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REACTIONS OF CHICKS TO VISUAL CHANGES DURING THE FIRST TEN DAYS AFTER HATCHING

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The behaviour of young precocial birds a few days after brief or extended exposures to conspicuous objects has been extensively studied (Sluckin 1964; Bateson 1966). In these experiments the young bird is often subjected to a complex environmental change in which it is carried by the human observer to a strange pen and its reaction to a conspicuous, often moving, object assessed. Birds of different ages react in different ways to such a situation. Bateson (1964) exposed naive chicks to a model in a runway on days 1 to 5 after hatching and found that the percentage of birds following was greatest on the first day and the percentage of birds avoiding was greatest on day 5. Similarly, Schaller & Emlen (1962) scaled avoidance reactions shown by various species of precocial birds when an object was suddenly pushed towards them and found that the reaction increased with age from 10 to 140 hr.

The behaviour of a bird in such tests is likely to be affected by any contact with the observer, perhaps the only moving object previously seen by that bird. In the experiments described here I have therefore studied the reactions of young chicks to changes in their visual environment which could be brought about without the chick detecting the presence of the observer. In the first experiment chicks were subjected to one of five changes at either 2, 6 or 10 days of age. The second is a more detailed study of the changes, over the first 10 days, in chicks' reactions to one of the tests.

In order to assess the reactions to a test situation, it is necessary to be able to compare the behaviour after the environmental change with that of the same birds while completely undisturbed (Broom 1969). These experiments have been designed to allow such comparisons.

Methods

Subjects

Eggs of a breed ('Chunkies') of domestic fowl were transported from a commercial hatchery to Glevum Superior incubators 3 to 4 days prior to hatching. They were placed in the incubators so that each egg was touching at least one other egg in order that any mechanisms for synchronization of hatching might be maximally effective (Vince 1964; 1966a & b). Seventy-five per cent of the eggs hatched during a period of 6 hr and the chicks were transferred to rearing pens when 2 to 8 hr old (experiment 1) or 9 to 15 hr old (experiment 2). The incubator was darkened and transfer was effected using an opaque box with a lid so that chicks did not see one another or the experimenter for more than a maximum of 30 sec.

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Conditions of Rearing and Observation

The chicks were kept in visual isolation in pens with a floor area of 700 cm^2 and with 23-cm high hardboard walls painted matt grey. In experiment 1, where overhead illumination was varied, the roof of the pen was translucent 'opal' Perspex with a tubular filament bulb above it and one wall was made of wire netting. In experiment 2 the roof of the pen was wire netting. A 6V, 0·3A torch-bulb was mounted 12 cm from the ground in the centre of one wall of each pen. This bulb was fixed in a grey-painted metal holder and could be silently illuminated by the experimenter.

All birds had ample food and water at all times. A standard measure of chick crumbs was put into each pen prior to transferring the chicks to the pens and at 5, 7 and 9 days. In experiment 1 water was supplied by a pipe with a 5-cm diameter hole on the upper surface in each pen. Chicks could easily drink from these holes and the pipe could be filled without disturbing the birds. In experiment 2 water dishes were provided which were filled on days 2 to 10. The mean temperature in each pen was maintained at 29° to 34°C.

During the feeding operations at 5, 7 and 9 days in both experiments and the provision of water on days 2 to 10 in experiment 2, one arm and the head of the experimenter were visible to each chick for 5 to 10 sec. Apart from this, the chicks did not see any humans during rearing

or testing for their pens were shielded by hardboard and black cloth partitions from the part of the room which the experimenter entered. The behaviour of the chicks could be watched from darkness through one-way plastic film so that the chicks could never see the experimenter. This was checked by looking at the observation points from the position normally occupied by the chicks. Chicks never fixated an observation point. All the experimenter's movements were kept as quiet as possible and a 5-min interval after reaching the observation position was always allowed before any recording. This was started at least 30 min after feeding or water provision, if this took place on the day of observation, and occurred between 09.00 and 13.00 hours GMT.

Several batches of eggs were necessary for both experiments. There appeared to be few differences between batches in any respect, but within each batch the number of birds allocated to each test condition and each testing age were kept equal so far as was possible. Each bird was tested once but, whatever the age when tested, all birds remained in their pens until 10 days old. The experiments were designed so that for each combination of age and test conditioning, N = 12. Since a few birds died, N varied from 9 to 12.

