

AUDITORY DISCRIMINATION: ROLE OF TIME AND INTENSITY IN THE PRECEDENCE EFFECT

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Rats were trained to respond on a lever adjacent to a sounding speaker (the sound source) when a single click was emitted. A second click (the artificial echo) was presented through a second speaker on the opposite side. In Condition I, the echo (equal in intensity to the source) was delayed from .015 to 32 milliseconds; greater than 75% correct responses were given for delay times between about .040 milliseconds (lower threshold) and 8 milliseconds (upper threshold). In Condition II, the echo (simultaneous with the source) was reduced in intensity relative to the source over a range from 2.5 decibels to 40 decibels; greater than 75% correct responses occurred for intensity reductions greater than 5 decibels. In Condition III, both the intensity and the delay time of the echo were manipulated in a manner analogous to that which would occur under natural conditions; greater than 95% correct responses were given for delay times from 1 to 32 milliseconds. These data indicate that both time and intensity differences are necessary for localization of primary sources, with delay time contributing more at short echo path distances, and intensity differences at long distances.

Key words: auditory discrimination, localization, precedence effect

The natural environments of many mammals contain echo producing surfaces or objects. This can readily be demonstrated by measuring the echoes produced by typical objects found in an animal's environment. Measurements made in this laboratory have shown that a freshly plucked leaf produced echoes of a click that were only 6 dB below those produced from a smooth steel plate. A small rock picked up in a local area occupied by wild rats gave echoes only 8 dB below those produced by the steel plate. These data indicate that monkeys and rats occupy environments in which primary sound sources create a number of secondary sound sources, each secondary source located at an echo producing object. Nevertheless, animals are able to behave appropriately toward the primary source of a sound under these conditions. It has been shown, for example, that the responding of rats and monkeys readily comes under the control of the position of sound sources of complex spectral content under conditions in which echoes (multiple secondary sources) were deliberately not excluded. (Downey & Harri-

son, 1972, 1975; Harrison, Downey, Segal, & Howe, 1971; Harrison, Iverson, & Pratt, 1977). Squirrel monkeys also oriented correctly to the sound source under similar conditions (Harrison & Briggs, 1977). These experiments suggest that in both rats and monkeys responding is under the control of the position of the primary source alone, and that the positions of the secondary sources are behaviorally ineffective.

Two types of information are available to an animal for discriminating a sound source from its echo: differences in the arrival times of sounds from the source and the echoing object at the listener's head, and differences in the intensities of the two; since the path of an echo to a listener's head will always be at least a little longer than that of a sound traveling directly from the primary source, the echo will arrive later and will be less intense.

The ability to respond to the position of the first in a pair of clicks or other fast rise-time stimuli has been investigated in humans. When pairs of clicks of equal intensity, their sources separated by 180°, are presented to human subjects, there is a fairly broad range over which the second click fuses with the first. Wallach, Newman, and Rosenzweig (1949) found that when the interval between the clicks was shorter than the maximum binaural

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time difference for a single click (about 1 msec), subjects heard a single click, the apparent location of which shifted toward the midline as the interval between the two clicks became smaller. In this situation the initial sounds reaching the subject's ears are similar to those in a single click situation. Wallach et al. reported that when the interval between the two clicks was greater than the maximum binaural time difference, subjects continued to hear a single click located at the source of the first click. Wallach et al. called this suppression of information about the location of the second click in a pair the precedence effect. In general, this effect has been found for click pairs separated by as much as 5 to 35 msec, depending on the method used to present stimuli. At intervals above about 10 msec, subjects begin to report hearing two clicks, but as the interval is increased, more errors are made in reporting the location of the first click; subjects report hearing two clicks but cannot determine the source of either click until the interval is increased still further. The precedence effect provides one way in which the primary source of a sound may be distinguished from those of its echoes (see Gardner, 1968, for a review of the precedence effect in humans).

The precedence effect has not been widely investigated in non-human species. Kelly (1974) has investigated the effects of small time differences on localization of click pairs of equal intensity by rats, using a conditioned suppression procedure and clicks separated by intervals from .031 to 32 msec. His data suggested that the precedence effect operates in the same manner in rats as it does in humans. He found a lower limit of discrimination between .031 and .062 msec, and an upper limit between 20 and 32 msec. Between .25 and 16 msec, animals readily discriminated shifts from a right-left series of click pairs to a left-right series, and vice versa. Kelly (1975) also studied the effects of intensity differences in this situation and found that differences of -2.8 to -4.2 dB were required for threshold performance on the localization task.

The present study investigated the effect of time and intensity differences between a sound source and its artificial echo on a location discrimination. Rats were trained to respond on one of two levers when a click (the sound source) was presented through one of two

speakers. A second click (the artificial echo) was presented at each trial under one of three conditions; in Condition I, the echo followed the source over a range of times from 0 to 32 msec; in Condition II, the echo (simultaneous with the source) was varied in intensity from -2.5 to -40 dB relative to the source intensity; in Condition III, the intensity and the time delay of the echo were varied together so as to resemble the properties of a real echo.

