EFFECTS OF AUDITORY STIMULI ON LAMBS

by

LAURENCE ALVIN AREHART

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David Ames
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THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

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Chapter I

INTRODUCTION

Livestock production in the United States has increased substantially the last 25 years. Improved nutrition, genetics and management are largely responsible for increased production. This marked increase may be reaching a plateau, thus researchers are seeking new approaches to improved animal response. One area which has not been extensively explored is the effect of physical environment.

To date most environmental research has dealt with nutrition and general management such as housing construction that will be of economic advantage to the producer. Slotted floors for livestock (sheep, swine and cattle), environmental controlled pig parlors, cage laying poultry houses, are a few examples. Some workers, Blaxter *et al.* 1959; Armstrong *et al.* 1960; Blaxter, Clapperton and Wainman, 1966; and Ames, Nellor and Adams, 1970; have been concerned with effect of the thermal environment on the physiological responses, energy metabolism and other aspects of animal function. Other environmental factors have not been extensively investigated.

One environmental factor receiving little attention has been the effect of sound on farm animals. Technological advances are adding to the noise level in our environment with jet aircraft, interstate highways, and increased population of mechanical equipment creating new problems. Power equipment for the farm or ranch and many new sources of noise such as automatic electric appliances, all are creating a new environmental problem termed "noise pollution."

This research was conducted in an effort to determine the effects of sound type and intensity of sound on the physiological responses and efficiency of early weaned lambs.

Chapter II

REVIEW OF LITERATURE

Methods and Scales of Noise Measurement

Since persons in fields unrelated to physical and psychological acoustics may find some terms difficult to understand, a brief review of terminology will be provided. This information will minimize digression from the main theme of this thesis.

Sound, as we know it, is progated in the form of a compressional wave. A compressional wave demands that the wave move in a physical medium which can be compressed and rarefied. Although there are other measurable attributes of the sound wave, most all data reported relating to the amplitude of sound waves is measured by pressure operated microphones sensitive to fluctuations in barometric pressure.

Two major classifications of sound wave types are used in acoustics, plane waves and spherical waves (Ward and Fricke, 1969). A plane wave results if the source is large and if the measuring point is at a long distance from the source, and if there are no reflecting surfaces of any kind between the sources and the measuring point. The spherical wave is classically described as the type of radiation coming from a small pulsating sphere where the point of measurement is reasonably close to the sphere and where there are no reflecting surfaces in the vicinity of the source. An important feature of the plane wave is that the pressure amplitude does not change with distance unless there is some form of absorption or dissipation in the medium. The spherical wave pressure amplitude decreases as the wave travels away from its source (Stevens, 1955).

The pressure variations of sound or noise are expressed in decibels (dB) according to the formula: $NdB = 20 \log_{10} \frac{(P)}{(Po)}$

Where: NdB = number of decibels
P = the average amplitude of pressure change
Po = a reference pressure, usually 0.002 dynes/cm^2

On this scale a zero dB sound pressure level corresponds to a pressure of 0.0002 microbar. A sound pressure level of 60 dB corresponds to a pressure not 60 times the reference pressure, but 1000 times the reference pressure or 0.02 microbar. A sound level of 100 dB corresponds to a pressure of 20 microbars.

Sound can also be measured as sound-power level (SPL). SPL is also expressed in decibels, but here the reference level is 10^{-12} watt. This means that a power level of zero dB represents a power of 10^{-12} watt. A power level of 60 dB represents a sound power of 10^{-6} watt; a power level of 100 dB corresponds to a power of 10^{-2} watt; and a sound power level of 120 dB corresponds to a power of 1 watt. These examples illustrate that most sounds encountered in the environment involve power less than 1 watt which seems insignificant when compared with normal power sources (Ward and Fricke, 1969).

Beranek (1966) reported SPL for everyday noise sources shown in Table 1.

TABLE 1. INTENSITY LEVELS OF COMMON SOUNDS

Source	dB Level
Zero loudness	0
Whisper	30
Quiet office	40
Home	45
Conversation	60
Automobile	70
Noisy office	75
Street	80
Airplane	105
Rocket	115
Thunderclap	120

Frequency is a basic part of sound and refers to the number of to and fro oscillations per unit time. Frequency is specified in cycles per second (cps), (H_Z), (Stevens, 1955).

