FACTOR ANALYSIS OF OPEN-FIELD BEHAVIOR
(OFB) IN CHICKS: AN ETHOLOGICAL
RECONSIDERATION

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Open-field (OF) test was first introduced by HALL (1) in order to measure the emotionality of rats. Since then a number of researchers of animal behavior have been using OF as a rather standardized situation for many other species as well. In spite of its prevalence, the meaning of this situation to the animal placed in it is not yet equally recognized by all researchers that use it. Some report that open-field behavior (OFB) reflects fear to the novel setting or general emotionality, others that it reflects exploration. MAKINO (2) and FUJITA (3) suggested that OFB was not one specific aspect of the animal's states, but involved some groups of behavior. One of the causes which make OFB obscure may be that the observation and measurement made by many researchers are restricted only to a few categories of OFB, *e.g.*, latency, general activity (locomotion), and/or defecation, while other various behaviors frequently occurring in OF are ignored by most investigators except for JONES (4, 5, 6).

The present study reexamined the meaning of OF to the animal and the function of OFB in the animal. The standpoints of this study are as follows:

First, OFB is investigated from an ethological point of view, that is, in terms of its ecological meaning in the natural habitat of the species concerned. GALLUP and SUAREZ (7) reconceptualized OFB in chicks from an ethological point of view. They suggested that OF had two meanings to chicks. One was that chicks were confronted to potential predators by being placed into the novel situation. Chicks

behave to decrease the possibility of being detected by potential predators. They attributed the latency of distress call and the latency of locomotion to this meaning. The other was that OF was a setting in which the animal was separated from the attachment objects, *i. e.*, the mother hen and peers. Chicks behave to increase the possibility of finding or reinstating contact with attachment objects. From these suggestions the possibility must be considered that meanings of OF are different depending on the species concerned, and also on developmental stages of the animal, because the ecological status may change over the developmental stages of an identical animal.

Second, the structure of behaviors is considered. As described above, in most studies to date only a few measures have been taken and analysed separately, *i. e.*, unstructurally. In his studies (4, 5, 6) JONES selected 17 measures as OFB but analysed separately. In fact, each behavior does not occur independently from each other, but is related to each other. The relations between behaviors must also be clarified in order to extract available and valid informations from OFB. Since one or two decades quantitative methods of extracting inherent structures of behaviors have been spreading in the field of ethology (8, 9). By these methods a vast of observed data can be meaningfully clumped, from which the underlying structures will be clarified. In the present study, as various behaviors as possible occurring in OF were measured. The factor analysis, which is a powerful tool for reducing various data to a small number of meaningful groups (factors), was applied to the data.

Method

Subjects and housing:

The subjects were 121 white leghorn chicks. Eggs were obtained from a commercial supplier and incubated in a forced draft incubator (Showa Electric Incubator P-01) at 37.5 °C. After hatching the chicks were housed in groups of 4-6 each in the home cages (wooden boxes measuring 37×37×40cm high). The cages were heated constantly to approximately 33 °C and illuminated with

a 100W fluorescent lamp. The dark-light condition was 12:12 hours. Food and water were continuously available in the home cages.

Apparatus:

The open-field apparatus was a wooden box, measuring 90×90×40 cm, the floor of which were divided into a grid of 9 squares measuring 30×30 cm each. The floor and the wall were painted grey. This apparatus was illuminated with two 150W incandescent lamps 60 cm above.

To detect distress calls, a specially constructed voice key, which was connected to a digital counter, was used. In order to record the other behaviors an operations recorder (Izumi Electric Co., Ltd.) was used.

Procedure:

The subjects were randomly assigned to one of 3 groups, being tested individually and only once at 1-, 4- or 7-day of age. Each chick was gently placed in the center square of OF, when two stopwatches were started, each of which measured the latency of locomotion or of distress call. Behaviors were observed directly through the one-way mirror by the experimenter for 20 min.

