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PAVLOVIAN ORIENTING REFLEX*

Bogusław ŻERNICKI

Department of Neurophysiology, Nencki Institute of Experimental Biology
Pasteura 3, 02-093 Warsaw, Poland

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Abstract. The concept of the orienting reflex is discussed from the historical perspective. The following conclusions are proposed: (1) in accordance with the spirit of Pavlov's concept the orienting reflex is a response to a stimulus unexpected in a given situation; (2) the reflex consists of targeting, arousal and perceptual components; (3) the reflex has three stages, which in the targeting component are represented by the movement towards the stimulus, the maintenance of fixation of the stimulus and the return movement; (4) when the reflex is evoked by a new stimulus, perceptual learning occurs in its second stage. The non-orienting targeting reflexes are reviewed. The pretrigeminal cat is discussed as a model for investigation of the ocular orienting reflex.

This lecture allows me an opportunity to look back to my first years of work, when under Jerzy Konorski I studied salivary conditioned reflexes in a Pavlovian chamber. My teacher, who introduced the conditioned-reflex method to the analysis of motor activity in dogs, was in his turn a pupil of Pavlov, in whose laboratory he worked for two years in the early nineteen thirties.

The concept of the orienting reflex originated in Pavlov's laboratory at the beginning of this century. Pavlov mentioned it for the first time in a lecture delivered in Petersburg in 1910 (13). Let us recall the

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* The lecture delivered at the round table "Analysis of Pavlovian conditioning" on the 50th anniversary of Pavlov's death. The round table was held during the annual meeting of the European Brain and Behaviour Society in Marseille, September 1986.

genesis of this concept. It was found that one of the factors disturbing salivary conditioned reflexes in dogs were accidental stimuli (12, 13). They were either completely new stimuli for an animal or new stimuli in a given situation. Thus they all had a common feature of being *unexpected*. These were frequently auditory stimuli, mainly accidental sounds. Chiefly for that reason Pavlov built his famous "silent tower", where experimental chambers were sound-proof.

A disturbing stimulus of that type evoked a characteristic movement of the eyes, head and sometimes of the whole body in the stimulus direction, which manifestly facilitated stimulus perception. Pavlov called such response a "what is it? reflex" and "orienting reflex". Each of these terms stressed its different characteristic and neither was especially fitting, for their literal meaning was broader than the described phenomenon (see below). With time, the second term gained acceptance.

In Pavlov's laboratory interest was taken mainly in the orienting reflexes evoked by the above mentioned stimuli devoid of definite biological significance, which were thus called "indifferent". However, the orienting reflex can be also evoked by an unexpected stimulus having a strong biological effect. In such case two situations may occur. In the first, it is owing to the orienting response that the stimulus is recognized as biologically significant and thus the orienting reflex constitutes the first stage of a chain reflex. For instance, due to the orienting reflex the animal recognizes a predator and the escape reflex follows in result. In the second situation, the stimulus elicits two responses at the same time. For example, the application of a painful stimulus to the animal's paw causes, concurrently with the flexion response, an orienting response consisting in turning of the head towards the stimulated place on the skin.

Notably, in the latter case the orienting reflex may disturb the course of its non-orienting counterpart. For example, it can inhibit or disinhibit the conditioned salivary reflex. This can be illustrated with an example from Pavlov's laboratory. After an elaboration of the salivary conditioned reflex to a definite stimulus, a new similar stimulus is applied, which elicits an orienting response and is unreinforced in order to produce conditioned differentiation. Owing to the phenomenon of generalization, this stimulus also causes salivation, but as a result of the inhibitory influence of the orienting reflex it is poor on the first trial. However, despite the lack of reinforcement the salivation gradually increases within the following trials (Table I). A gradual habituation of the orienting reflex enables a fuller manifestation of the generalization phenomenon. That process can be observed both when the new stimulus is applied several times during one experimental session

TABLE I

The liberation of generalization of the conditioned salivary reflex from external inhibition in the course of habituation of the orienting reflex. A reaction to a new, nonreinforced stimulus (square) increases for three consecutive days. The salivation (in divisions of scale) was recorded during 30 s of stimulus action. The extract from experiment in Pavlov's laboratory in 1916. (From Pavlov, 12).