A third characteristic of sound is phase angle. The phase angle has meaning only in relation to an arbitrarily selected reference instant and designates the part of its cycle in which, at the reference instant, a point on the wave finds itself[1/] (Licklider, 1958).

Physiological Responses of Man to Sound Stress

Jones (1968) defines noise as an undesired sound. Extensive studies have been conducted relating human responses to various noise. McKenzie (1934) and Jones (1968) indicated that intense noise (90 dB or higher) will result in hearing loss. This loss may be temporary, permanent, or a combination of the two. They also found that high intensity sound (130 dB) will produce pain and blurred vision with danger of traumatic rupture to the ear. Hearing loss due to high intensity noise has prompted research aimed at developing noise exposure criteria for safe-guarding ear damage. Universal acceptance to such criterion has not occurred.

Some research indicates that noise causes physiological disorders in addition to hearing loss. Parrack (1950) indicated that loud noise reduced human efficiency while Laird (1927) suggested that office personnel are 19 percent more efficient in quiet surroundings compared to noisy areas.

[1/]expression $a = \sin (2\pi ft. = \phi)$, the whole quantity $2\pi ft. + = \phi$ is the instantaneous phase angle

Morgan (1916), Davis (1932), Finch and Culler (1934), and Freeman (1939) reported intermittent noise as more annoying than sustained noise. Intermittent noises caused tension in man each time the sound was heard. The effect, however, quickly disappeared. McCord, Teal and Witherbridge (1938) reported that loud noise increased blood pressure. Davis (1932) indicated that sounds decreased electrical skin resistance. Demling, Izschoppe, and Classen (1970) found a significant reduction of gastric acid secretion when three types of music were played to subjects at intensities normally obtained in concert halls.

Peiper (1925) reported increased kicking and body movement of the fetus during late months of pregnancy in response to loud sound applied to the mother's abdomen. Sontag and Wallace (1935), using an electric doorbell indicated increased fetal movement in 92 percent of the test cases with concurrent increases in fetal heart rate. Bernard and Sontag (1947), working with eight and nine month feti were able to significantly increase fetal heart rate, using audio frequency ranges of 20 to 4000 cps. Spelt (1948) reported having achieved fetal conditioning, i.e., the fetus learned to anticipate the noise produced by striking a wooden box with a wooden clapper at five second intervals. Sounds of lower intensities can have adverse effects. Laird (1932) reported that sound can reduce saliva flow by 17 percent at 40 dB and reduce gastric secretion 44 percent at 60 dB.

Meyer (1969) reported that blasts of 6000 cps sound at 80 to 90 dB for two hours daily for three consecutive days stimulated the hypothalamus in women resulting in the secretion of follicle stimulating hormones.

Various authors have reported psychological responses to sound. Beranek (1966), suggested noises influence high divorce rate, social conflict, indigestion and other organic disabilities. His work suggests that in areas where a specific source (such as airplanes) produces a constant din, about one third of the population acclimate to the noise; however, one fourth were increasingly bothered by the noise. Konz and McDougal (1968) observed that sound type affected automobile drivers with music causing an increase in speed and less weaving.

These reported effects of noise on man's psychological and physiological functions result in reduced work capacity, disruption of rest, annoyance reactions, and general mental and physical distress. The complexity and variability inherent in evaluating noise-induced disturbances on man is difficult because criteria for judging adverse effects of noise on man have not been established. Noise annoyance, as reflected in negative feeling and attitudes, can be shaped not only by the qualitative and quantitative features of the acoustic stimulus but also by the information conveyed by such sound.

Physiological Responses of Laboratory Animals to Noise

When animals are exposed to any of a variety of noxious or potentially noxious stimuli, there is an increased secretion of adrenoconticotropin (ACTH) by the anterior pituitary. Selye (1952) defined noxious stimuli which increase this ACTH secretion as "stressors." This stress syndrome directly involving the adrenal glands has often been reported. Most authors have reported an increase in adrenal weight following a period of stress (Sackler, Weltman and Jurtshuk, 1959, 1960); while others report no significant change (Anthony and Ackerman, 1955) and (Anthony and Babcock, 1958). Geber and Anderson (1967a) reported a slight decrease in organ weights of stressed animals with the exception of increased adrenal and kidney weights of aged rats. Sackler *et al.* (1959) applied sound stimulus of 110 dB intensities at frequencies of 375-500 cps, which resulted in decreased weight of the rat adrenal. Adrenal hyperphasia, partial inhibition of ovarian activity, reduction in weight of vascularity of the uterus, and loss in liver weight were noted. Although no changes in either pituitary or thyroid weight was induced by intense sound stimulation, changes in pituitary cell type and thyroid colloid storage did result. Anthony and Ackerman (1955) and Anthony and Babcock (1958) concluded that sound levels of 110-140 dB either did not influence the rat body weight, or if any response was obtained it was not significant in degree or duration. Farris,Yeakel and Medoff (1945) indicated a lasting and profound weight change for rats under influence of noise.