METHOD

Subjects

Six male albino rats, Sprague-Dawley strain, served. Four of the animals (RH 2, RH 3, RT 49, and RT 50) were 5 months old at the start of the experiment and 9 months old at the conclusion. Two animals (RJ 6 and RJ 7) were 19 months old at the start of the experiment, and 31 and 33 months, respectively, at the conclusion; RJ 6 became sick and died in the last stage of Condition I. The animals were housed individually and were food deprived to maintain their body weights at approximately 80% of those under free-feeding conditions.

Apparatus

The apparatus consisted of a wire mesh cage, 27 cm by 47 cm by 40 cm high (Figure 1). Levers (R1 and R2) were mounted on opposite walls of the cage, 3 cm above the floor. A speaker (University T2002) was mounted behind each lever (S1 and S2). A standard pigeon key (Gerbrands G 6320) was mounted on the front wall midway between the two levers, 2 cm above the floor. A dipper feeder (Gerbrands G 5600) was mounted on the wall opposite the key. The experimental cage was suspended in the center of a cubicle 1 m by 1.5 m by 2 m high; the walls, ceiling, and floor of the cubicle were covered with perforated acoustical tile. A separate room housed the programming and sound-generating equipment.

Sounds and Sound-Generating Equipment

Fifty microsecond square-wave electrical pulses were generated using a Tektronix waveform generator (Type 162), connected to two Tektronix pulse generators (Type 161). Operation of the waveform generated produced a pulse from each of the pulse generators, the time interval between the onsets of the two

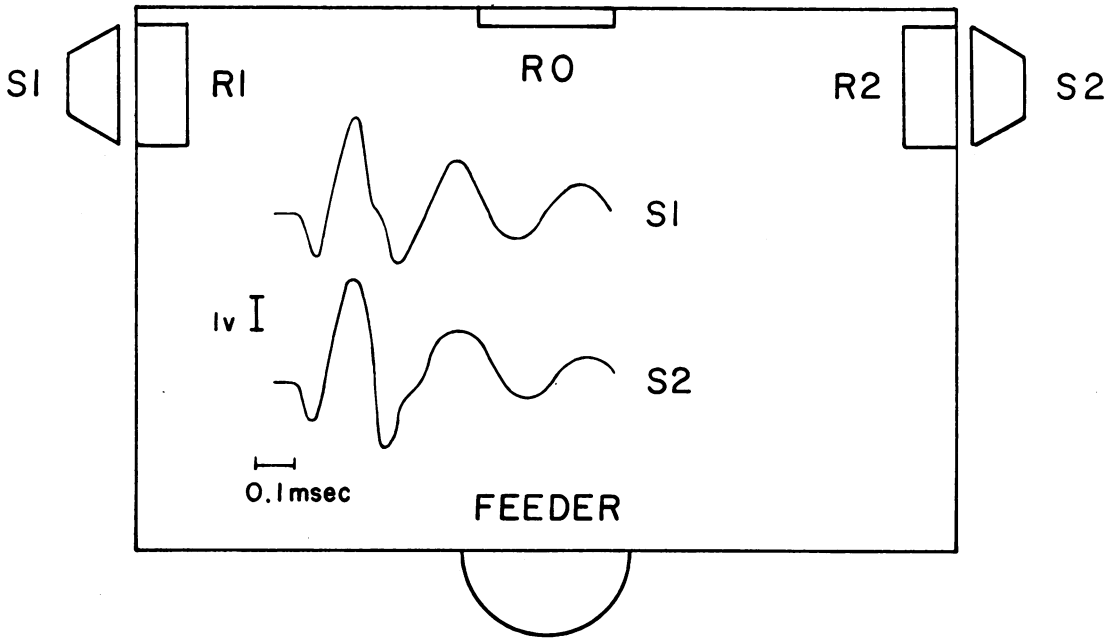


Fig. 1. Schematic illustration of the arrangement of the speakers and levers in the apparatus. S1, S2, speakers; R1, R2, response levers; R0, response key. The inset shows the waveforms of the clicks (from S1 and S2) at the response key.

pulses being adjustable from 0 to 40 msec. The pulse from each generator was fed to a separate power amplifier (General Radio, Type 1206-B) and then to a matching transformer (Krohn-Hite, Model MT 56). The temporal spacing and amplitude of the electrical pulses were continuously monitored on a double beam oscilloscope (Tektronix Type 5301 N).