The characteristics recorded were as follows: (1) latency to the first step from the place where it was placed (FSL). (2) latency to the first distress call (DCL). (3) difference between FSL and DCL (FSL-DCL). (4) rate of distress call per minutes calculated by the formula: (the number of distress call occurring in 20 minutes) / (20 min. - DCL), (DC). The number of DC in 20 minutes and DCL were mutually exclusive measures, and therefore certain inverse relationship was inevitable between these two. The formula above was assumed to remove this relationship. (5) rate of locomotion per minutes calculated by the formula: (the number of squares passed by subject in 20 minutes) / (20 min. - FSL), (Locomotion). The meaning of this formula was the same as with DC. (6) ratio of the number of passing the center square to the number of all squares passed (Centering). (7) Defecation. (8) Pecking. (9) Jumping. (10) Head-shake. (11) Body-shake. As to the measures of 7-11, the topographies of these behaviors were discrete and fixed, and could be easily recognized, so that the number of occurrences in 20 minutes were recorded.

The Spearman's rank correlation coefficients among measures were calculated and the factor analysis (principal component solution) was performed on the 11×11 correlation matrix. The extracted factors (eigenvalue>1) were rotated to a simple structure using the varimax solution. All analyses were performed in

the HITAC M-180 at the Information Processing Center of Hiroshima University.

Results and Discussion

The factor tables for OFB in chicks aged 1-, 4- and 7- day are presented in Table 1, 2 and 3. At the bottom of each table are recorded also the percentages of common factor variance attributable to each factor. From the factor analysis 4 factors were extracted for each day. The behaviors with high loadings on Factor 1 are DCL (except for 1-day of age), FSL, FSL-DCL and Defecation (except for 3-day of age). In the novel situation, which ethologically means to them the high danger of predation, the young animals freeze and fail to emit distress call or other active behaviors. These behavioral tendencies are assumed to decrease the possibility to be detected by predators. So Factor 1 was interpreted as anti-predator behavior. The behaviors with high loadings on Factor 2 are DC (except for 7-day of age), Locomotion, Jumping and Centering (negative). These behaviors are related, in the situation of being separated from the attachment objects, to escaping from the situation or searching for the attachment objects. According to GALLUP and SUAREZ's (7) reconsideration of OFB, Factor 1 is equivalent to what they call minimizing detection in the face of possible predation, Factor 2 to what they call reinstating contact with conspecifics. The present results support the GALLUP and SUAREZ's approach, *i. e.*, an ethological analysis of OFB, which succeeds in dividing OFB into two different meanings for the chick, while former analyses could not distinguish this difference.

The behaviors which have high loadings on Factor 3 (for 7-day of age, Factor 4) are Pecking, Head-shake (except for 1-day of age) and Body-shake. The former observations in the semi-natural settings by the present experimenter indicated that these behaviors were mutually related and occurred closely in time. Pecking has been classified into exploration by most observers of chick's behaviors. But the previous study (10) by the present author showed the pecking could

Table 1. Rotated factor matrix for the OFB in chicks aged 1 day.

	Factor 1	Factor 2	Factor 3	Factor 4
DCL	-0.06618	-0.10355	0.03692	0.95610
FSL	0.94523	-0.12203	-0.18363	0.20191
FSL-DCL	0.92092	-0.09873	-0.18478	-0.09707
Defecation	0.44755	-0.12520	0.11903	0.01675
DC	-0.21216	0.76626	0.12964	-0.17266
Locomotion	-0.20501	0.70146	0.37253	0.01972
Jumping	-0.06150	0.52800	-0.08531	0.20135
Centering	0.02712	-0.67345	-0.27485	0.01051
Pecking	-0.16027	0.16935	0.55554	-0.04639
Head-shake	-0.12763	-0.12819	0.04482	-0.67930
Body-shake	0.09824	0.15396	0.97944	0.03018
Contributions	19.0	17.6	14.5	13.6

Table 2. Rotated factor matrix for the OFB in chicks aged 4 days.

	Factor 1	Factor 2	Factor 3	Factor 4
DCL	0.71741	-0.26281	-0.00057	0.33287
FSL	0.97796	0.16330	-0.09610	0.08206
FSL-DCL	0.61261	0.3526	-0.25902	-0.40856
Defecation	0.09651	0.04632	0.06405	0.56636
DC	0.09361	0.46080	-0.08974	-0.29282
Locomotion	-0.18324	0.71181	0.24445	0.13307
Jumping	0.07883	0.63019	-0.05477	0.00996
Centering	-0.16062	-0.62433	0.09703	-0.51344
Pecking	-0.01585	0.15526	0.30915	0.01252
Head-shake	-0.00956	-0.22181	0.58224	0.03818
Body-shake	-0.14200	-0.00619	0.78981	0.06220
Contributions	17.7	16.4	11.1	8.9

Table 3. Rotated factor matrix for the OFB in chicks aged 7 days.

