THE INFLUENCE OF LIGHT ON THE SPONTANEOUS MOVEMENTS OF CHICK EMBRYOS

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One approach to the problem of the evolution of coordinated mechanisms is to study the role of external factors at the maturation of the afferent systems concerned in the formation of various kinds of motor activity. The object of the present investigation was to determine the influence of light on the development of motor acts, from the time of their first occurrence in the early embryo. For this purpose we used chick embryos taken between the end of the 4th day and the 9th day of incubation.

Physiological and morphological data suggest that the visual organ of the chick embryo matures functionally by the end of incubation. Thus, the motor response of embryos to light does not occur until the 17th-18th day of incubation [7, 8]. Electrical responses of the retina to photic stimulation can be observed before the 18th day of incubation [10]. Morphological and certain histo-chemical data also indicate that the specific differentiation of the original elements takes place during the second half of incubation and is not complete before the 17th day [1, 11, 12]. Thus in the period investigated (4-9th day of incubation) the eye is in a rudimentary condition. Consequently our investigations were not carried out by removal of the relevant receptor apparatus; (the experiments of Tracy [13] showed that no results could be obtained by this method at early developmental stages). In our experiment the embryo was subjected to intense light stimulation.

EXPERIMENTAL METHOD

The experiments were carried out on 50 chick embryos incubated under laboratory conditions. The movements were recorded by the mechanical and electrical device described by Voino-Yasenetskii and Moskalenko [2]. The source of light was a 500w photographic lamp giving an intensity of illumination in the plane of the object of the order of 17-20 klux. A heat-insulating filter was used, consisting of a 20 mm thickness of copper sulphate enclosed between two glass plates. Light was applied for 10-20 sec at intervals of 1-2 min, according to the frequency of movements. Records were made of these so-called "spontaneous" or non-stimulated movements of the head (on the 4th and 5th days of incubation), and of the feet (on the 6th-9th days of incubation). We investigated the duration and the nature of the separate movements, as well as their total duration in a period of 5 min.

EXPERIMENTAL RESULTS

Changes in the spontaneous motor activity under the influence of light could be elicited from the time that these movements first occurred, on the 4th day. Under conditions of intermittent illumination the total duration of the movements increased on average by 37%. The effect was chiefly due to an increase in the number of the movements, but in many cases also to their becoming more complicated. Without the illumination isolated flexion or extension of the cervical region of the body was observed, and the record took the form of a single phase of oscillation, whereas under the influence of light these movements merged into one, giving a biphasic oscillation on the trace (Fig. 1A).

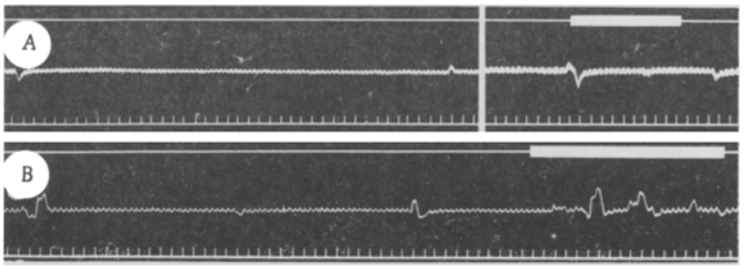

Fig. 1. Head movements of a 4-day-old (A) and a 5-day-old (B) embryo. Above, marker indicating light has been switched on, below time marker (1 sec).

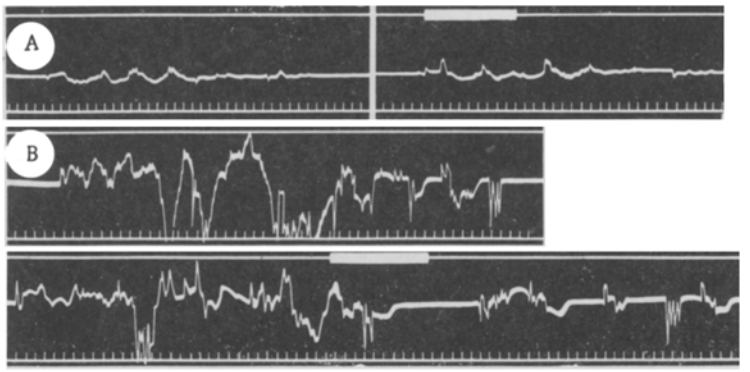

Fig. 2. Movements of the leg of a 7-day (A) and of a 9-day (B) embryo. A) Increase of the rapid component of the movements; B) Arrest of the movement after the light had been switched off. Remaining indications as in Fig. 1.