Day	Time	Stimulus	Salivation	Reinforcement
28 Nov.	13.20	circle	14	yes
	13.53	square	3	no
29 Nov.	14.44	circle	16	yes
	15.00	square	7	no
30 Nov.	13.24	circle	15	yes
	13.32	square	10	no

and when it is applied only once in each consecutive experimental session (Table I). Only within a number of trials is the salivary response to the unreinforced stimulus gradually extinguished.

In Pavlov's laboratory interest was focused on the motor, directional component of the orienting reflex. In later years, chiefly in the first decades after the second World War, a number of unspecific elements of the orienting reflex were described: pupillary dilatation, EEG arousal, psychogalvanic response, increase of cerebral blood flow, etc. For that complex of reactions I propose the name of "arousal component" of the orienting reflex. It should be stressed that it is very strong in the orienting reflex. The arousal level is sufficient to prepare the animal for rapid activity, should the unexpected stimulus be biologically important.

The intensity of the arousal component and easy recording of some of its elements turned attention away from the directional component of the orienting reflex. For example, in some studies of the habituation of the orienting reflex only the EEG arousal was recorded.

Moreover, fascination with the arousal component is probably one of the reasons why many consider the orienting reflex as unspecific (see 16, 17). It is emphasized that the reflex is produced by stimuli of any modality (visual, auditory, etc.) and by both the appearance and disappearance of the stimulus. However, the directional component of the orienting reflex is certainly specific. While the magnitude of the arousal component increase with the stimulus intensity, the direction and magnitude of the directional component depends on the stimulus location. For example, a strong visual stimulus appearing at a small

distance from the fixation point of the eye, causes a large arousal but only a slight eye movement, which brings the stimulus image with precision to the center of the retina (26).

There also exists another ambiguity. The directional response, facilitating stimulus perception, obviously occurs not only to an unexpected stimulus. For that reason some authors (see 2, 8) believe that the term orienting reflex should have a broad meaning.

In my opinion, the way out of these conceptual and terminological difficulties was introduced by Konorski in 1967 who used the broad term "targeting reflex", defined as adjusting lower levels of a given sensory system for the best reception of the stimulus, mainly owing to the action of suitable effectors connected with the given receptive area (6). For example, the ocular targeting reflexes consist in turning the eyes in the direction of a given object (fixation reflex), their convergence and accommodation.

Utilizing this term and taking into consideration the original meaning of the orienting reflex, I propose to distinguish three components in it: the "targeting", "arousal" and "perceptual" components. Treating the last as a reflex component is arbitrary, as central perceptual processes are not, for the most part, a direct link of an overt reaction.

I also suggest that three stages should be distinguished in the orienting reflex. As they are clearly visible in its targeting component (Fig. 1), I shall call them "the stage of movement towards the stimulus", "the stage of maintenance of the stimulus fixation" and "the stage of return movement".

Let us analyse some properties of the orienting reflex in such sequence. One can assume that a stimulus appearing at the periphery of

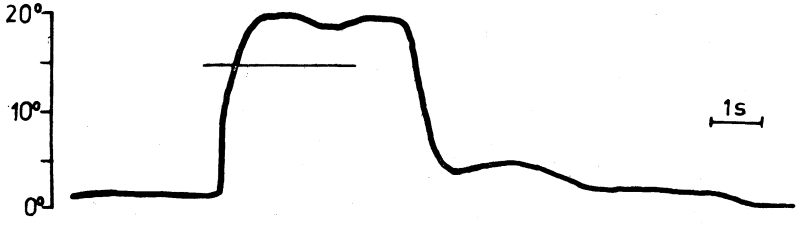

Fig. 1. Orienting fixation reflex in the cat. The stimulus was an oscillating horizontally a horizontal light slit (marked with a fine line). Ordinate: inclination of the eye; the zero point refers to the mean position of the eye of pretrigeminal cat at rest. The reflex was recorded from the right eyeball while the left was occluded. In the position of rest the eye was inclined upwardly about 2°. During maintenance of fixation the upward overshoot of the eye was about 5°. The return movement appeared about 1 s after stimulus disappearance. The reflex was recorded in the acute pretrigeminal cat. (From Żernicki, 24).

the sensory field must be immediately classified as belonging or not to a set of stimuli expected in a given situation. If the stimulus is unexpected, the orienting reflex is bound to appear, if is expected, the reflex will not follow. The orienting reflexes to expected stimuli are presumably inhibited. In this inhibition the prefrontal cortex would play an important role. In the prefrontal animal the resistance to habituation of the orienting reflex is dramatically increased (23) and this reflex can appear to conditioned stimuli (21).