	Factor 1	Factor 2	Factor 3	Factor 4
DCL	0.57000	-0.29984	0.49217	-0.12356
FSL	0.97931	-0.07429	0.15320	0.08338
FSL-DCL	0.86877	-0.00245	-0.19451	0.18887
Defecation	0.39094	-0.12760	-0.08503	-0.03948
DC	-0.45764	0.06964	-0.17168	0.20557
Locomotion	-0.34667	0.74603	0.06475	-0.03274
Jumping	0.01677	0.75858	-0.00029	0.08674
Centering	-0.03400	-0.03730	-0.58011	-0.24308
Pecking	-0.36107	0.27589	0.47571	0.34315
Head-shake	0.06393	-0.01864	0.15626	0.49487
Body-shake	-0.05585	0.06125	0.05217	0.52356
Contributions	24.2	12.1	8.5	7.3

not simply be involved in exploration, but it was first controlled by a rather general motivation in its own and, only after that, would become controlled by specific motivations, such as hunger, exploration, aggression, etc. So this factor was interpreted as pecking-related behavior rather than exploration. Factor 4 (for 7-day of age, Factor 3) could not interpreted. Further analysis and discussion for this factor will not be performed at present.

The present results provide also the finding concerning developmental changes. The factor analysis generally clarifies developmental changes of two aspects: factor structure itself and factor scores. The former was not detected in the present results. Factor 1, 2 and 3 are assumed to underlie OFB through at least one week after hatching, because behaviors having high loadings to each factor are unchanged except for a few behaviors. To reveal the latter the factor analysis were performed on the data with days pooled (see Table 4)

Table 4. Rotated factor matrix for the OFB in chicks with days pooled.

	Factor 1	Factor 2	Factor 3
DCL	0.65693	-0.12068	0.09812
FSL	0.89148	-0.01379	-0.39429
FSL-DCL	0.63382	0.02308	-0.58365
Defecation	0.35705	-0.03711	0.03036
DC	-0.36314	0.42540	-0.05499
Locomotion	-0.29426	0.70703	0.21837
Jumping	-0.06755	0.52934	0.20992
Centering	-0.07949	-0.50095	-0.03787
Pecking	-0.03739	0.32777	0.45775
Head-shake	0.01425	0.00413	0.43745
Body-shake	-0.00753	0.28323	0.52044
Contributions	18.1	12.9	11.6

and the factor scores were calculated. The factor scores of each subject were estimated by the total Z scores of measures, which had high loadings (greater than .4) on each factor (Factor 1=FSL+DCL + (FSL-DCL), Factor 2=Locomotion + DC + Jumping - Centering, Factor 3=Pecking+Body-shake+Head-shake; see Figure 1). The analysis of variance indicated that the effect of day were all significant (Factor 1, $F(2, 118)=5.129$; Factor 2, $F(2, 118)=8.820$; Factor 3, $F(2, 118)=15.032$) at the level of $p<.01$. Thus it was shown that at least during the first week after hatching chicks in OF show the decreasing tendency of antipredator behavior and the increasing tendencies of attachment-related and pecking-related behaviors.

The present investigation was performed from two points of view, an ethological and structural analysis of OFB, and showed that OFB was divided into three meaningful group of behaviors, each of which changed over 1-, 4- and 7-day of age. In conclusion this approach to OFB provides more important informations about the animal placed in OF than one being used to date.

Fig. 1. Representation of developmental changes in the factor scores, each subject of which are estimated by the total Z scores of measures which have high loadings to each factor (Factor 1 = FSL + DCL + (FSL - DCL), Factor 2 = Locomotion + DC + Jumping - Centering, Factor 3 = Pecking + Body - shake + Head - shake). Vertical lines represent 95% confidence intervals.

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