Somewhat later by the end of the 4th or 5th day of incubation the inference of light on the grouping of the solitary movements became more marked. In cases where initially only solitary movements had been observed, when the light was applied they became grouped into sets of two or three movements.

On the 5th day of incubation, under the influence of light, in all the embryos investigated the number of movements increased considerably. The duration of the movements over a 5-min period increased correspondingly, on average by 22%. The periods of movement and of rest became more clearly defined as a result of an increase in the intervals between the sets of movements, and through a shortening of the time intervals between the grouped single movements. The number of movements in a group increased sometimes by 2-3 times or more. In some cases, during the illumination a continuous movement developed (Fig. 1B), one which normally would not be observed until the 6th-7th day of incubation.

The influence of light on the 6th day of incubation was shown by a 36% increase in the total duration of the movements. This effect was mainly due to an increase in the number of the groups of movements, and to a much smaller extent to an increase of their duration. The most characteristic result of illumination of the embryos on the 6th day was a closer grouping of the movements, due to a reduction of the short intervals of rest between them which are always present in these complexes, particularly towards the end of a group. Under the influence of light these intervals were reduced on average by 47%.

On the 7th day of incubation, under the influence of light there was also an increase in the duration of the movements brought about by an increase in the number and the duration of every complex movement. However in some cases the duration of a group was shortened through a reduction in the number of slow (tonic) contractions of a limb. As far as the rapid (phasic) component of the movements was concerned appearing at this time in most cases the amplitude and the number of contractions was somewhat increased (Fig. 2A).

From the 7th day of incubation onwards there was a change in the nature of the influence of light on the compactness of the groups of movements. By the 4-6th day of incubation we observed a tendency for the isolated movements to approach each other and for the time intervals within a group to be shortened, whereas on the 7th, and particularly on the 8th and 9th days of incubation these intervals were often extended under the influence of light. Sometimes we observed short periods of arrested movement during or after the illumination (Fig. 2B).

By the 9th day of incubation, as a result of the action of the light, both the duration of a single group of movements and the total duration of the movements over the 5-min period were reduced. The duration was reduced less, because the reduction in the duration of each group was to some extent compensated (in 30% of the cases) by an increase in their number. The table below gives the figures corresponding to these facts.

From a comparison of the results of the action of light on successive days it is easy to see that the greatest activating influence was exerted at the early stages of the development of spontaneous motor activity. By the 8th day this influence had weakened, and by the ninth, according to some of the indices, the effect had reversed.

Changes in the motor activity of embryos elicited by light are not chance occurrences. Previously it has been shown [3] that the normal development of motor activity in chick embryos occurs in the first half of the period of incubation, and in the following directions; 1) There is an increase in the total duration of the movements; 2) Solitary movements are arranged in groups; 3) Superimposed on the slow movements, from the 7th day onwards a rapid (phasic) component appears, which subsequently increases in strength. Under the influence of light the motor activity changes in the direction of normal development, i.e., features characteristic of normal later stages occur. Thus it comes about that on the 4-7th days of incubation the influence of light is shown by an increase in the duration of the movements, by an increased tendency to grouping of the movements, a closer packing of the groups of movements, and an increase in their duration. The influence of light was also shown, though more weakly, in an increase of the phasic component.

This parallelism is disturbed by the eighth, and particularly by the ninth day of incubation. During this period, instead of activation there is a suppression of motor activity. An analysis of the results of the different experiments shows that in this case the nature of the action of light may depend upon the initial condition. On the 5-7th day of incubation in almost 100% of the cases, and quite independently of the initial condition, the motor activity was enhanced by light. On the 9th day in more than half the cases the total duration of the movements during illumination were related inversely to the original activity: the duration of the movements before illumination was lower than the statistical mean for this period, but under the influence of light it increased; if the initial activity exceeded the mean level, under the action of light it was decreased (Fig. 3). In other words light tended to restore motor activity to normal. In certain cases this relationship was shown also on the 8th day. (Naturally, in this case there is some lack of precision, because the established "mean level" cannot be a single normal for each embryo, but nevertheless it enables the level of initial activity in individual cases to be evaluated.)