Testing and Recording Procedure

Experiment 1. The testing and rearing conditions were varied in one of two ways. (1) The torch-bulb on the wall of the pen was either illuminated, using a constant voltage supply, or not illuminated. (2) The diffuse overhead illumination provided by a tubular, filament bulb above an 'opal' Perspex sheet 4·8 mm thick was made 'high' or 'low' by adding or removing a resistor from the circuit. The sizes of the resistors in this circuit were adjusted so that the average of six readings from a Weston Master 5 light meter, taken at 90 degrees to one another in the centre of the pen, was the same as that obtained by this method when the torch-bulb was on (4·2) or off (2·6). The effect of these illumination differences on the temperature of the pen was negligible.

The birds were watched for: (1) 15 min while undisturbed, (2) 15 min after the observer had moved a single, silent slide-switch which altered the illumination in one of the 5 ways, and (3) a further 15 min after the illumination had been returned to its initial level. The five experimental changes are detailed in Table I.

Birds' activities were recorded by means of an Edgcumbe moving-paper event recorder whose twelve pens could be deflected by means of a switchboard on the lap of the observer. The switches were selected for their quietness and modified so that they made less noise than a chick's footfall. The event recorder was kept in a different room from the chicks since it made some noise when the pen was deflected.

The behaviour observed was coded on to the twelve channels of the event recorder using the 'period occurrence' technique. At the end of successive 10-sec periods, each of fifteen measures of behaviour were recorded by a pen deflection (or two) if they had occurred in that period. Using this method, two or three animals could be observed at once but every activity seen during the watch was shown on the final record. The disadvantage that no differentiation is made between activities which occur continuously and those which occur once during each period was minimized by making the period as

Table I. Description of Five Experimental Changes

Group	Rearing condition— 15-min watch			Testing condition— 15-min watch			Return— 15-min watch
	Diffuse illuminaton from above	Bulb on wall	Mean light intensity (Weston 5)	Diffuse illumination from above	Bulb on wall	Mean light intensity (Weston 5)	
1 Brighter	low	off	2·6	high	off	4·2	Return to rearing conditions
2 Dimmer	high	off	4·2	low	off	2·6	
3 Dimmer, Bulb-on	high	off	4·2	low	on	4·2	
4 Bulb-on	low	off	2·6	low	on	4·2	
5 Bulb-off	low	on	4·2	low	off	2·6	

short as possible. The 10-sec intervals were indicated by means of a tape recorder, in an adjacent room, connected to an earphone 1 to 2 cm from the ear. This noise could not be heard by the chicks.

Calls were arbitrarily classified into only two groups, 'loud calls' and 'twitters'. Chicks seemed able to make calls, which appeared as various shapes on a sonogram, both quietly and loudly but 'twitter' calls were almost always quiet. The conclusion that a continuum exists in chick calls was in agreement with Andrew (1964). An elaborate analysis like that of Guyomarc'h (1966) might reveal new information but would require continuous tape recording during observation.

Experiment 2. The procedure was the same as that for experiment 1 except that only one change was used, the illumination of the torch-bulbs in pens at the lower of the two illumination levels, and the behaviour after the return to initial illumination was not watched. The chicks were tested at one of the following ages: 1½, 2½, 3½, 4½, 5½, 6½, 8½, or 10½ days after hatching.

Results

The initial reaction (3 sec) to a change was the same for all birds tested. Provided the chick was awake when the change occurred, it started suddenly or abruptly stopped whatever it was doing and fixated the torch-bulb if this had been illuminated or extinguished. This reaction, which was also observed when the reverse change was brought about, habituates after successive presentation of the same change (Broom 1968).

After the first 3 sec there is a period during which most of the chick's activities are recorded less frequently than among undisturbed birds. This period of reduced activity may start as complete immobility and occasionally merges gradually into sleep. After some time the frequency of activities returns to the undisturbed level but there is often a subsequent period of increased activity when the chick may jump up the sides of the pen and peck at the walls.

Vocalizations are loud and frequent after the environmental change and may continue even if the chick is immobile. Twitter calls reappear when the other activities of the chick return to the undisturbed level.

Figure 1 shows, for 5-day-old birds, the change in the median percentage of 10-sec periods in which four measures of behaviour were recorded at 3-min intervals after the illumination of a torch-bulb in the pen.

Where a modification of behaviour was still evident at the end of the 15-min test situation, the behaviour usually returned towards the undisturbed level when the reverse change occurred.