For Condition I (time difference alone), the amplitudes of the outputs of the two amplifiers were equated, and the time delay of the second pulse was adjusted via the pulse generator. For Condition II (intensity difference alone), the pulses occurred simultaneously; the amplitude of one pulse was held at the same level used in Condition I, while that of the other was reduced by varying amounts. For Condition III (combined time and intensity difference), the amplitude of the first pulse was maintained at the level used in Condition I, and the amplitude of the second, delayed pulse was reduced as the interval between the two was increased, according to the function shown in Figure 2. This function was calculated as follows: the distance that a perfectly reflecting object would have to be

from the animal to produce a given time difference was calculated. Using this distance and the inverse square law of the intensity change of sound with distance, the difference, in dB, between the original click and the hypothetical echo was calculated. The appropriate voltage level for the second electrical pulse was calculated from this and adjusted accordingly. In all conditions, whether the first pulse (the source) was delivered to S1 or S2 and the second pulse (the echo) to S2 or S1 varied from trial to trial in an irregular manner determined by the programming equipment.

The acoustic pulses (the clicks) were investigated using a Bruel and Kjaer $\frac{1}{4}$ -inch condenser microphone (#4135) placed directly in front of the response key between the two speakers. The two speakers were selected from the available supply to produce sounds that were essentially identical in appearance (Figure 1) and similar to those used by Kelly (1974). Analysis of the clicks using a bandpass filter (Krohn-Hite model 3500) set to octaves between 128 Hz and 50 kHz revealed that the bulk of the acoustic energy lay between 2.048 kHz and 16.384 kHz. The maximum level was 81 dB, SPL, at 8.192 kHz (reference 20 μ N/

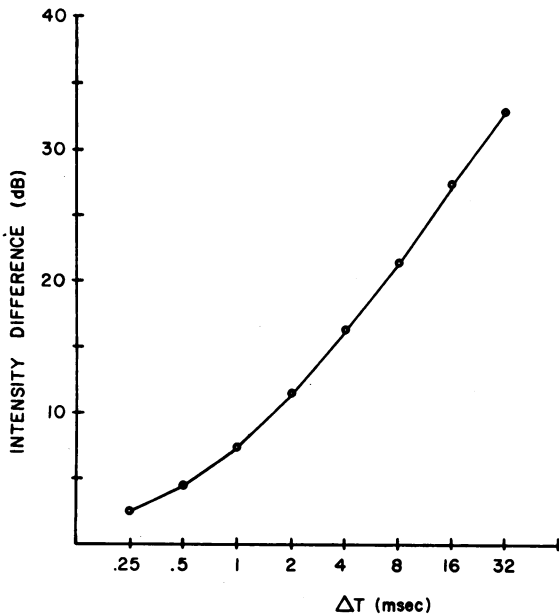


Fig. 2. The intensity of the echo for different echo arrival times calculated for a perfectly reflecting surface on the basis of the inverse square law of sound intensity reduction with distance.

m^2). The peak intensity level of the clicks was 87 dB. Measurements of background noise were made at various positions within the enclosure; the noise level between 2 and 16 kHz averaged 37 dB, with a maximum of 40 dB at 8.192 kHz. Measurements were also made to determine the presence of any actual echoes of single clicks at various points inside the enclosure; the only echo detected was that from the response lever and speaker opposite the sounding speaker. In front of the key, this echo had a maximum intensity level of 75 dB, and its onset time was 2 msec after that of the source click. This remained constant throughout all phases of the experiment. The microphone was calibrated using a Bruel and Kjaer pistonphone (#4220) to obtain the SPL levels.

The Grason-Stadler relay programming equipment was arranged to produce a single click pair on each trial (S1 followed by S2, or vice versa).

Procedure

The animals were trained, using a trial by trial method, to respond on the left lever, R1, when a single click pair was presented in the order S1-S2, and on the right lever, R2, when

the click pair occurred in the order S2-S1. Trials, on a variable interval of 30 sec, were initiated by responding on the key; this ensured that the animal's head was centered between the two speakers at the occurrence of each trial.

Preliminary training consisted of shaping pressing on both levers using as reinforcement sweetened condensed milk presented by the dipper feeder. A single click was then presented through either S1 or S2 (in an irregular order), and a response on the lever adjacent to the speaker which had sounded (correct response) was reinforced. A correct response also terminated the trial and started the intertrial timer. A response on the lever opposite the speaker which had sounded terminated the trial and started the next intertrial interval but was without further behavioral consequence. If no response occurred within the 5-sec interval following the click, the trial was terminated and the next intertrial interval started. When lever pressing was judged to be under the control of the clicks, responding on the center key was shaped using the click as a conditioned reinforcer. The programming equipment was then arranged so that the first response on the key after the end of the intertrial interval initiated a trial. Intertrial responding on either R1 or R2 prevented key responses from setting up a trial for 5 sec. Animals continued in this condition until the rate of responding on the key and the percentage of correct responses on the levers appeared to have reached stable levels.