The facts we have presented lead us to conclude that despite the low level of organization and the absence of the receptors in chick embryos at early stages, an external factor such as light is able to exert an influence on the developing mechanisms of motor acts. At present it is not clear how such influences are mediated. From published reports it is difficult to suppose that at this period the eye is involved by virtue of its photoreceptors. The results of

Influence of Light on Certain Characteristics of the Motor Activity of Embryos (as percentage of original values)

Day of incubation	No. of isolated movements	Total duration of movements in 5 min	Mean duration of groups	Intervals within groups
4	141±14	137± 7,7		
5	143±14	122± 7,8	156± 1,6	70±8
6		136±12	115±13	53±3,8
7		134± 5,6	119± 8,2	
8		120±11,4	102± 5,7	
9		92± 6,2	77± 4,6	

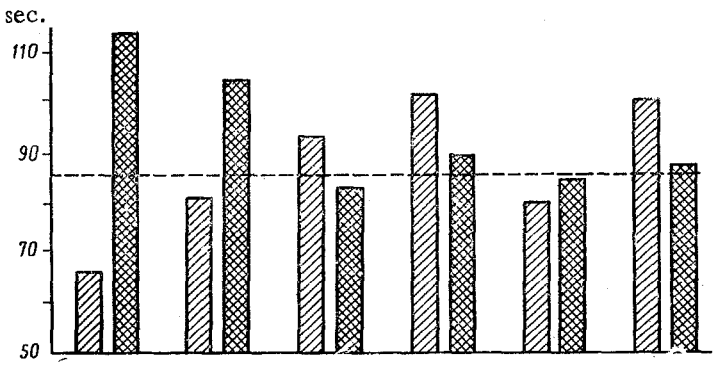

Fig. 3. Relationship between the total duration of the movements of 9 day embryos exposed to periods of illumination (light columns) as compared with the initial activity (dark columns). Each pair of columns is the result of separate experiments. The height of the column represents the time of movement in sec during a 5-min period. The dotted line is the statistical mean level of activity.

phylogenetic studies [5, 6] in this direction indicate the possibility of responses by organisms to light in the absence of any specialized receptor structure. Possibly during the period investigated the response of the embryos to light was due to such primitive forms of photoreception as, for example, cutaneous or muscular receptors. Also, we must not exclude the possibility of a direct influence of light on the motor centres of the spinal cord. Indirect evidence of the possibility of cutaneous photoreception is afforded by changes in the nature of the influence of light on motor activity after the seventh day of incubation, because it is just at this period that a functional connection of the cutaneous receptors with the spinal cord and with the motor neurone has been established.

SUMMARY

In experiments on chick embryos made between the 4th and 9th day of incubation it was found that the light influenced motor activity as soon as it set in. Initially the effect was activation, but after seven days of incubation it became inhibitory. A characteristic feature was that the effect of light was inversely related to the initial level of activity.

LITERATURE CITED

1. Ya. A. Vinnikov, The retina of the eye of vertebrates [in Russian], Moscow (1947).
2. A. V. Voino-Yasentskii and Yu. E. Moskalenko, Fiziol. Zh. SSSR, No. 9, (1961) p. 1205.
3. A. V. Voino-Yasentskii and A. V. Bursian, Fiziol. Zh. SSSR, No. 5, (1963) p. 609.
4. A. A. Volokhov, Features of the ontogenesis of nervous activity in the light of evolutionary knowledge. [in Russian], Moscow, Leningrad (1951).
5. A. A. Zavarzin, Outlines of evolutionary histology of the nervous system, [in Russian], Moscow, Leningrad (1941).
6. L. P. Zagorul'ko, The photoreceptor function of the skin of the frog, and certain mechanisms for its regulation. Candidates dissertation, Leningrad (1936).
7. V. I. Chumak, In book: Problems of the physiology and pathology of the central nervous system of man and of animals in ontogenesis. [in Russian], Moscow, (1961) p. 63.
8. Z. Y. Kuo, J. exp. Zool., (1932) Vol. 61, p. 395.
9. D. W. Orr and W. F. Windle, J. comp. Neurol., (1934) Vol. 60, p. 271.
10. M. A. Patetta Queirolo and E. Garcia-Austt, Electroenceph. clin. Neurophysiol., (1956) Vol. 8, p. 155.
11. S. C. Shen, P. Greenfield, and E. J. Boell, J. comp. Neurol., (1956) Vol. 106, p. 433.
12. A. Stafenelli, E. Cataldi, and L. A. Jerard, Atti Accad. naz. Lincei. Rend. Cl. sci. fis., mat. e. natur., (1961) Vol. 30, p.664; H. C. Tracy, J. comp. Neurol., (1925-1926) Vol. 40, p. 253.