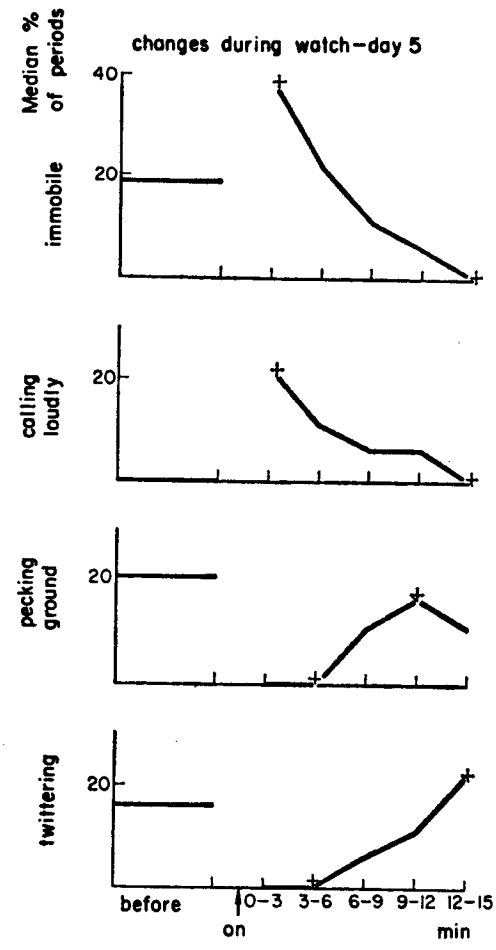

Fig. 1. Behaviour of chicks while undisturbed and after illumination of a torch-bulb in their home pen. Each point is the median of 12 birds. Wilcoxon tests comparing points marked + : 'immobile' and 'calling loudly' $P<0{\cdot}01$, 'pecking ground' $P=0{\cdot}1$, twittering $P<0{\cdot}1$ (all 2-tailed).

The reactions of birds of various ages to the several tests used have been quantified in two ways: firstly by the increase or decrease, as compared with the undisturbed level, in the frequency with which each measure of behaviour was recorded in a period of time after the change, and secondly by the delay before the undisturbed level of each activity was reached.

In experiment 1 the differences between tests

in their effects on behaviour were apparent at all ages and the differences between ages were in the same direction in each test. The results described under the heading 'Test Differences' refer to experiment 1. The effects of increasing age on the reactions of chicks to a visual change were the same in experiments 1 and 2 so the results of the more detailed study in experiment 2 are reported under the heading 'Age Differences.'

Test Differences. It has been established (Broom 1969) that there are no large differences in activity while undisturbed between birds reared at the two levels of illumination used in these tests. There were however differences in the reactions of chicks to the various tests.

Birds subjected to tests 2 (dimmer) and 5 (bulb-off) gave fewer loud calls after the initial change than did those subjected to tests 1 (brighter), 3 (dimmer, bulb-on), or 4 (bulb-on). The increase was greatest in tests 3 and 4 in which a torch-bulb was switched on. The percentage of birds calling loudly in the 15 min while undisturbed (B), after the change (C), and after the return (R) is shown in Fig. 2 for each age and each change. Table II shows the results of Wilcoxon tests on this data and Fig. 3 shows that most birds called loudly just after bulb-on in tests 3 and 4 and the period of loud calling extended for longer in tests 1, 3 and 4 than in tests 2 and 5.

A period of reduced activity or immobility followed all of the initial changes but was prolonged if the illumination level was low after the change. Fig. 4 shows the median percentage of periods in which any movement occurred that included one or more of the following activities: walking, preening, pecking the ground or wall, drinking, or twittering. Wilcoxon tests comparing undisturbed levels and levels after the change gave a value of $P<0{\cdot}01$ (2-tailed) for the decrease in test 2 at 2 days and 10 days and in test 5 at 2, 6 and 10 days. There was no decrease for which $P<0{\cdot}01$ in tests 1, 3, and 4.

It can be seen from Fig. 4 that the activities of all the 6-day-old birds gradually increased after the drop when the change occurred. This increase was continued after the reverse change in tests 1, 3, and 4 so that the final level was higher than the undisturbed level but when the illumination conditions were restored to their previous level in tests 2 and 5, the activity of the birds rapidly recovered to the undisturbed level.

A reduction in illumination level depressed chick activity but otherwise caused a less marked reaction than did other tests. Calling could have continued despite reduced activity. The similarity of the results of tests 3 and 4 indicates that the increase in the mean illumination level which occurred in 4 but not in 3, was less important than the sudden appearance of a point source of light in determining the reactions of a chick.