At this point, click pairs were substituted for single clicks. For Condition I (time difference alone, equal intensity clicks), click pairs with a separation of 2 msec were substituted. This value was chosen on the basis of Kelly's (1974) data, which indicated that at 2 msec rats gave well above 90% of responses to the side of the first click. In the present experiment, all animals gave at least 90% correct responses within 2 sessions at 2 msec. In each trial, a response within 5 sec on the lever adjacent to the speaker that sounded first was reinforced. The four rats used in this condition (RJ 6, RJ 7, RT 49, RT 50) were studied for at least two sessions at each of 12 interclick intervals (Δt) ranging from .015 to 32 msec, and also at 0 msec (simultaneous clicks) as a control point (see Figure 3 for Δt values). A given value of Δt was used throughout each

session, and the time intervals were presented in an irregular manner which differed for each animal, with the restriction that following any session in which the animal's responding was below or close to threshold (75%), in order to maintain stimulus control the Δt used in the next session was one at which the animal gave above 90% correct responses. Each session lasted until 50 reinforcers had been delivered.

For Condition II (intensity difference alone), simultaneous click pairs were introduced with a 40 dB intensity difference between them, so that the lower-intensity click was close to the background noise level in the room. On each trial, a response on the lever adjacent to the louder click was reinforced. In Condition II, two naive animals (RH 2 and RH 3) were studied for at least two sessions at each of 9 intensity differences ranging from -2.5 to -40 dB (see Figure 4).

Condition III (combined time and intensity differences) was started after the conclusion of Condition I. Three of the animals which had been studied in condition I (RJ 7, RT 49, and RT 50) were studied for at least 2 sessions at each of 6 Δt intervals ranging from 1 to 32 msec; at each value of Δt , an intensity difference calculated as described above in the Procedure was used (see Figure 2). The death of RJ 6 prevented its inclusion in this condition.

RESULTS

The results for Condition I are presented in Figure 3, which shows the percentage of correct responses for each animal at each value of Δt . The upper and lower echo arrival times at which correct responses would fall to the 75% level (upper and lower thresholds) were estimated from these data and are presented in Table 1. The lower thresholds are close to those reported by Kelly (1974) for five rats (.043, .049, .047, .082, and .046 msec). The upper thresholds are below those reported by Kelly, who gave upper thresholds for two rats as lying between 20 and 32 msec. However, the decline in performance at longer intervals shown in his Figures 4 and 5 is comparable to the results presented here, given the differences in the two procedures. As would be expected, the percentage of correct responses for a Δt of 0 msec was approximately 50%.

Table 2 presents the data obtained from one animal, RJ 7, in Conditions I and III.

Table 1

Upper and lower echo delay times estimated to give 75% correct responses (thresholds).

Animal	Lower threshold (msec)	Upper threshold (msec)
RJ 6	.036	7.7
RJ 7	.045	8.2
RT 49	.036	6.5
RT 50	.060	10.9

These data also illustrate the results obtained from the other animals in the two conditions. It should be noted that the wide range of the number of sessions at each value of Δt in Condition I is due to the restriction discussed above; proportionately more sessions were run at values between .5 and 4 msec.

The results for Condition II are presented in Figure 4. When only the intensity of one click in each pair was altered, the animals gave above 95% correct responses for intensity reductions from -11.5 to -40 dB. With intensity differences less than -11.5 dB, the percentage of correct responses fell off; with an intensity difference of -2.5 dB, the animals made fewer than 60% correct responses. The intensity reduction at which the animals would give 75% correct responses (threshold) was estimated from the data presented in

Table 2

Mean percentages of correct responses (across sessions), standard deviations, and number of sessions at each Δt in Conditions I and III for RJ 7.

Δt (msec)	X	SD	N
CONDITION I			
0	48.75	15	7
0.015	61	11.6	4
0.031	66	9.5	3
0.062	78	14.7	7
0.125	88.7	10.6	10
0.25	98.2	2.78	14
0.5	99	1.73	20
1	99.1	1.19	22
2	98.6	3.56	65
4	89	8.5	17
8	75	9.5	10
16	64	9	6
32	63	9	7
CONDITION III			
1	98	2	2
2	94	7.78	2
4	97	1.41	2
8	97	1.41	2
16	99	1.41	2
32	98.6	2.31	3

