re-reinforcement

of the stimuli leads to a much more prompt restoration of the instrumental response to the specific tactile than to the auditory stimulus, while the restoration of the salivary response is more prompt to the auditory stimulus.

5) The peculiar motogenic potency of the specific tactile CS in comparison with other instrumental CSi is discussed.

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