Age Differences. The differences between

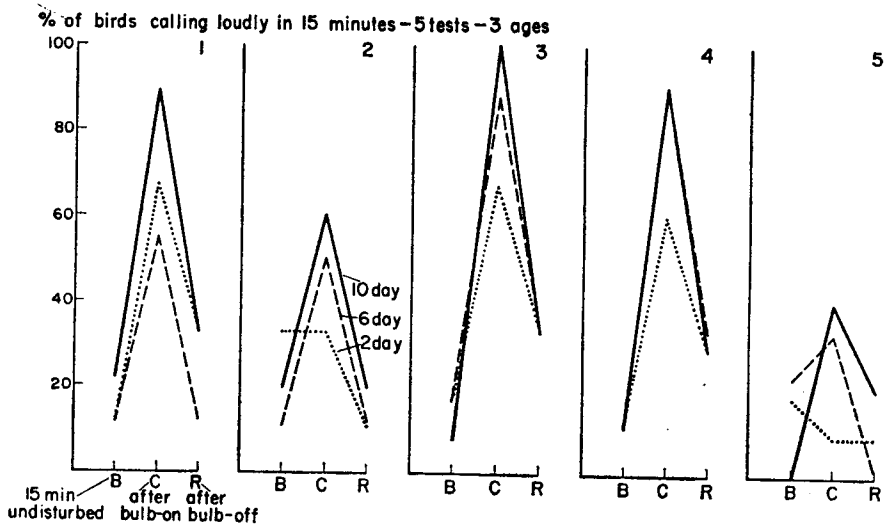

Fig. 2. The increase in loud calls by all chicks after bulb-on was greatest in tests 3 and 4 and least in tests 2 and 5. Older chicks showed a larger increase than younger chicks.

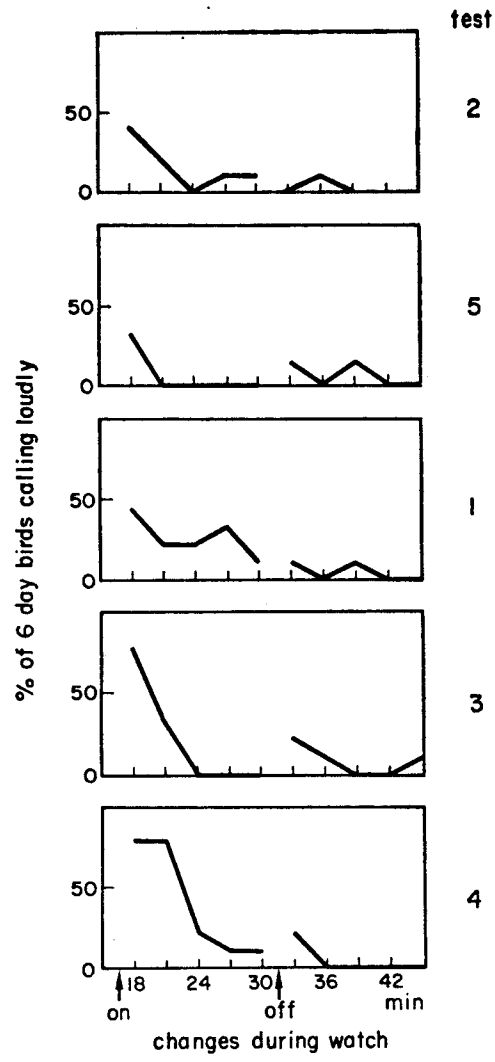

Fig. 3. Behaviour of chicks in successive 3 min intervals after an illumination change (15 to 30 min) and after return to previous level. Each point is the median of 9 to 12 birds.

