

SOME NOTES ON THE AUDITORY SENSITIVITY OF THE WHITE RAT

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Since the publication of the earlier work on the auditory sensitivity of the white rat (1), it has been possible to secure additional data that merit publication. Inasmuch as the material, however, comes from several diverse lines of work rather than from one systematic study, it is thought best to present it in the form of notes.

I

Mr. Otto Weir tested the sensitivity of eight rats to the tone 4096 d.v. sounded on a tuning fork. Of the eight rats, six (rats 1 to 6) were adults and two (rats 7 and 8) were young rats. Rat 6 was a female; the sex of rat 4 was undetermined; and the others were males. All of the rats were untrained save rats 1 and 2 who had mastered the Watson circular maze. Ten trials daily with punishment and reward were given using a varying presentation to prevent the formation of position habits. The apparatus was the same as that used in the earlier experiments, consisting of the T-shaped discrimination box wired for the administration of an electric shock when errors were made. This box is illustrated in figure 1. The tuning fork was securely clamped by the shank about 12 inches above the center of the apparatus. Contact with the apparatus was possible through the clamps, rods and table upon which latter the apparatus rested. Pads of cotton were placed between the shank of the fork and the clamps partly in order to reduce accessory vibrations and partly to produce a clearer tone. No resonator was used. The tuning fork was activated by striking with a metallic hammer especially constructed for the purpose by the instrument maker.

The attempt was made to compel the rats to associate turning to the right through the box with the tone produced by striking the fork. In the six older rats, turning to the left was to be associated with a noise produced by striking the fork with the hammer while holding the prongs of the fork between the thumb and finger. In this case the fork was struck at the same tempo as when a tone was produced. Noises of two slightly different kinds were present, although at one time the tone was absent and at another it was absent. In the two younger rats (rats 7 and 8), turning to the left was to be associated with silence.

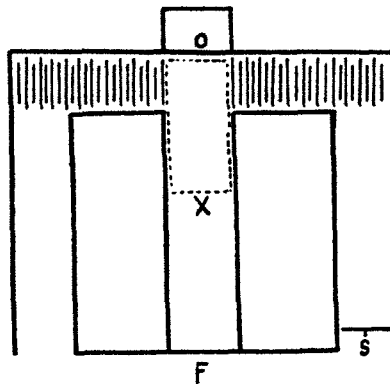


FIG. 1. T-SHAPED DISCRIMINATION BOX

O, the box containing the light; *F*, food bowl; *S*, alley stop; *X*, point above which tuning forks and whistles were clamped. The dotted area indicates the position of the sandpaper in certain tests.

Table 1 gives the percentage of correct responses made by each rat for each successive fifty trials of the learning period. It will be seen from an examination of this table that rat 3 was the only one who made significant progress toward the establishment of the required habit. This rat made better than 70 per cent of correct reactions for the last three groups of fifty trials. It was therefore given certain control tests in order to determine the nature of the cue guiding its response.

It did not prove practical to eliminate noise by using electrically driven forks because of the fork's small amplitude of vibra-

TABLE 1

Percentage of correct responses in each succeeding 50 trials

TRIALS	RATS							
	1	2	3	4	5	6	7	8
50	32	40	28	36	58	42	60	54
100	44	58	52	58	54	42	50	56
150	26	44	60	42	56	54	64	56
200	52	52	72	50	54	52	56	50
250	48	52	65	68	60	54	56	64
300	38	44	65	53	64	58	54	50
350	24	52	50	42	52	48	48	52
400	58	48	45	50	57	54	60	64
450	34	42	54	42	44	36	74	48
500	62	48	28	48	48	36	56	56
550	50	56	80	60	60	52	50	34
600	46	56	74	60	60	40	54	56
640	48	47	70	56	50	50	54	58

tion. The controls are therefore not conclusive, although the indication is that tone sensitivity is absent. The following controls were used with rat 3:

Control 1. The noise stimulus ordinarily used only for turning to the left was used for all trials. This substituted a certain "thud" for the "tone and thud" previously used as a cue for turning to the right. No tone therefore was given. All other conditions normal. The response was counted correct if it coincided with the order of presentation.