Anthony, Ackerman and Lloyd (1959) reported that the behavioral responses varied during sound 110 dB at frequencies ranging from 10,000 to 20,000 cps. One strain of mongrel Swiss albino mice demonstrated a high incidence of convulsions. The physiodynamic theory of abnormal behavior and its relation to the deleterious consequences is strengthened by these results.

The literature emphasizes hypertension as a common response of the cardio-vascular system to noise. This effect of sustained noise has been reported by Rosecrans, Watzman and Buckly (1966); McCann *et al.*(1948); and Medoff and Bongonanni (1945). Using essentially the same type of audiogenic stimulation, Geber and Anderson *et al.*(1967) demonstrated hypertrophy of the heart following two weeks of intermittent noise at intensities above 100 dB.

Uteroplacental blood flow resulting from maternal sound stress was noted in the study by Geber (1966). Observed variations in blood flow in different areas of the uterus combined with prolonged fetal response to a given stress indicate that alteration of blood flow (both maternal and fetal) could account for abnormal fetal development, particularly if it occurred during critical periods of fetal organogenesis (Franklin and Brent, 1964; Wigglesworth, 1966; and Senger, Lose and Ulberg, 1967). Geber (1966) reported complete loss of rat litters in rats in approximately 50 percent of sound stressed (bells, gongs, buzzers, alarms, horn and white noise, produced intermittently 10 percent of the time for a three week period) females; litter size was reduced by an average of two feti per litter and a wide range of developmental abnormalities was observed in surviving feti. Sontag (1941) first noticed fetal cardiovascular responses to maternal audiogenic stress. Several studies by Zondek and Tamari (1960, 1964, 1964) described the effect of audiogenic stress on reproduction and fetal development pointing out that noise stress reduced the number of feti per litter in addition to decreasing the number of pregnancies.

Studies with laboratory animals indicate that auditory stimuli induce changes resembling those produced by other stress stimuli. The underlying physiological changes responsible are not clearly understood, but indications of neuroendocrine involvement are prevalent.

Effects of Loud Sounds on the Physiology of Farm Animals

Jones (1968) suggested that the noise levels in the United States are increasing at the rate of 1 dB per year. Because of this increase in intensity of sound, questions arise concerning the effect of noise levels on livestock. Work reported in this regard is not extensive and results in many instances do not agree.

Ely and Peterson (1944) presented data in which Jersey cows were subjected to fright stimuli by exploding paper bags. This resulted in an immediate cessation of milk production. Parker and Bayley (1960) surveyed the measureable effect of jet aircraft noise and flyovers on the milk production of dairy herds. Results of this survey indicated no effect on milk production. Casady and Lehmann (1956) observed animal installations during sonic boom conditions. They observed approximately 10,000 commercial feedlot beef cattle, 100 horses, 150 sheep and 320 lactating dairy cows. They noted a nervous reaction in sheep and horses subjected to sonic boom noise. Dairy cattle were not apparently affected by sonic booms, although a slight milk reduction was noted initially with a return to normal within a two-week period. Only 19 of 104 booms produced reactions evidenced by a temporary cessation of eating, raising of heads, or slight startle effects in feedlot cattle.

Bond and Winchester (1963) exposed swine to reproduced aircraft and other loud sounds (usualy intensities ranged from 100 to 120 dB) at various stages of the life cycle. No evidence was found to indicate that rate of gain, feed intake, feed efficiency or reproduction was influenced by these loud sounds.

Geber (1962) and Geber and Anderson (1967b) indicated that in sheep regional flow of blood in the uterus and placenta were often altered in opposite directions (increase vs decrease), and certain areas responded for longer periods of time than others in the pregnant ewes exposed to pure tones from an audio generator. Exposure of the ewe to frequencies ranging from 20 to 650 cps at 95 dB produced no measurable uterine blood flow changes but resulted in decreased placental (cotelydon) flow.