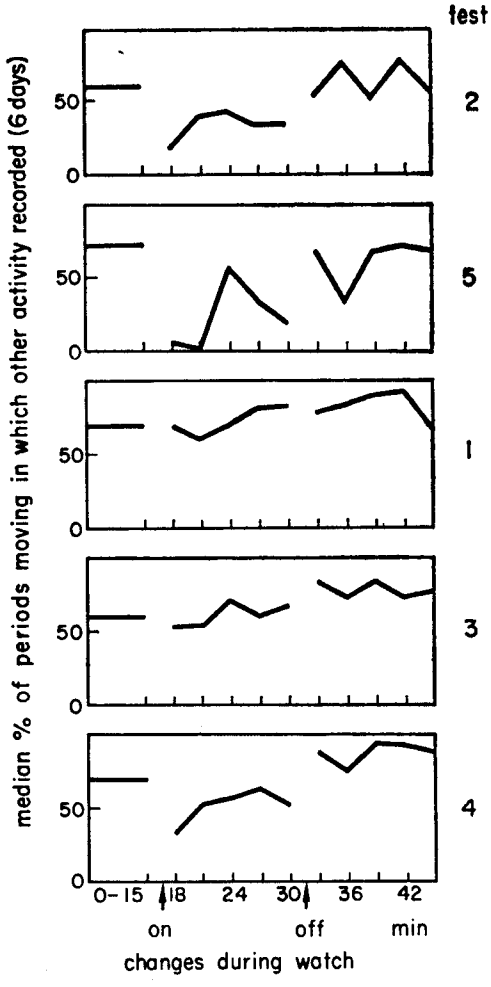

Fig. 4. Behaviour of chicks while undisturbed (0 to 15 min) and in successive 3-min intervals after an illumination change (15 to 30 min) and after return to previous level. Each point is the median of 9 to 12 birds.

younger and older chicks in their reactions to the illumination of a torch-bulb are more quantitative than qualitative. In both experiments the reactions of older birds were initially more obvious to an observer, and the durations of those reactions were greater. For a thorough analysis of the differences between birds of different ages, many measures of behaviour were used.

Jumping and calling loudly were very rare among undisturbed birds, so the data after the change for different ages can be compared using a Mann–Whitney U test. There was considerable individual variation in the number of calls given but older birds called more (comparison of day $5\frac{1}{2}$ and day $1\frac{1}{2}$ $P<0{\cdot}02$) and jumped more (day $8\frac{1}{2}$ v. day $1\frac{1}{2}$ $P=0{\cdot}033$, day $10\frac{1}{2}$ v. day $1\frac{1}{2}$ $P=0{\cdot}01$, all 2-tailed).

Other behavioural measures also indicate a greater reaction to the environmental change by older birds. A direct comparison of ages is not possible since older birds are more active at all times (Broom 1969) so the activity after the change must be compared with that while undisturbed.

The change with age in the duration of the

Table II. Results of Two-tailed Wilcoxon Tests Comparing Undisturbed Level (B) with Level after Change (C) and (C) with Level after Return (R)

Test	1		2		3		4		5	
Comparison / Age	B v. C	C v. R	B v. C	C v. R	B v. C	C v R	B v. C	C v. R	B v. C	C v. R
2 day					+ <0·02					
6 day	+ 0·1	— 0·1	+ 0·1		+ <0·01	— 0·05	+ 0·05	— 0·05		
10 day	+ <0·01	— 0·01	+ <0·1		+ <0·01	— <0·01	+ 0·01	— <0·01		

+ indicates an increase and — a decrease. No figure is included if the comparison gave a value of $P>0{\cdot}1$.

reactions is exemplified in Fig. 5 by the median number of periods during which the birds were immobile after successive 3-min intervals during the test. The older birds took longer to drop to the undisturbed level of percentage of time immobile (Table III), longer to reach their minimum level after bulb-on, and longer before they moved in every 10-sec period out of 3 min. Table III shows the delay after bulb-on before returning to the undisturbed levels of moving, pecking the ground and twittering. The delay is very short at 1½ days but increases considerably by 2½ days and goes on increasing until 10½ days.

As a consequence of these changes in the duration of the reaction to bulb-on by birds of different ages, the total frequency of the various measures at a fixed time after bulb-on, e.g. 15 min is more likely to show an increase among young birds but an overall decrease among older birds. The reduced activity period occupies a greater proportion of the 15-min test at 10½ days than it does at 1½ to 3½ days. Thus, when the median number of 10-sec periods moving in the 15 min after bulb-on was compared with the median for the same birds while undisturbed, the result was a decrease for the first 3 days (day 1½ $P<0{\cdot}05$, 2½ $P<0{\cdot}02$, 3½ $P<0{\cdot}01$) but an increase for older birds (day 6½ $P = 0{\cdot}02$). The measures twittering, pecking the ground, walking and moving near the bulb also showed an increase among younger birds but a decrease or no change among older birds.

Some measures of behaviour were not affected by the change with age in the duration of the period of reduced activity. In addition to 'calling loudly', 'jumping' and 'pecking the wall' showed an increase over the undisturbed level at all ages. Both of these might be interpreted as attempts to get out of the pen and away from the unfamiliar light. The median number of periods 'preening' or 'drinking' did not reach the undisturbed level by the end of this 15-min test at any age.