Control 2. The supports of the tuning fork were fastened to tripods resting upon the floor and in some cases upon two adjacent tables. This control ruled out the possibility of contact cues due to the transmission of vibrations through the table to the discrimination box.

Control 3. Cotton was forced between the prongs of the fork. Striking the fork now produced a faint tone of high pitch as well as a noise of new quality. The same stimulus from striking the fork was given in each trial. The reactions were counted as correct if they fitted the series of presentations.

Control 1 caused a breakdown in the rat's high percentage of correct responses. When this control was alternated with normal conditions on intervening days, correct responses did not

exceed 60 per cent, although the normal conditions gave 73 to 80 per cent correct response. Clearly something was eliminated that had served to determine the rats responses. The results, however, do not prove tone sensitivity because the "thud" caused by the free fork was different from the "thud" of the fork when held and may have served as the basis of the original discrimination.

Control 2 did not disturb the accuracy of the rat's responses.

Control 3 was given one day with an accuracy of 50 per cent; two days, with 70 per cent; and one day each with 60, 50, and 40 per cent. In this control the stimulus used for each trial was the same. The results of this control indicate, therefore, that a high percentage may be made without using an auditory cue. They are also partly in harmony with the view that the original response was influenced by the differences in the noises involved.

These three controls have not determined the exact basis of the response during the normal tests. Inasmuch as the percentage of correct responses was not stable during those tests, and was not particularly high, it seems probable in the light of these controls and of other published work, that rat 3 was not reacting to tone stimulation.

II

The experiments on audition to be reported in this section were made in the summer of 1914 and again in the spring of 1915 at the University of Texas. In the course of some correspondence, Professor Carr of the University of Chicago described some of the work then being carried out at that university by Mr. Harry Wylie on transfer of training. At that time the present writer was making a study of auditory sensitivity and of habit interference as published in the 1915 and 1917 articles listed above. The methods and apparatus employed were peculiarly adapted to the study of Wylie's method dealing with transfer between sense fields. The method of inter-sense transfer was therefore employed with the result that valuable data bearing upon tone sensitivity were secured. This data was not made public until Wylie presented his report at the 1915 meeting of

the American Psychological Association (2), when a verbal report of the present finding was made.

The apparatus used was the T-shaped discrimination box of the earlier experiments, figured above. A hole about 1 inch in diameter was cut in the box at the point marked *O* in the figure. Outside of the apparatus and directly in front of this hole was placed a 10 candle power light enclosed in a covered box. This light could be turned off and on as desired. The hole in the box was closed with a square of clear glass over which a layer of bond typewriter paper was placed. The result was a diffused light of good intensity (somewhat less than 10 candle power).

The first rats used were rats 46 and 47 of the 1915 paper. These rats were about six months old at the time of the present observations. They had been trained to discriminate a piston whistle tone of 3906.17 d.v. from silence by running to the right when the tone was given and to the left for silence. Controls had been used which indicated that the rats would substitute for the whistle either: "rush of air" sound made by the whistle without the tone; a "rush of air" sound made with the experimenter's lips; or handclapping of medium intensity. In other words, the rat would run to the right when either of the above stimuli were given, and to the left for silence. On the other hand when the following tonal stimuli were substituted for the whistle the rat failed to discriminate them from silence: one 1280 d.v. fork; a 1152 d.v. and a 1280 d.v. fork sounding simultaneously; and the normal whistle when it was removed to a distance, thus eliminating the usual noise accompaniment. Transfer was therefore possible without training from one noise (that of the whistle) to various others; but not possible from the noise in question to tonal stimuli.