During the second stage the animal presumably estimates whether or not the unexpected stimulus is already known, i.e. if it has appeared in its life. Consistently with Konorski's concept of gnostic units (6) and to some extent with Sokolov's concept of neuronal models (14, 17-20) one can assume that the properties of the stimulus are compared with the existing perceptual units for the familiar stimuli. When the perceptual unit is absent a new one can be formed (see 6). The termination of this perceptual learning can be a signal that the return movement should occur, even if the stimulus is still acting.

If the same stimulus reappears after a short time, it is to a degree expected and the orienting reflex is weaker, often as much as by half. With repetition of the stimulus, the habituation process intensifies. It can be assumed that the perceptual unit, well established due to repetition of the stimulus, can be activated even from the peripheral part of the sensory field.

Targeting reflexes, obviously, appear not only as a component of the orienting reflex. However, in the conditioned-reflex experiments the non-orienting targeting reflexes are observed infrequently. In Pavlovian experimental situations some dogs before turning their head to the food bowl take a ritual look at the conditioned stimulus, such as a moving metronome. Strong targeting reflexes are typical in instrumental conditioning experiments with dogs and cats if the stimulus source is distant from the place of food presentation (4, 9). In birds the targeting reflex appears during classical conditioning — a pigeon approaches and finally pecks at the source of the conditioned light stimulus, the so called autoshaped response (1, 2, 5). Finally, an instrumental conditioned targeting reaction can be easily elaborated by food reinforcement (15). It must be stressed that the non-orienting targeting reflex is usually accompanied by only a small arousal component and rather not by perceptual learning. In addition, it is controlled by a definite drive (e.g., hunger) and thus it does not habituate. In other words, its biological sense is different from that of the orienting reflex.

The non-orienting targeting reflexes can appear in long sequences. An animal watching its adversary during a fight may serve as example.

Such reflexes often constitute an element of complex behavior, which comprises also locomotor and manipulatory reflexes. They are directed by a definite program, controlled in its turn by a definite drive (curiosity, hunger, fear, etc). Characteristic long sequences of targeting reflexes are typical for human behavior. They as a rule serve to fill the memory store (e.g., reading a book) or have just hedonistic value (e.g., looking at a sculpture, see 22).

The targeting reflexes are more difficult for recording than locomotor and manipulatory reflexes. It is particularly hard to study the easily habituating targeting component of orienting reflexes. However, recently metodological progress has been made in this field. Eye movements, the essential element in many targeting reflexes, can be now recorded with accuracy in free-moving animals.

In our Laboratory to study the ocular fixation component of the orienting reflex we have been using the pretrigeminal cat, which is obtained by transecting the brain stem just in front of the roots of trigeminal nerves (24). Although the fixation reflex is less exact than in an intact animal, it can be more conveniently analyzed in that preparation (see 24). It is, among other things, undisturbed by other stimuli, the absence of pain stimuli being of special importance. The pretrigeminal preparation is, in a sense, a perfect Pavlovian "silent tower", in