In commercial poultry incubators sound intensities of 96 dB had no measurable effect on hatchability or quality of chicks produced (Stadelman, 1958) however, intensities of approximately 115 dB resulted in interrupting the setting tendency of brooding hens. Stiles and Dawson (1961) subjected hens to dog whistles and radio noise and found significant increases in blood spotted eggs and decreased egg shell thickness.

The literature indicates that noise can have a physiological effect on man, rodents and farm animals. These reported changes are in many instances inconsistent, lacking concrete explanations of cause and effect relationships.

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Chapter III

AUDITORY THRESHOLD FOR SHEEP

Acoustic experts report that sound levels are increasing in both rural and urban areas. Cohen (1968) has stated that noise, defined as "unwanted sound," will be a more serious pollutant in the future. Some have suggested that sound may affect meat animals (Bond and Winchester, 1963), however, research is limited with no discussion on the effects of sound on sheep. The logical approach to studying the effects of sound on sheep is to first determine the auditory threshold for this species. Auditory thresholds have been carefully measured in man (Sivian and White, 1933); the pigeon (Heiser, 1963); the cat (Neff and Hinds, 1955); the marmoset monkey (Seiden, 1957), and other animals. The only information available for sheep was reported by Wollack (1963) and based on three ewes. The present experiment is an attempt to more accurately determine the auditory threshold curve for sheep.

Experimental Procedure

Ten Suffolk ewes, from 8 to 10 months of age were housed and managed in a conventional drylot manner with no preconditioning before the testing period.

Auditory acuity trials were conducted in a soundproofed, 2.4 x 2.4 m chamber in a thermally controlled room (21° C). Walls and ceilings were constructed of two 3.8 cm layers of styrofoam separated by 7.6 cm dead air space. The exterior layer of styrofoam was covered with rock wool insulation and a layer of fiber board. Burlap draped the interior and the floor was covered with 4 cm of dried wood chips. The noise level of the soundproofed chamber was 24 decibels background intensity (decibel [dB] is a logarithmic ratio of power or intensity level with reference to a sound pressure level of 0.0002 dynes per cm^2). A one-way window (30.48 cm^2) permitted visual observation.

Sound frequencies were generated by an audio oscillator (General Radio, Model 210) with the signal amplified (Ranland Borg Company Amplifier, Model SA51A 25-70). The speaker (Heath, Model AS-48) capability ranged from 40 to 20,000 Hz and was suspended from the center of the soundproof room 2 m above the floor. Sound intensity was determined using the C scale of a sound level meter (General Radio, Model 1551C). The experiment arragnement is shown in figure 1.

The sound system was tested for overtones and distortions using an oscilloscope (Heath, Model 10-12). Overtones and other distortions from the audio system are shown in table 1; they did not occur at frequencies or intensities studied.

Auditory thresholds were determined by two methods: (1) changes in electroencephalograph patterns (EEG) and (2) behavioral responses. EEG's were monitored via a telemetry system (E & M Physiograph) on a retalinear strip chart recorder. Electrodes were placed on the animal anterior to the poll in the area of the superatemporal plane of the cerebral cortex. Changes in EEG patterns were identified by simultaneously integrating the area of the EEG pattern. Changes in the integrated recording were interpreted as perception of auditory stimuli by the animal. Behavioral responses such as pricking the ears, turning the head, or looking at the speaker were observed via one-way window and were considered to indicate auditory perception.

Frequencies of 100, 200, 500, 1000, 2000, 5000, 6000, 7000, 10,000, 11,000 and 12,000 Hz were selected for recordings and observations. Order

TABLE 1. DECIBEL LEVELS AT WHICH DISTORTION AND OVERTONES APPEARED ON OSCILLOSCOPE SCREEN

Frequency (Hz)	Decibel levels
100	91
200	93
500	103
1,000	107
2,000	94
5,000	94
6,000	83
7,000	61
10,000	60
11,000	50
12,000	56