It was at this point that the suggestion derived from Wylie's work was applied. The rat was placed in the apparatus and stimulated with a light in place of the whistle in order to see if a transfer would be made between the two sense fields in spite of the fact that the previous transfer within the auditory sense field had not occurred. The results for the two animals are given in table 2. The rats were given the regular whistle test in a dark

room on the first day in order to be certain that the darkness would not disturb the reaction. On the following day the rat was placed in the apparatus with the room dark and the light at *O* turned on. A correct response consisted either of running to the right for the light or to the left for darkness. As the table indicates, rat 46 failed to make the substitution, making only 5 correct reactions out of 10 on each of two days with the light. This was mere chance. Rat 47, on the other hand, made the substitution on each of three days, making 9, 8, and 9 correct reactions respectively.

TABLE 2
Data on light substitution

	TRIALS	TRIALS CORRECT
Rat 46:		
Normal whistle in dark.....	10	9
Light.....	10	5
Light.....	10	5
Normal whistle in dark.....	10	8
Rat 47:		
Normal whistle in dark.....	10	9
Light.....	10	9
Light.....	10	8
Light.....	10	9
Normal whistle in the dark.....	10	9

These results indicate clearly a greater similarity, for the behavior of rat 47, between noise and light than was found between noise and tone. This is harmonious with the apparent fact of insensitivity to the tones as indicated in the earlier papers.

Five rats, 1, 7, 9, and 11, had been trained in 1915 to discriminate handclapping from silence, using the same apparatus, by running to the right for handclaps and to the left for silence. (A description of this work is published in the 1917 article.) No direct tests were made on their ability to substitute tones for the noise. It is legitimate to assume that, like all of the many rats heretofore tested, they would have failed. They were tested however upon their ability to substitute a tactual and a visual stimulus for the noise. For the tactual stimulus a piece of coarse

sandpaper was laid in the alley at the point indicated in dotted lines in the figure. (The rat was to run right for the contact and left for its absence.) The visual stimulus was the same used with the two rats above described.

The results secured are given in table 3. It will be seen from this that rat 1 failed to substitute the light for the noise. The sandpaper gave 70 per cent correct reactions, which is slightly better than chance but which does not demonstrate clearly that the substitution was made. Rat 7 clearly failed on the sandpaper, but gave slight evidences of substituting the light. The same statements are true of rat 9. Rat 11 failed to substitute the sandpaper. On the other hand, the data on light indicate a clear-cut and all but perfect substitution similar to that in the case of rat 47 described above.

It is perhaps a safe conclusion that light and noise are more similar for the behavior of rat 11 than are noise and tone, although no direct tests of tone sensitivity were made. The justification for such a conclusion would rest upon the lack of evidence for tone sensitivity in the white rat, and upon the behavior of rat 47 above. With all of these rats careful controls indicated that they were not dependent upon the series of presentations, but were guided, normally, by auditory stimuli.

III

In the 1917 paper, tests were described in which three rats, 7, 15, and 23, acquired the habit of running to the right for handclaps and to the left for silence. They were then trained to run to the left for a buzzer and to the right for silence. At the close of this second training, when retested on the first habit, no one of the three fell below 80 per cent correct responses for 30 trials. Rat 27 also acquired the two habits serially. Rats 7 and 27 were continued in the experiments, to be described in this section, for the purpose of determining additional features underlying their reactions.

Each of these rats could respond correctly in either of the two following three ways: run right for handclaps (h.c.) and left for

TABLE 3

Data on the substitution of light and sandpaper

RAT	CONDITION OF TEST	NUMBER OF TRIALS	NUMBER CORRECT
1	Normal handclaps.....	10	8
	Sandpaper.....	10	7
	Handclaps.....	10	8
	Sandpaper.....	10	8
	Sandpaper.....	10	7
	Sandpaper.....	10	7
	Sandpaper.....	10	7
	Handclaps.....	20	17
	Light.....	10	5
	Handclaps.....	10	5
	Handclaps.....	10	7
	Handclaps.....	20	18
	Light.....	10	6
	Handclaps.....	10	6
	Handclaps.....	20	16
7	Normal handclaps.....	20	20
	Sandpaper.....	10	5
	Handclaps.....	10	10
	Sandpaper.....	10	6
	Handclaps.....	10	7
	Handclaps.....	10	8
	Sandpaper.....	10	6
	Handclaps.....	30	26
	Light.....	10	7
	Handclaps.....	10	10
	Light.....	10	5
	Handclaps.....	10	7
	Handclaps.....	10	8
	Light.....	10	7
	Handclaps.....	20	16
9	Normal handclaps.....	20	16
	Sandpaper.....	10	5
	Handclaps.....	10	10
	Sandpaper.....	10	5
	Handclaps.....	10	6
	Handclaps.....	10	10
	Sandpaper.....	10	5
	Handclaps.....	20	14
	Handclaps.....	10	8
	Light.....	10	7
	Handclaps.....	10	10
	Handclaps.....	20	17