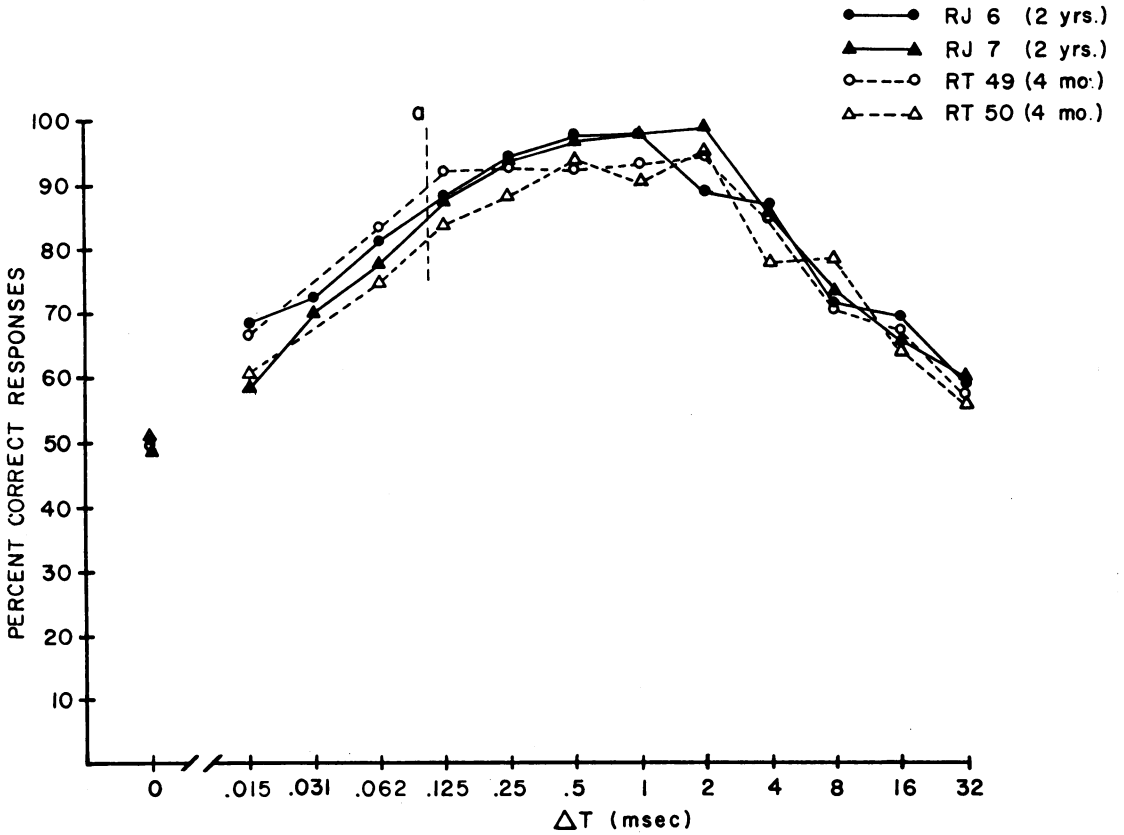


Fig. 3. The percentage of correct responses for echo delay times (Δt) of 0 to 32 msec. The vertical line, *a*, indicates the minimum Δt that could occur under natural conditions. Note: there is no difference between the 2-year-old and the 4-month-old animals.

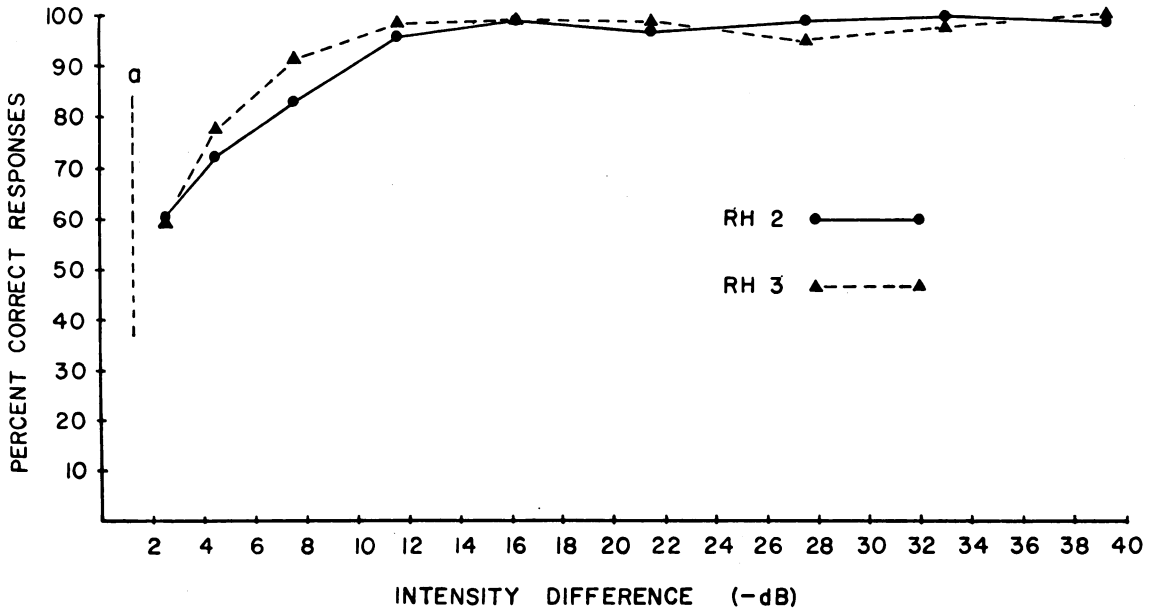


Fig. 4. The percentage of correct responses for echo intensity reductions of 2.5 dB to 40 dB. The vertical line, *a*, indicates the intensity reduction for a delay of 0.11 msec.