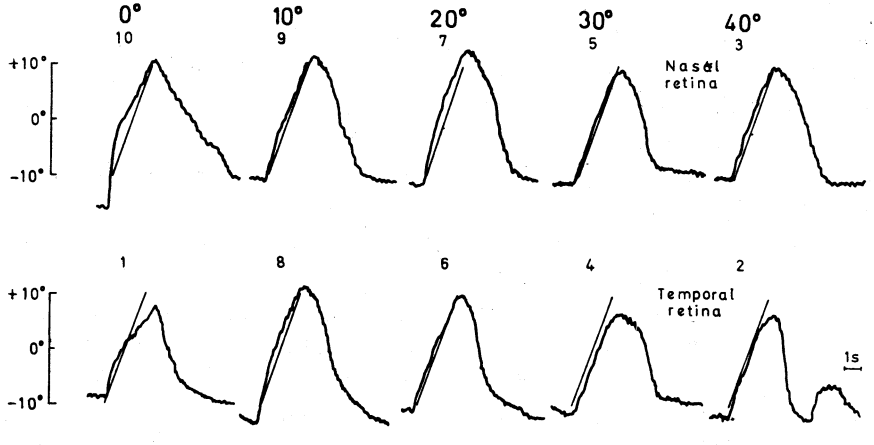

Fig. 2. Orienting ocular following reflexes in the acute pretrigeminal cat. The stimulus was the horizontal black stick (1×4°) moving upwards along the vertical meridian or parallel up to 40° in the nasal or temporal hemifield. Averaged four reflexes for each locus are indicated with heavy line and the presentation of stick with fine line. Small oscillations represent mainly the noise of the recording system. Small numbers indicate the order of four reflexes series. The resting position of the eye was continuously low, occasionally even lower than the stimulus onset position. Other explanations as in Fig. 1. (From Michalski et al., 11).

this case adapted to the study of the ocular fixation reflex. The reflex presented in Fig. 1 was recorded in the pretrigeminal preparation. We usually present a stimulus that moves across the visual field; it is much stronger than a motionless one. If the stimulus moves slowly with a constant speed, the eyeballs in the fixation stage follow it in a similar manner: the following reflex appears. Figure 2 shows orienting following reflexes produced by a small object moving vertically through different parts of the pretrigeminal cat's visual field. Due to the absence of horizontal eye movements (their coordination center lies posterior to the brain stem transection), the vertical reflex is also produced by a stimulus moving in the lateral visual field.

Using the pretrigeminal preparation we have investigated some properties of the fixation component of the orienting reflex in the cat (11, 25) and the effects of cerebral (see 24) and "environmental" (7) lesions. Figure 3 shows an example of our results. The lack of visual experience

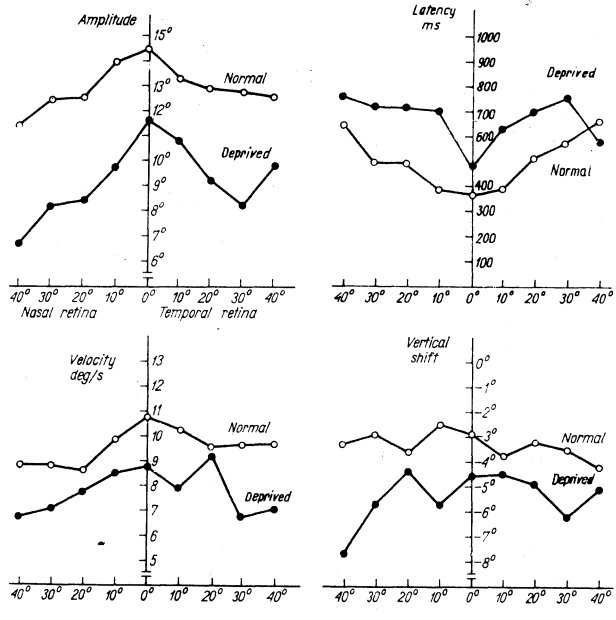

Fig. 3. A comparison of properties of orienting following reflex in normally reared cats (open circles) and cats deprived visually during the first six months of life (solid circles). Recording was done in acute pretrigeminal preparations. The stimulus was the horizontal black stick (1×4°) or the light slit of the same size moving upwards or downwards at different distances from the vertical meridian. Mean data for all cats and for four stimulus varieties (slit and stick, upward and downward movement). For the vertical shift of the following movements (last graph) negative values represent the lag of the eye movement in respect to the stimulus movement. Other explanations as in Fig. 1. (From Kossut et al., 7).

in early life (the cats were visually deprived during the first six months) has impaired the following reflex. Its amplitude and speed are decreased and its latency increased. Also, the shift between the image position and the vertical meridian of the retina is increased.

It should be added that the pretrigeminal cat is also convenient for the study of the accommodation component of the orienting reflex (3) and of some elements of its arousal component.