TABLE 3—Continued

RAT	CONDITION OF TEST	NUMBER OF TRIALS	NUMBER CORRECT
9	Light.....	10	8
	Handclaps..	10	8
	Light	10	6
	Handclaps.....	10	8
	Normal handclaps.....	10	8
	Sandpaper	10	5
	Handclaps..	10	8
	Sandpaper.....	10	8
	Sandpaper.....	10	6
	Sandpaper.....	10	6
11	Handclaps ..	10	8
	Sandpaper...	10	5
	Handclaps..	30	24
	Light.....	10	10
	Handclaps.....	10	10
	Light.....	10	9
	Handclaps.....	10	9
	Light.....	10	10

silence; run left for buzzer and right for silence; or run right for h.c. and left for buzzer. Each day's work was begun with either of the auditory stimuli. This determined the right or left turn and silence was then treated accordingly. Controls were now instituted in an attempt to determine just wherein the difference between the two noises lay. Illness in the animals finally prevented an entirely satisfactory solution. The data are presented in their present fragmentary form because it will probably rarely happen that an experimenter will have rats possessed of these two habits, thus making possible the extension of the work.

The work on auditory sensitivity in the white rat has indicated an insensitivity to tones in the lower portion of the scale and also to some as high as the pitch 4096 d.v. on the fork. It has also demonstrated that the rat can hear noises. In the case of rats 7 and 27, the opportunity was offered to extend these previous observations on noise. *Are noises for the rat grouped into the three classes of continuous, intermittent and beat noises as Hensen claims for man?* The buzzer used in the tests with rats 7 and 27 gave a continuous sound and the handclaps constituted an inter-

mittent noise of about 150 interruptions per minute. The experimenter had been using handclaps for a noise stimulus for many months and had reduced the clapping to an automatism which varied but slightly in rate.

The following are the controls used in the analysis of the two habits described. (In the formation of the habits, punishment and reward were used. In the controls, punishment was never used for fear of breaking up the association.)

K = turn right for h.c. and left for buzzer

h.c. = turn right for h.c. and left for silence.

B = turn left for buzzer and right for silence.

Control 1. Hissing through the teeth, turn left.

Control 2. Hissing through teeth, turn right.

Control 3. "Rush of air" sound with lips, turn right.

Control 4. "Rush of air" sound with lips, turn left.

Control 5. Buzzer sounded for two seconds, at intervals of one second, turn left.

Control 6. Buzzer sounded normally, turn right.

Control 7. Metronome beating 120 per minute, turn right.

Control 8. Metronome beating 120 per minute, turn left.

Control 9. Metronome beating 200 per minute, turn right.

Control 10. Metronome beating 200 per minute, turn left.

Control 11. Metronome beating 160 per minute, turn right.

Control 12. Metronome beating 176 per minute, turn right.

Control 13. Motor knocking 180 per minute, turn right.

Control 14. Motor knocking 232 per minute, turn left.

Control 15. Motor knocking 140 per minute, turn left.

Control 16. Motor knocking 240 per minute, turn right.

Control 17. Motor knocking 250 per minute, turn left.

Control 18. Motor knocking 500 per minute, turn left.

Control 19. Beats 120 per minute with 512 v.s. forks, turn right.

Control 20. Beats 142 per minute with 512 v.s. forks, turn right.