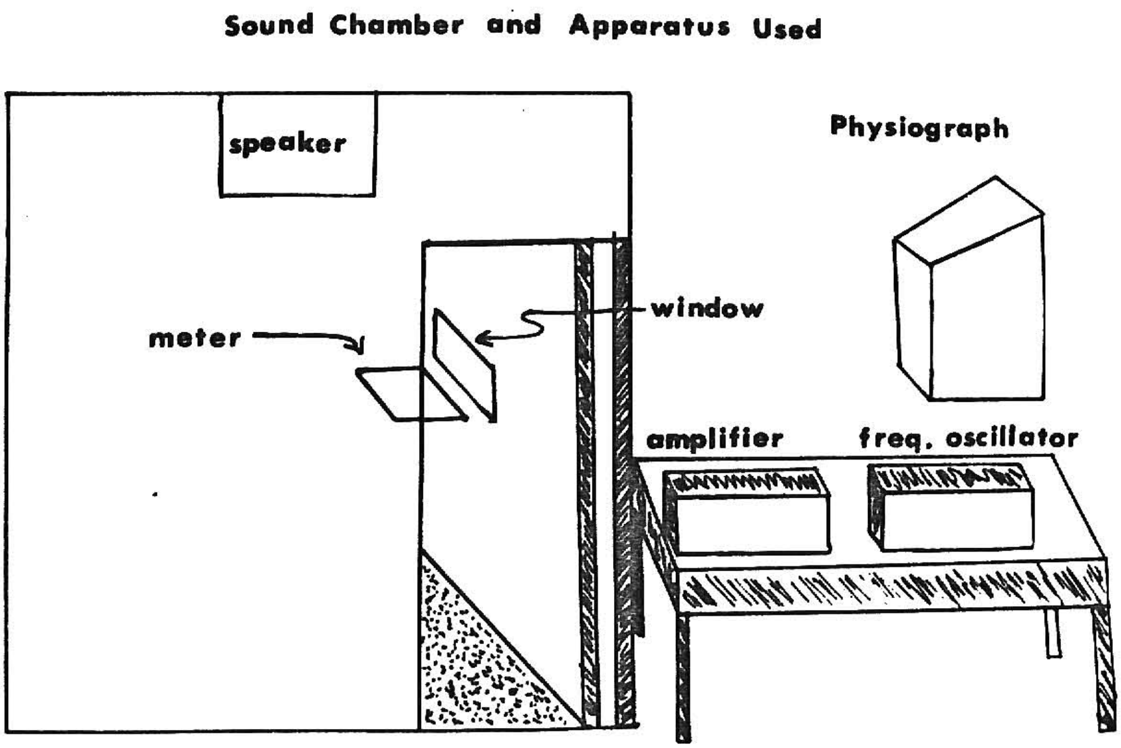

Figure 1. Schematic drawing of experimental facility

of frequencies in a given test period were chosen at random. During a given test period at a specific frequency, power was increased via amplifier until a change in the EEG integration pattern and/or behavioral reaction was noted, then dB levels were recorded. Three tests at each frequency were conducted on each animal. There was a minimum of 20 minutes between each frequency test and a second sheep was present during each test to avoid unduly exciting the test animal. A total of 330 observations were made on 10 sheep.

Analysis of variance and Duncan's Multiple Range Test (Kramer, 1956) were used to analyze data statistically.

Results

There was a significant ($P < .05$) difference in the sensitivity of sheep at different frequencies (table 2). Standard errors were highest at lowest frequencies (highest standard error of 4.98 at 100 Hz), with lowest in the 5000 to 7000 range. The standard deviations for individual observations ranged from 0.0 to 4.02 with 66 percent of the tests having a standard deviation of less than one.

The threshold curve (figure 2) declined gradually from 100 Hz to 500 Hz then fell more rapidly until it reached its lowest point at 7000 Hz. Auditory threshold increased rapidly as frequency increased above 7000 Hz. Decibel levels above background (25 dB) was highest (18.5 dB) at 100 Hz and lowest (7.3 dB) at 7000 Hz (table 2).

Methods to determine auditory threshold (EEG pattern changes and behavioral responses) correlated highly ($r = 0.95$).