I have summarized comparisons between the 15 min while undisturbed and the 15 min after bulb-on in Fig. 6. The measures at the top of the figure are those which showed a decrease at all ages while the increase becomes more dominant with progression down the figure, until at the bottom, the measures showed it at all ages tested. The arrangement of measures is entirely based upon the direction of the change in 15 min after bulb-on. The four measures which showed a 5 to 6 day peak (Broom 1969) while undis-

Table III. Median Time (min) during Test before Activity Recorded as much as while Undisturbed

Day	Moving	Pecking ground	Twittering
1½	1½	4½	7½
2½	4½	6	12½
8½	7½	10½	15+
10½	9	15+	15+
Mann–Whitney U test (2-tailed)			
1½ v. 2½	>0·1	>0·1	0·06
1½ v. 8½	<0·02	<0·02	<0·02
1½ v. 10½	<0·02	<0·02	<0·02
2½ v. 10½	<0·03	0·04	>0·1

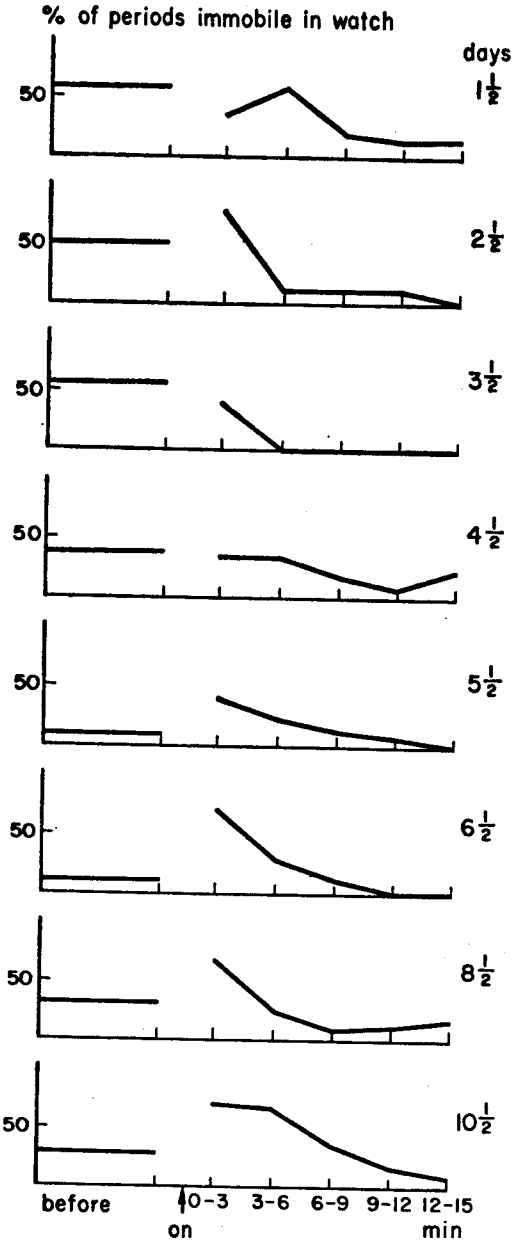

Fig. 5. Behaviour of chicks while undisturbed and after illumination of a torch-bulb in their home pen. Each point is the median of 9 to 12 birds.

turbed, those which are the characteristic activities of undisturbed birds, are all in the upper half of this Figure, while those which did not show such a peak, with the exception of 'drinking', showed more of an increase.

The changes on day 10½ were generally the most pronounced while those on day 1½ were smallest. This is shown at each stage during the test but is most obvious when the undisturbed level is compared with the 3 min after bulb-on. Such a comparison shows a decrease for most measures, if there was a change, for the effect of the period of reduced activity was evident at most ages. The decrease was, however, shown by the most measures at 10½ days and by the least at 1½ days.

Some components of reactions to environmental change are common to birds of all ages but, using the measures of behaviour described, the reaction becomes more obvious to the observer and more prolonged as the chick gets older. The increase in reaction is most pronounced between the 1st and the 2nd or 3rd days but there is still some increase between the 6th and 10th days.

Discussion

In experiment 1, chicks reacted to each change in the same way initially but their further reactions differed in duration and in the extent that they were obvious to an observer according to the change. The largest increase in calling loudly occurred if a torch-bulb was illuminated and the duration of the period of loud calling was greater if the overall illumination level was raised than if it was reduced. Activity levels were affected by the illumination level after the change. They recovered to the undisturbed level more quickly on return to the rearing condition, if that change had been a decrease in illumination.