Table 3

Intensity reduction of the echo required to give 75% correct responses (threshold).

<i>Animal</i>	<i>Intensity</i>
RH 2	-5.4 dB
RH 3	-4.3 dB

Figure 4. The results are given in Table 3. These numbers are similar to those reported by Kelly (1975) for click pairs in a conditioned suppression procedure; his threshold estimates ranged from 2.8 to 4.2 dB for six animals.

Table 4 presents the data obtained from one animal, RH 2, in Condition II. The data given by the other animal in this condition were similar.

Figure 5 gives the percentage of correct responses for Condition III, in which the intensity of the second click was reduced by an amount obtained from the function shown in Figure 2. All three animals responded at levels above 90% correct at all time intervals from 1 to 32 msec.

It was thought that the precedence effect might be sensitive to the age of the animal because of the short time differences involved. For this reason, animals of two age groups were used in Conditions I and III. In Condition I, RJ 6 and RJ 7 were 19 months old at the start of the experiment and 31 months old at the end. RT 49 and RT 50 were 5 months old at the start and 9 months old at the conclusion. Figure 3 shows that there were no differences between young and old animals. In Condition III, RT 49 and RT 50 were 9 months old at the start and 10 months old at the conclusion, and RJ 7 was 32 months old at the start and 33 months old at the conclu-

sion; Figure 5 shows that there was no difference between the animals.

DISCUSSION

The data of the present experiment can be interpreted in terms of the behavioral implications of an analogous situation in which the rat's head is located between a sound source on one side and an echo producing surface on the other. Two possible arrangements of the echo producing surface are shown in Figure 6. For any arrangement of the echo surface, Δt as defined in this experiment corresponds to the difference between the arrival time of the direct sound from the source at plane *a*, the animal's left ear in Figure 6, and the arrival time of the echo at plane *b*, the animal's right ear. In terms of distance, Δt equals the time required for the sound to travel the distance $ac + bc$. The minimum possible Δt occurs when the echo producing surface is adjacent to the animal's head (plane *b*, Figure 6). The Δt in this situation is given approximately by the time required for the sound to travel the width of the animal's head, .11 msec. Thus, the echo arrives almost simultaneously with the direct sound. There is very little difference between the initial sounds reaching the animal's ears in this situation and those reaching its ears in a simple localization in which no echo is present. Longer values of Δt would be produced when the echo producing surface is in any other position, such as *c* in Figure 6. In this case the situation is more complex, as the direct sound reaches the animal's right ear (plane *b*) before the returning echo does.

The dashed vertical line, *a*, in Figures 3 and 4 represents the minimum naturally occurring Δt discussed above. Figure 3 shows that, with equal intensities, at a time delay of .11 msec the animals would have given between 85% and 90% correct responses. The data in Figure 4 show that with simultaneous clicks, at the intensity reduction corresponding to .11 msec, the animals would respond at the chance (50%) level. Presumably, then, for short echo path distances, the animal's ability to respond to the source and to reject the echo depends primarily on the time delay rather than the intensity difference of the echo. It should be noted, however, that the intensity reductions used here were calculated

Table 4

Mean percentages of correct responses (across sessions), standard deviations, and number of sessions at each intensity difference for RH 2.

<i>Intensity (dB)</i>	<i>X</i>	<i>SD</i>	<i>N</i>
-2.56	59.9	6.43	5
-4.54	71.9	6.57	4
-7.5	83.0	9.21	5
-11.47	95.2	3.64	7
-16.25	99.2	1.10	5
-21.57	97.4	1.96	6
-27.23	98.7	2.31	6
-33.06	98.7	1.60	6
-38.97	98.7	1.15	3