REFERENCES

1. BROWN, P. L. and JENKINS, H. M. 1968. Auto-shaping of the pigeon's key-peck, J. Exp. Anal. Behav. 11: 1-8.
2. BUZSÁKI, G. 1982. The "where is it?" reflex: autoshaping the orienting response, J. Exp. Anal. Behav. 37: 461-484.
3. ELUL, R. and MARCHIAFAVA, P. L. 1964. Accommodation of the eye as related to behavior in the cat. Arch. Ital. Biol. 102: 616-644.
4. GRASTYÁN, E. and VERECZKEI, L. 1974. Effects of spatial separation of the conditioned signal from the reinforcement. A demonstration of the conditioned character of the orienting response of the orientational character of conditioning. Behav. Biol. 10: 121-146.
5. HEARST, E. 1984. Signals, conditioned directed movements, and species-typical response predispositions in nonmammalian vertebrates. *In* P. Marler and H. S. Terrace (ed.), The biology of learning, life sciences research report 29. Springer-Verlag, Berlin, p. 341-355.
6. KONORSKI, J. 1967. Integrative activity of the brain. Univ. Chicago Press, Chicago, 530 p.
7. KOSSUT, M., MICHALSKI, A. and ŻERNICKI, B. 1978. The ocular following reflex in cats deprived of pattern vision from birth. Brain Res. 141: 77-87.
8. KUPALOV, P. S. and YAROSLAVTSEVA, O. P. 1949. The possibility of elaboration of conditioned orienting reflex to the functional state of the cerebral cortex (in Russian). Trudy Fiziol. Lab. Pavlova, Akad. Med. Nauk SSSR 15: 53-63.
9. ŁAWICKA, W. 1979. Auditory targeting reflexes: their determining role in directional instrumental responding. Acta Neurobiol. Exp. 39: 537-552.
10. MAJOROV, F. P. 1948. Istoriya ucheniya ob uslovnykh refleksakh. Izdat. AMN SSSR, Moskva, 374 p.
11. MICHALSKI, A., KOSSUT, M. and ŻERNICKI, B. 1977. The ocular following reflex elicited from the retinal periphery in the cat. Vision Res. 17: 731-736.
12. PAVLOV, I. P. 1927. Conditioned reflexes. An investigation of the physiological activity of the cerebral cortex. Oxford Univ. Press, Oxford, 430 p.
13. PAVLOV, I. P. 1938. Dwadtsatiletnij opyt izucheniya vysshej nervnoj deyatel'nosti (povedeniya) zhivotnykh. Med. Lit., Leningrad, 236 p.
14. ROHRBAUGH, J. W. 1984. The orienting reflex: performance and central nervous system manifestations. *In* R. Parasuraman and D. R. Davies (ed.), Varieties of attention. Acad. Press, Orlando, p. 323-373.
15. SANTIBANEZ, G. 1976. The targeting reflex. Acta Neurobiol. Exp. 36: 181-203.
16. SIDDLE, D. A. T., KUIACK, M. and STENFERT KROESE, B. 1983. The orienting reflex. *In* A. Gale and J. A. Edwards (ed.), Physiological correlates of human behaviour. Vol. 2. Acad. Press, London, p. 149-170.

17. SOKOLOV, E. N. 1960. Neuronal models and the orienting reflex. *In* M. A. B. Brazier (ed.), The central nervous system and behavior. Josiah Macy Jr. Foundation, New York, p. 187-276.
18. SOKOLOV, E. N. 1963. Perception and the conditioned reflex. Pergamon Press, Oxford, 309 p.
19. SOKOLOV, E. N. 1963. Higher nervous functions: the orienting reflex. Ann. Rev. Physiol. 25: 545-580.
20. SOKOLOV, E. N. 1975. The neuronal mechanisms of the orienting reflex. *In* E. N. Sokolov and O. S. Vinogradova (ed.), Neuronal mechanisms of the orienting reflex. Lawrence Erlbaum Associates, Publ. Hillsdale, New Jersey, p. 217-235.
21. STĘPIEŃ, I. 1974. The magnet reaction, a symptom of prefrontal ablation. Acta Neurobiol. Exp. 34: 145-160.
22. YARBUS, A. L. 1967. Eye movements and vision. Plenum Press, New York, 222 p.
23. ŻERNICKI, B. 1972. Orienting response hypernormality in frontal cats. Acta Neurobiol. Exp. 32: 431-438.
24. ŻERNICKI, B. 1986. Pretrigeminal preparation. Arch. Ital. Biol. 124: 133-196.
25. ŻERNICKI, B. and DREHER, B. 1965. Studies on the visual fixation reflex. I. General properties of the orientation fixation reflex in pretrigeminal and intact cat. Acta Biol. Exp. 25: 187-205.

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