Discussion

Auditory stimuli reaching the reticular formation of the brain generate

TABLE 2. AUDIBILITY THRESHOLDS FOR SUFFOLK EWES IN DECIBELS[1,2]

Animal	Frequency (Hz)										
Number	100	200	500	1,000	2,000	5,000	6,000	7,000	10,000	11,000	12,000
1	19.7^{c} ±0.6	20.0^{d} ±0.0	18.4^{ab} ±1.9	14.3^{abc} ±3.4	15.3^{a} ±1.1	10.6^{a} ±2.4	8.0^{a} ±0.0	6.0^{a} ±1.0	7.0^{a} ±1.0	11.7^{a} ±2.1	16.7 ±0.6
2	21.0^{c} ±1.0	14.0^{a} ±2.0	12.6^{a} ±0.7	13.0^{ab} ±1.0	15.0^{a} ±0.0	13.0^{b} ±0.0	11.3^{c} ±0.7	7.8^{ab} ±0.7	11.3^{b} ±3.1	13.3^{ab} ±0.7	15.3^{b} ±2.1
3	20.6^{c} ±1.1	20.0^{d} ±0.0	15.3^{ab} ±2.1	15.3^{c} ±2.1	17.0^{a} ±0.0	10.0^{a} ±0.0	8.3^{ab} ±0.7	7.6^{ab} ±0.7	10.0^{b} ±1.0	14.3^{ab} ±0.6	16.6^{b} ±2.4
4	12.3^{a} ±1.6	16.0^{ac} ±0.0	15.6^{ab} ±0.9	13.3^{abc} ±0.6	12.0^{a} ±0.0	12.0^{ab} ±0.0	8.3^{ab} ±2.6	9.3^{c} ±1.1	14.6^{b} ±1.2	16.6^{c} ±1.5	19.0^{b} ±1.0
5	17.0^{b} ±1.0	16.6^{bc} ±0.7	16.3^{ab} ±1.5	15.0^{bc} ±1.0	13.3^{a} ±0.6	11.0^{ab} ±1.0	9.0^{b} ±1.0	7.0^{a} ±1.0	12.0^{b} ±1.0	16.0^{c} ±1.0	17.0^{b} ±1.0
6	17.3^{b} ±0.6	18.3^{cd} ±1.5	16.6^{ab} ±0.7	15.6^{c} ±0.9	13.0^{a} ±1.0	11.6^{ab} ±0.6	9.3^{b} ±0.6	7.0^{a} ±1.0	13.3^{b} ±1.5	15.0^{c} ±1.0	18.0^{b} ±1.0
7	24.0^{d} ±0.0	20.3^{d} ±1.5	19.6^{b} ±2.1	24.6^{e} ±1.1	15.6^{a} ±3.5	11.6^{ab} ±1.5	8.6^{ab} ±0.6	7.6^{ab} ±0.6	13.3^{b} ±0.7	13.3^{a} ±0.6	14.0^{a} ±1.0
8	27.0^{e} ±1.7	25.0^{e} ±1.0	20.3^{b} ±1.1	12.3^{a} ±0.6	14.3^{a} ±4.0	11.6^{ab} ±1.5	9.3^{b} ±0.6	6.3^{a} ±0.7	10.0^{b} ±1.0	15.3^{ab} ±1.3	18.6^{bc} ±0.6
9	11.0^{a} ±1.0	14.6^{ab} ±0.6	16.3^{ab} ±1.1	14.6^{abc} ±0.6	12.0^{a} ±0.0	13.0^{b} ±0.0	8.3^{ab} ±0.6	7.6^{ab} ±0.6	12.3^{b} ±0.6	18.3^{c} ±0.6	19.6^{bd} ±0.6
10	15.3^{b} ±1.5	17.0^{c} ±1.0	20.0^{b} ±0.0	19.3^{d} ±1.5	17.3^{b} ±1.0	13.0^{b} ±0.0	9.0^{b} ±1.0	7.0^{a} ±0.0	11.0^{b} ±1.0	14.3^{ab} ±0.6	16.6^{b} ±1.5
Mean	18.5 ±5.0	18.1 ±3.3	17.1 ±2.4	15.9 ±4.1	14.5 ±2.1	11.8 ±0.8	9.0 ±0.9	7.3 ±0.9	11.5 ±0.6	14.9 ±1.9	17.3 ±1.7

[1]All dB levels are the mean of 3 observations
[2]All numbers within columns with different subscripts are significantly different ($P < .05$)