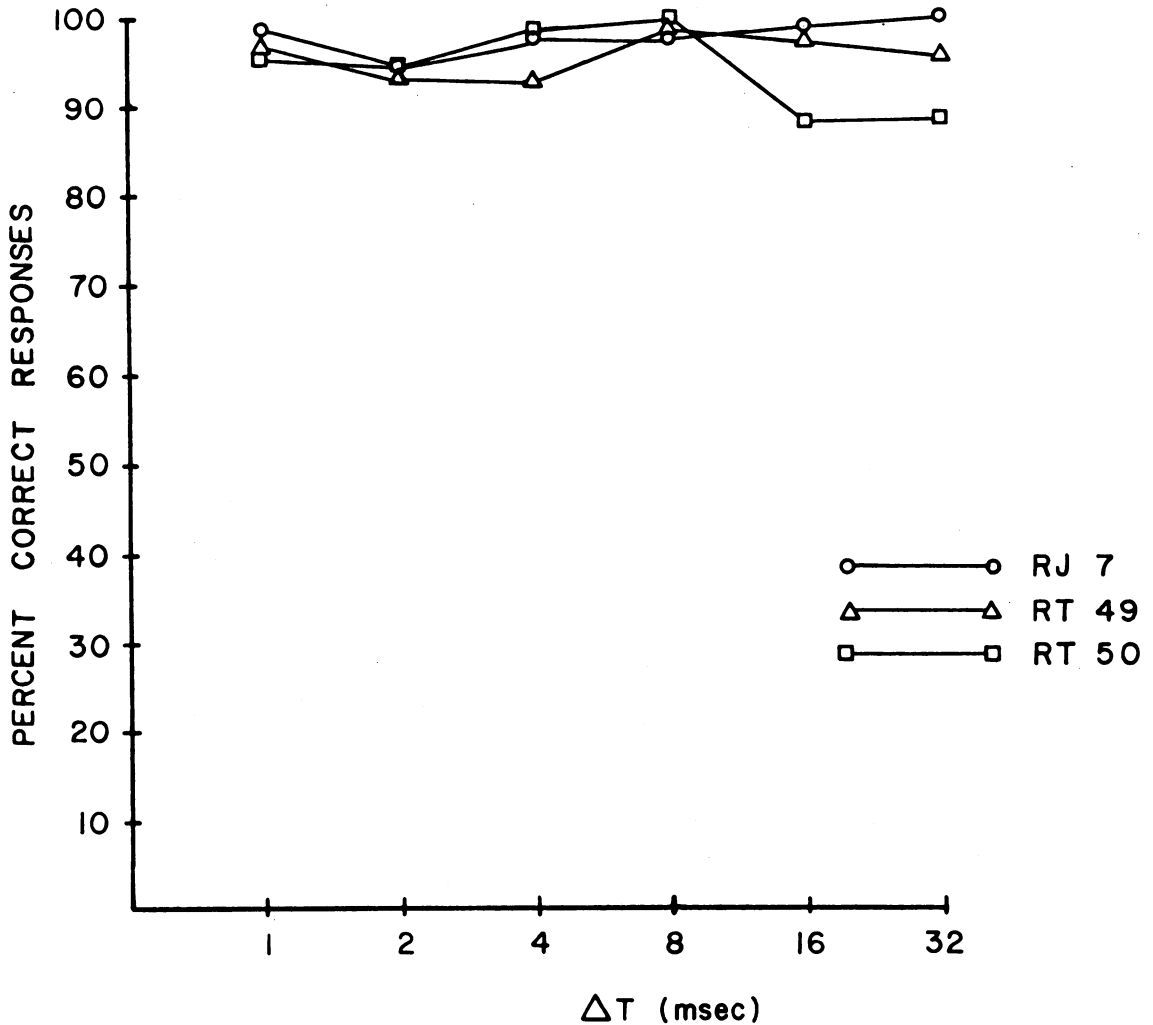


Fig. 5. The percentage of correct responses for echoes having both a delay and an intensity reduction relative to the source.

using a hypothetical perfect reflector and that, under most natural conditions, the intensity reduction of an echo would be larger and therefore more useful to the animal.

The results obtained with equal intensity clicks at values of Δt below a in Figure 3 can be interpreted in terms of the localization of a single click; the presentation of two clicks from opposite sides of the animal's head, separated by time differences smaller than .11 msec, corresponds in terms of the timing of the stimuli initially reaching the animal's ears to the presentation of a single click located between 0° and 90° from the midline. This interpretation of the decline in the percentage of correct responses at these very small Δt 's, found in the

present study and in that of Kelly (1974), is consistent with reports of human subjects that at Δt 's below 1 msec (the maximum binaural Δt for humans) the apparent location of the single heard click is shifted toward the midline as Δt is decreased (Wallach et al., 1949).

The results obtained with equal intensity clicks at long values of Δt confirm previous findings that subjects' ability to respond to the first click in a pair decreases as Δt is increased (Gardner, 1968; Kelly, 1974). Wallach et al. (1949) found that human subjects reported that, at values beyond 6 msec, they began to have difficulty localizing the first click in a pair. The animals in the present experiment gave upper thresholds ranging from 7

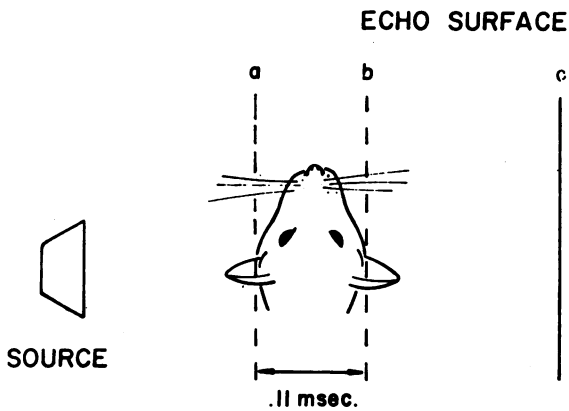


Fig. 6. Schematic illustration of the natural analogue of the present experiment. Echoes are produced by a reflecting surface which is located on the side of the rat's head opposite the source. As the surface is moved from *b* to *c*, the echo is reduced in intensity and the echo delay is increased.

to 11 msec, and at 32 msec were responding at near chance levels. Thus, there is a range of relatively long values of Δt over which a time-based suppression effect ceases to be sufficient to support localization.