Since similar results were obtained at each of the ages studied, it seems likely that all the chicks were able to detect the different changes. As far as can be tested, a chick is just as capable of discriminating quite small visual differences a few hours after hatching as at 1 week old (Tallarico 1961; Fishman & Tallarico 1961). After the initial reaction the period of reduced activity, often complete immobility first of all and then some movement and loud calling, occurs for any large, novel environmental change but the subsequent period of increased activity may be specific to a novel increase in illumination level.

The interpretation of these results, which shows that the duration of the various stages in reactions to an environmental change affects the overall frequency of activities in a test of fixed length, may account for some of the results of Hogan (1965). He studied the reactions of jungle

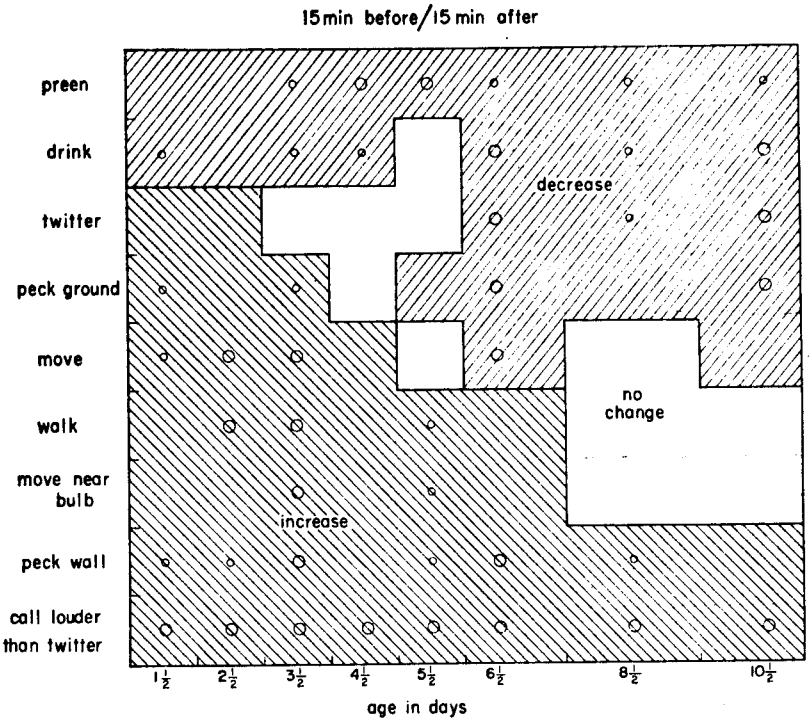

Fig. 6. Each of the nine horizontal lines indicate the difference between the percentage of periods in which the behaviour was recorded before bulb-on and that after bulb-on at ages from 1½ to 10½ days. The results of a 2-tailed Wilcoxon test is shown at each point (o. . . . . $P<0{\cdot}1$, O . . . . $P<0{\cdot}02$).

fowl chicks, 4 to 12 days old, to a mealworm and found that birds tested in a strange pen moved, pecked and preened less than did birds watched in their home pen. When the strange pen was in the familiar room, 'shrill calling' increased and 'sleeping' decreased as compared with the home pen results, but when that pen was in a strange room there was a large increase in 'sleeping' but no change in 'shrill calling'. It seems likely that the period of immobility was more marked among birds tested in both a strange pen and a strange room.

In experiment 2, 1½-day-old birds showed the smallest number of changes in their behaviour when their environment was changed, and became habituated to the change most quickly. Older birds showed a more obvious and a more prolonged reaction to the change. These findings are of particular interest in view of work on brain recording. Tuge, Kanayama & Yueh (1960) found that a depression in EEG was just detectable after the illumination of a very bright light near a chick on the last day before hatching but that this depression became successively more marked at 3 and 6 days after hatching. Corner, Peters & van der Loeff (1966) recorded from the cerebral hemispheres and found that the duration of a desynchronized period following a sudden sound was considerably shorter on day 1 than on subsequent days.

My results are also in accord with those of Kaufman & Hinde (1961), Schaller & Emlen (1962), Bateson (1964), and others who have found that actions such as calling loudly on moving away are more frequent amongst older than amongst younger birds if their environment is sufficiently changed. An increase in the duration of chicks' reactions with increasing age was also shown by Hogan (1966). Working with jungle fowl, he found that birds presented with a mealworm for the first time on days 1, 2, 4 or 7 ran around carrying that mealworm for the longest period at 7 days and for the shortest on the first day, before eating it.