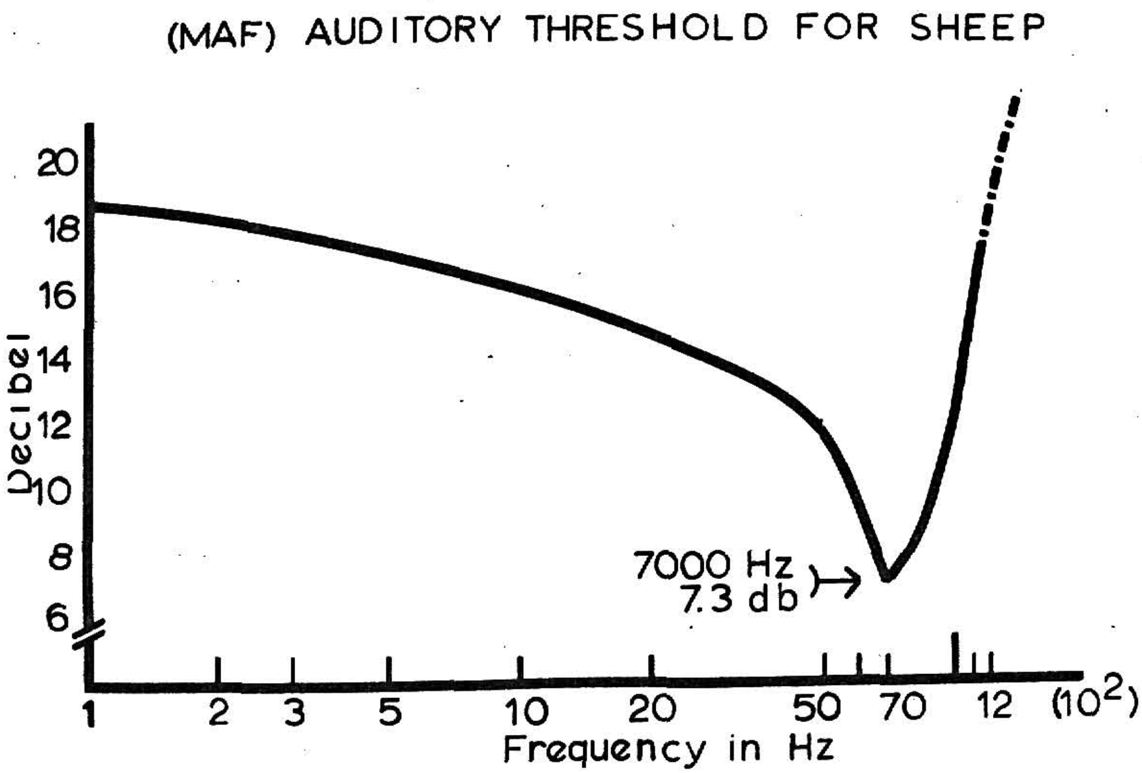

Figure 2. Plot of minimum audible field with intensity (db) shown in terms of absolute sound pressure level.

new stimuli that spreads throughout the cerebral cortex. Biological sense of the system is to arouse an animal to focus attention on external acoustical information. At the same time, the activating system also spreads the stimulus to the centers of the autonomic nervous system which stimulates internal organs such as the respiratory, cardiovascular and digestive systems. Such effects may produce favorable or unfavorable performance responses by animals. Many animals are far more sensitive to both level and frequency of sound than is the human. Consequently, it is logical to suspect that noise may cause various disruptive behavior in domestic animals. The logical approach to studies involving effects of sound in livestock is to first construct an audiogram for the species concerned. The auditory threshold curve resulting from these trials is presented in figure 2.

Auditory thresholds depicted in figure 2 are referenced to the absolute sound power level (SPL) with one decibel corresponding to 0.0002 dynes per cm^2 (microbar).

Most descriptions of auditory acuity in man are referenced to ISO audiometric zero, which is universally accepted as the mean auditory sensitivity for the human population (figure 3). When that reference is used, sensitivity is reported as either plus or minus in number of decibels required to elicit a response compared to the mean number of decibels required from the sample population. The auditory threshold for sheep in this study was referenced to sound pressure level (absolute zero) as no audiometric zero has been reported for sheep. SPL and ISO audiometric zero are directly comparable and one can be deduced from the other. The obvious reason for not using audiometric zero is the different sensitivity levels of this species compared to the human. In essence, the audiogram presented (figure 2) should not yet be used as audiometric zero for sheep becuase it represents only 10 animals of one breed

