NOTES AND SHORT ARTICLES

CROSS-MODAL CONDITIONAL DISCRIMINATION LEARNING IN JAPANESE MONKEYS¹

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In these several years, the cross-modal integration of sensory inputs has excited wide interest. Geschwind (1965) once stated that the cross-modal associations were hardly formed in sub-human primates because of their poor development of new neural structures in their cerebral cortices called angular and supra-marginal gyri where, in man, fibers from several sensory cortices converge to. He cited some neuro-anatomical findings supporting his theory. However, in spite of many relevant experiments, there have been yet no appropriate behavioral evidences to evaluate the validity of his theory. In several experiments reported by Ettlinger and his collaborates, it was suggested that in monkeys the cross-modal transfer between the two sense modalities did not occur even when the same test objects were exposed in each of both modalities in the case of simple discrimination transfer experiments (Burton & Ettlinger, 1960; Ettlinger, 1960), and of experiments on the cross-modal transfer in conditional discrimination tasks (Ettlinger & Blakemore, 1966; Moffett & Ettlinger, 1966). But these negative findings are open to the interpretation that the monkeys might not be using the same part of the stimulus objects, when making discrimination in each of the two modalities. So, only from these we cannot yet

decide whether the cross-modal integration would occur in monkeys or not.

For crucial experiments to argue about the ability of the cross-modal integration in monkeys, two experimental controls are necessary. The one is to devise a training situation in which monkeys are required to integrate informations which come from different modalities, and the other is to design experiments so that the data from the cross-modal task can be compared with those from the intra-modal one.

The purpose of this work is to search for some reasonable type of experiments which will meet the above requirements.

Monkeys are firstly trained to react to the joint values of the two kinds of visual stimulus presented simultaneously, and then to the joint values of one auditory and one visual stimulus presented simultaneously. As, in these experimental controls, each component of the joint values has no relevance in itself; that is, each is a part of a positive stimulus compound as well as of negative one, monkeys should form the intra-modal (visual-visual) integration in the former case, and the cross-modal (auditory-visual) one in the later case in order to learn correct responses.

METHOD

Subjects: The subjects were five male Japanese monkeys, *Macaca fuscata Yakui*. Their ages and previous training experiences were various and details of them are shown in Table 1.

Apparatus: A modified W.G.T.A. was used. The animals' response was to push one of the two stimulus objects placed on the test panel away from the subjects. If their response was correct, the object moved backward along the track, and they could obtain reward, a small cut of sweet potatoes, from

¹ This study was supported by a Grant in Aid for Scientific Researches, Ministry of Education, to Prof. B. Yagi, University of Tokyo, and the experiments were carried out in the primate laboratory of the Department of Psychology, University of Tokyo. The author wishes to thank Prof. Yagi for his advice and encouragement throughout the course of the study, and also his warm thanks to Prof. H. Umezu, Kansai University, for his critical readings and comments.

TABLE 1
Ages and the previous experiences of the subjects

Subject	KAPO	TARO	ZURU	BORI	KUMA
Age in years	6	7	7	6	8
Visual discrimination	—	—	+	+	—
Patterned string problem	+	+	+	+	—
Visual learning set	+	+	—	—	—
Visual discrimination extinction	+	+	+	+	—
Visual discrimination reversal	+	+	—	—	—

the foodwell appeared by their pushing. When incorrect, the object did not move anyway. The two stimulus objects were illuminated by a long tube of 10-w fluorescent light burried in the foremost part of the surface of the test panel.

General procedures: At the beginning of each trial, when the intervening opaque screen was removed, the apparatus was about 30 cm away from the animal's cage, so that the animal could only observe the stimuli well being unable to respond to the objects in a flurry. After 5 seconds, the apparatus was brought near to the cage and the animal could make a response. Conventional noncorrection method was adopted throughout. The left-right position of the stimulus objects and of reward and the presence of the two kinds of conditional stimuli were presented randomly so that the same components of each stimulus condition did not continue more than three consecutive trials. The criterion of mastery of learning was 18 correct trials in any series of 20 trials and the last 10 trials of them were all correct. Throughout training, no attempt was made to isolate the animal from the usual background noises of the laboratory. In order to adapt them to the training situation, all subjects were pretrained in a simple visual discrimination (white triangular pyramid vs. white cube), because, though having many training experiences in W.G.T.A., they had no careers to respond in such a pushing type.

EXPERIMENT I

Subjects: Three monkeys named Kapo, Taro and Zuru were used.

Trainings: After the pretraining, five stages of the intra-modal conditional discrimination training and one stage of the cross-modal one were given.

Intra-modal:

Stage 1. The stimulus objects were a pyramid and a cube. When both were red, the pyramid was positive and the cube was negative. When yellow, vice versa.

Stage 2. The stimulus objects were a triangular prism and a sphere. When both were red, the prism was positive and the sphere was negative. When yellow, vice versa.

Stage 3. A white prism and a white sphere were placed before a colored background which surrounded the two objects on three sides except the front. When the background was red, the prism was positive and the sphere was negative. When yellow, vice versa.

Stage 4. The stimulus objects were a white cross and a white doughnut-like shape. Color of the background was blue or green. When the background was blue, the cross was positive and the doughnut was negative. When green, vice versa.