A chick, or any other animal, must learn the characteristics of its immediate environment over a period of hours and days and must therefore be more familiar with that environment when

older. The 'model' of the long-term surroundings which the bird has formed is more firmly established among older birds so that their mechanism for detecting a change will reveal a greater discrepancy and will be followed by a greater behavioural change than would occur in a younger bird. This idea that the extent of the reaction of an animal to a novel experience is related to the nature of the previous experience, i.e. to the degree of novelty, has been proposed by Bindra (1959), Kruijt (1964) and others.

Summary

The reactions shown by young chicks to environmental changes were estimated by comparing their behaviour whilst undisturbed with that after the change. The observer was not a part of the rearing or testing conditions.

After a brief, general reaction to any change, naive 2-, 6- and 10-day-old chicks showed a greater, more prolonged reaction to an increase in illumination, especially if due to a torch-bulb, than to a decrease. The magnitude and duration of chicks' reactions to torch-bulb illumination increased from 1½ to 10½ days, particularly during the first 2 to 3 days.

It is assumed that animals gradually learn the characteristics of their environment and that the results of this learning, which might collectively be called an environmental model, form the basis for comparisons made when the environment changes. The reaction to a change is greater if the model has had longer to become established.

Acknowledgments

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REFERENCES

Andrew, R. J. (1964). Vocalization in chicks, and the concept of 'stimulus contrast'. *Anim. Behav.*, **12**, 64–76.

Bateson, P. P. G. (1964). Changes in chicks' responses to novel moving objects over the sensitive period for imprinting. *Anim. Behav.*, **12**, 479–489.

Bateson, P. P. G. (1966). The characteristics and context of imprinting. *Biol. Rev.*, **41**, 177–220.

Bindra, D. (1959). *Motivation.* New York: Ronald Press Co.

Broom, D. M. (1968). Specific habituation by chicks. *Nature, Lond.*, **217**, 880–881.

Broom, D. M. (1969). The behavior of undisturbed 1–10 day old chicks in different rearing conditions. *Develop. Psychobiol.*, **1**, in press.

Corner, M. A., Peters, J. J. & van der Loeff, P. R. (1966). Electrical activity patterns in the cerebral hemisphere of the chick during maturation, correlated with behaviour in a test situation. *Brain Res.*, **2**, 274–292.

Fishman, R. & Tallarico, R. B. (1961). Studies of visual depth perception: II. Avoidance reaction as an indicator response in chicks. *Percept. mot. Skills*, **12**, 251–257.

Guyomarc'h, J-C. (1966). Les émissions sonores du poussin domestique, leur place dans le comportement normal. *Z. Tierpsychol.*, **23**, 141–160.

Hogan, J. A. (1965). An experimental study of conflict and fear: an analysis of behaviour of young chicks towards a mealworm. I. The behaviour of chicks which do not eat the mealworm. *Behaviour*, **25**, 45–97.

Hogan, J. A. (1966). An experimental study of conflict and fear: an analysis of behaviour of young chicks towards a mealworm. II. The behaviour of chicks which eat the mealworm. *Behaviour*, **27**, 273–289.

Kaufman, I. C. & Hinde, R. A. (1961). Factors influencing distress calling in chicks, with special reference to temperature changes and social isolation. *Anim. Behav.*, **9**, 197–204.

Kruijt, J. P. (1964). Ontogeny of social behaviour in Burmese red jungle fowl (*Gallus gallus spadiceus*). *Behaviour* Suppl., **XII**:

Schaller, G. B. & Emlen, J. T. (1962). The ontogeny of avoidance behaviour in some precocial birds. *Anim. Behav.*, **10**, 370–381.

Sluckin, W. (1964). *Imprinting and Early Learning.* London: Methuen.

Tallarico, R. B. (1961). Studies of visual depth perception: III. Choice behaviour of newly hatched chicks on a visual cliff. *Percept. mot. Skills*, **12**, 259–262.

Tuge, H., Kanayama, Y. & Yueh, C. H. (1960). Comparative studies on the development of EEG. *Jap. J. Physiol.*, **10**, 211–220.

Vince, M. A. (1964). Social facilitation of hatching in the bobwhite quail. *Anim. Behav.*, **12**, 531–537.

Vince, M. A. (1966a). Potential stimulation produced by avian embryos. *Anim. Behav.*, **14**, 34–40.

Vince, M. A. (1966b). Artificial acceleration of hatching in quail embryos. *Anim. Behav.*, **14**, 389–394.

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