The data suggest that in conditions in which both time and intensity differences are present and when the echo must travel more than a very short distance, the ability to respond to the source depends mainly on the intensity reduction rather than on the delay of the echo. Figure 3 shows that the percentage of correct responses to equal intensity click pairs began to decrease by 4 msec for all animals. A delay time of 4 msec is equivalent to an echo path distance (in Figure 6, the distance $ac + bc$) of approximately 1.35 m, or, in the case of a rat, a reflecting surface located about 65.5 cm from the animal's head in the simple case illustrated in Figure 6. Figure 2 shows that for a delay time of 4 msec, the minimum intensity reduction to be expected is approximately 16 dB; any surface that is not a perfect reflector will give an echo that is attenuated still further, a situation even more favorable to the animal's using the intensity reduction of the echo in localization. Thus, the time/intensity difference combinations used in Condition III represent the least favorable expectable conditions in this situation; nevertheless, as Figure 5 shows, the intensity reductions used were sufficient to permit accurate locali-

zation at all values of Δt including the longest used. However, intensity differences alone are not sufficient to support localization of a primary source in all situations; Figure 4 shows that when intensity differences alone were used, the percentage of correct responses declined sharply for intensity differences less than -11.5 dB, which would correspond to Δt 's below about 2 msec.

In any situation, a reflecting surface sufficiently far from the animal will give an echo which, by the time it reaches the animal, will be within the level of the background noise and will be masked. It is the region between plane *b* in Figure 6 and the point at which echoes are masked for which, under natural conditions similar to those in the present experiment, the problem of distinguishing primary sound sources from secondary sources (echoes) exists. The data obtained in the second condition indicate that intensity differences alone are sufficient to permit this for all except very small values of Δt . Thus, it seems that it is for these very small values that a time-difference based precedence mechanism is required to permit animals to respond to the primary sound source in an echo producing environment of the kind studied. Time differences alone support behavior directed to the sound source with a high degree of accuracy from the minimum naturally occurring Δt (.11 msec in rats) to approximately 4 msec. Beyond 4 msec, control of responding by time differences alone becomes progressively worse, and it appears that it is in this range that intensity differences between the primary sound and the echo are behaviorally significant.

Taken together, the results presented in this study suggest that there would be substantial redundancy in the time and intensity cues present in natural situations. Time differences alone provide some support for localization even when they are as long as 8 to 16 msec. Similarly, intensity differences as small as -4 dB support near-threshold percentages of correct responses. In most natural situations, the intensity differences present would be greater than those produced by the hypothetical perfect reflector discussed here. Thus, in most situations both time and intensity cues are available to support behavior toward primary rather than secondary sound sources. The results presented here suggest that neither time differences alone nor intensity differences alone

are sufficient to support localization of primary sound sources in all situations.

REFERENCES

- Downey, P., & Harrison, J. M. Control of responding by location of auditory stimuli: Role of differential and non-differential reinforcement. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 453-463.
- Downey, P., & Harrison, J. M. Control of responding by sound location in monkeys: Rapid acquisition in darkness. *Journal of the Experimental Analysis of Behavior*, 1975, 23, 265-276.
- Gardner, M. B. Historical background of the Haas and/or precedence effect. *Journal of the Acoustical Society of America*, 1968, 43, 1243-1248.
- Harrison, J. M., & Briggs, R. Orientation and lever responding in auditory discriminations in squirrel monkeys. *Journal of the Experimental Analysis of Behavior*, 1977, 28, 233-241.
- Harrison, J. M., Downey, P., Segal, M., & Howe, M. Control of responding by the location of auditory stimuli: Rapid acquisition in monkey and rat. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 379-386.
- Harrison, J. M., Iversen, S., & Pratt, R. Control of responding by the location of auditory stimuli: Adjacency of sound and response. *Journal of the Experimental Analysis of Behavior*, 1977, 28, 243-251.
- Kelly, J. B. Localization of paired sound sources in the rat: Small time differences. *Journal of the Acoustical Society of America*, 1974, 55, 1277-1284.
- Kelly, J. B. Studies of stereophonic hearing in the albino rat. *Journal of the Acoustical Society of America*, 1975, 56, 39-40 (supplement). Paper presented at the Nov. 1974 meeting of the Acoustical Society of America.)
- Wallach, H., Newman, E. B., & Rosenzweig, M. R. The precedence effect in sound localization. *The American Journal of Psychology*, 1949, 62, 315-336.

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