Control 21. Beats 174 per minute with 512 v.s. forks, turn right.

Control 22. Beats 3840 per minute with 512 v.s. and 576 v.s. forks, turn left.

Not all of these controls could be used with each rat, and the limitations of time prevented their being exhaustively applied. The buzzer used was an ordinary commercial one and was sus-

pended above the apparatus in a manner which prevented the transmission of vibrations directly to the box. When the metronome was used, it was placed upon a ledge just to the back and above the apparatus and entirely separated from direct connection with the experimental table. The forks used (mounted upon resonance boxes) were suspended in the same manner as the buzzer. In controls 13 to 18 a strip of metal was fastened to the spindle of a motor in such a manner that the rotations of the motor caused it to strike at a definite rate against a cardboard. This gave an excellent noise of medium intensity and of volume and quality different from the handclaps. The motor (a silent one) was placed upon a nearby table.

The results secured are summarized in table 4. Rat 7, who was tested with the beats from the forks, ignored them and would not class them either with the continuous or with the interrupted noises. Hissing and the "rush of air" sound were substituted readily for the buzzer, *i.e.*, at least 80 per cent correct reactions were made going to the left for these noises and to the right for silence. The metronome beating at 120 and at 176 were substituted for the handclap successfully; whereas the rat persistently refused to run to the right for the metronome at 200 and to the left for silence. Two 512 v.s. forks mistuned to give beats of 142 and 174 per minute were ignored as were the beats from the forks 512 v.s. and 576 v.s. sounding together. *The evidence suggests that the rat was insensitive to the beats, which is very interesting inasmuch as beats are periodic variations in intensity and the rats seem insensitive to tone.* The evidence also indicates that the transition between continuous and intermittent noises occurs in the region of 200 interruptions per minute.

Rat 27 ran to the left for hissing, and for the motor knocking at the rate of 500 per minute. It refused to go to the left for the motor knocking at the rate of 232 per minute and for the metronome at 200 per minute (right for silence). The motor rate of 250 was neither clearly rejected from nor clearly included with the continuous sounds. The rates of 120 and 180 per minute were definitely substituted for the handclaps, whereas hissing, the buzzer, and the metronome at 160, 200 and the motor at 240 were

TABLE 4
Controls used with rats in analysis of buzzer-h.c. habit

RAT 7		RAT 27	
Control	Number correct in 10	Control	Number correct in 10
K	9	K	9
1	9	2	7
5	3 of 7	1	7
K	18 of 20	B	6
5	9	B	9
3	4	1	8
4	9	B	8
7	8	2	6
9	5	B	7
K	9	K	7
7	8	K	9
9	5	K	35 of 40
K	9	1	8
K	10	1	8
20	6	2	4
7	7	B	8
7	8	7	8
9	4	9	4
K	10	6	4
20	6	16	5
19	7	17	10
K	10	17	7
19	6	9	7
19	5	K	10
19	5	9	8
K	9	10	6
12	9	K	7
9	5	K	9
K	10	h.c.	16 of 20
22	5	11	5
22	4	11	6
B	8	11	19 of 30
		9	5
		B	9
		10	6
		h.c.	7
		h.c.	10
		9	6
		B	7
		h.c.	9
		1	9
		9	4
		h.c.	16 of 20
		9	6
		h.c.	9
		11	7
		h.c.	18 of 20
		9	6
		h.c.	9
		9	31 of 50

clearly rejected from the class of interrupted noises. Because of the rat's refusal to class the metronome at 160 with the intermittent noises, the results are not so clear cut as might be desired. However, as with rat 7, the indication is that the frequencies around 200 are the critical ones.

It seems probable that the discriminations here made by the two animals were discriminations of "qualities" rather than of "rates." The difference between the noise group of hissing, buzzing and "rush of air" and the noise group of handclaps and slow metronome beats is the qualitative difference of continuous and intermittent pointed out by Hensen. The indications are, therefore, that for the white rat there are two classes of noises—beats are apparently not sensed.

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