Stage 5. The conditional stimuli were two kinds of flickering light, 3 Hz and 16 Hz, generated from a stroboscopic light put on the ceiling of the apparatus. The light was so intensive that flickering could be easily observed under the usual apparatus illumination. The stimulus objects were a white rectangular solid and a white star shape solid. When flicker was 3 Hz, the rectangular was positive and the star shape was negative. When 16 Hz, vice versa.

Cross-modal:

Conditional stimuli were two kinds of pure tone, 200 Hz and 2000 Hz, sounded from a loudspeaker placed on the ceiling of the apparatus. The stimulus objects were a white triangular solid and a white semicircular solid with arc below. When 200 Hz tone was sounded, the triangular was positive and the semicircular was negative. When

TABLE 2
Numbers of trials and errors to criterion

Subject		KAPO		TARO		ZURU	
		Trial	Error	Trial	Error	Trial	Error
Intra-modal	Stage 1	58	17	46	18	—	—
	Stage 2	65	29	64	29	—	—
	Stage 3	114	36	95	45	—	—
	Stage 4	68	27	161	56	—	—
	Stage 5	162	69	175	80	94	35
Cross-modal		1774	724	(1800)†	(731)	775	381

† The animal failed to reach the criterion within 1800 trials.

2000 Hz, vice versa.

RESULTS

Table 2 shows the numbers of trials and errors to criterion for each subjects in each stage of the trainings. One monkey, Zuru, was received only the training of the fifth stage among the five intra-modal tasks. The results showed that the performances on the auditory-visual cross-modal task were markedly inferior to the visual-visual intra-modal ones. Among the five stages of the intra-modal tasks, the fifth one was most analogous in stimulus conditions to the cross-modal one. So, it is reasonable to compare the performance on this stage with that on the cross-modal one. Here, too, the differences are very great. Since in two monkeys, KAPO and TARO, the intra-modal tasks were given in a series from easier to harder step by step, their performances on the fifth stage might have been facilitated by the transfer effect. But in Zuru, who was given only the fifth stage, the difference was definite, too. So it may be concluded that the clear differences of the performance between the intra-modal task and the cross-modal one are due to the nature of the tasks itself. But it has been known that the monkey is a 'visual' rather than a 'auditory' animal (Stepien & Cordeau, 1960). Furthermore, as shown in Table 1, all the previous trainings of our subjects had been ones with visual cue. Therefore it might be reasonable to suppose that the subjects were accustomed to use the visual cue and not to

use the auditory cue. This would be one of the reasons that made the auditory-visual cross-modal task more difficult. In the next experiment, the problem whether monkeys could use the auditory cue as well as the visual cue or not was examined by comparing a simple auditory discrimination with a simple visual one.

EXPERIMENT II

Subjects: Two monkeys named Bori and Kuma were used.

Trainings: After the pretraining, a simple auditory frequency discrimination and a simple visual flicker discrimination were given.

Auditory task: All the stimulus components were same as those used in the cross-modal task of Exp. I. But in this case subjects were required to respond to the left-handed side or the right only with regard to the auditory stimuli independent of the visual stimuli. When 200 Hz was sounded, the left side was positive. When 2000 Hz, the right side positive. The position of the two stimulus objects was changed randomly without regard to reward.

Visual task: All the stimulus components were same as those used in the fifth stage of the intra-modal tasks of Exp. I. Subjects were required to respond to the left-handed side or the right only with regard to the flickering lights. When 3 Hz was given, the left side was positive, and when 16 Hz, the right positive.

Results: Table 3 shows the numbers of trials and errors to criterion for each subjects in each task. The sophisticated subject, Bori, took more trials to learn the auditory task than the

TABLE 3
Numbers of trials and errors to criterion

Subject	BORI		KUMA	
	Trial	Error	Trial	Error
Auditory	63	23	105	39
Visual	32	11	118	48

visual one. But he learned both tasks rather easily. In the naive one, Kuma, there was no difference between the performances of the two tasks. Therefore these results suggest that the monkeys could use the auditory cue as well as the visual one. So, it might be possible to say that the marked inferiority of the performance on the cross-modal task observed in Exp. I could not be resulted from the inability to use the auditory cue.

DISCUSSION

The data from our study show that, while monkeys have good ability to use the auditory cue as well as the visual one when each given alone, learning of the cross-modal (auditory-visual) conditional discrimination is markedly difficult than that of the intra-modal (visual-visual) one. These seem to give a support for Geschwind's theory.

As our study is rather a preliminary one, we have no intention to say anything about the precise effect of the poor cross-modal integration of monkeys on their whole behavioral processes. But we might suggest that this poor ability might be one of the main origins which markedly differentiate monkeys from man, especially in their higher behavioral processes.

Finally we would emphasize that there can be at least two types of the "cross-modal integration". One is the sensory-integration type such as the alteration of the sensory threshold occurring as a function of stimuli given simul-

taneously in other modalities. This type of integration is that between rather primitive aspects of the stimuli, such as on or off of them, and it can occur rather easily in animals, too. But such a integration might have, we suppose, no important relations to the higher behavioral processes. The other is what we wanted to use in our study, namely, the integration between rather complex aspects of stimuli, such as form or pattern. Some authors, like Ettlinger (1967), are arguing the nature of the higher process in animal behavior, such as the symbolic process, taking it granted that animals would have the good ability of the cross-modal integration. But, we suppose, it would be at first necessary to make clear what type of the cross-modal integration would be treated in their assumption.

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(Received Oct. 12, 1968)