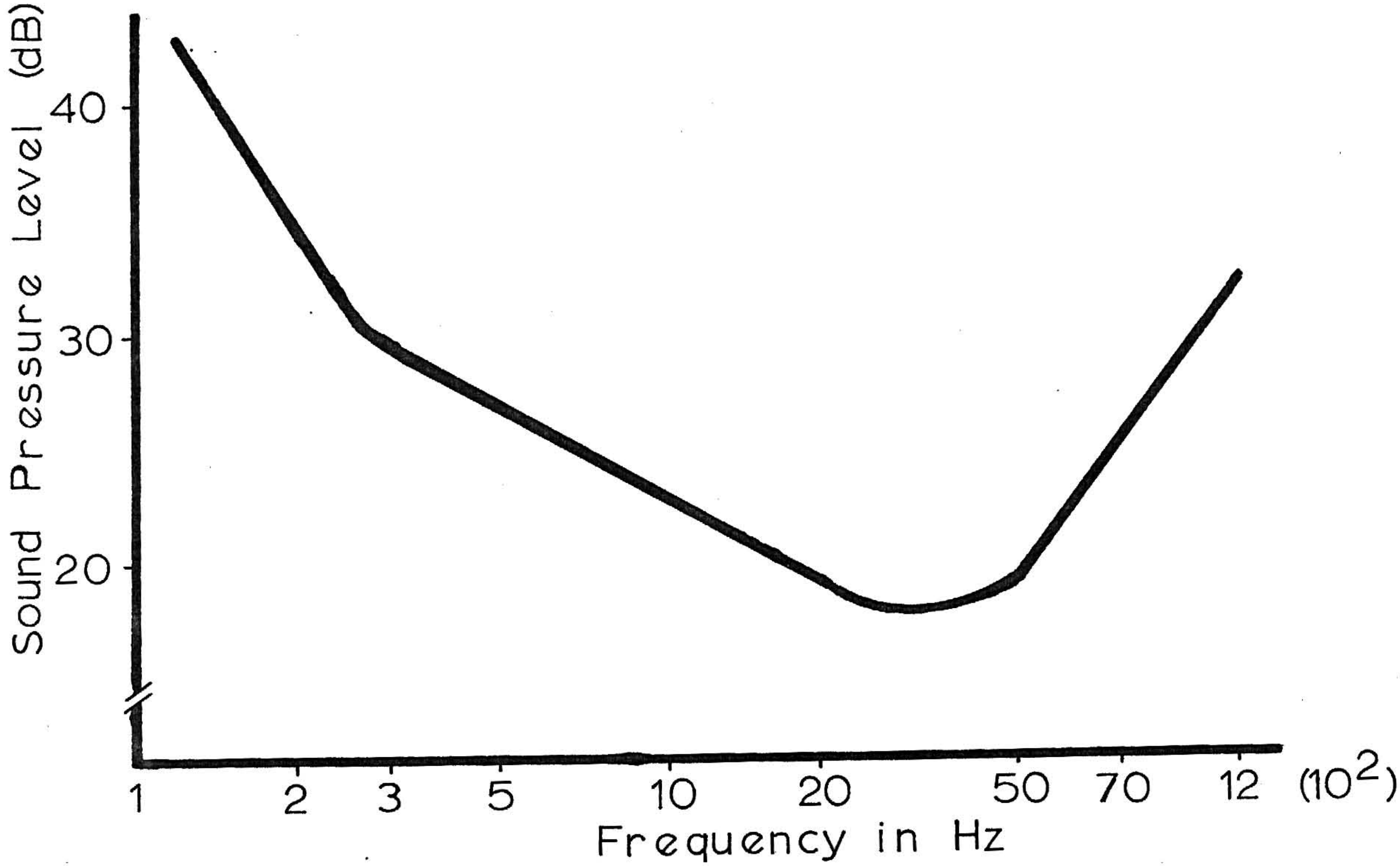

Figure 3. ISO reference audiometric zero

and sex and therefore does not represent the entire sheep population. Additional data representing more sheep are needed to establish audiometric zero for sheep.

The general shape of the auditory threshold curve in figure 2 is comparable to those for man and other animals. The relatively slow decline at low frequencies with more rapid decline as the frequency reaches lowest threshold is typical. Most workers (Stevens, 1955; Sivian and White, 1933 and Prossor and Brown, 1965) report maximum sensitivity for humans ranges from 1000 to 3000 Hz. In general, animals have maximum sensitivity at higher frequencies with indications of being able to interpret sounds in the ultrasonic range (greater than 20,000 Hz) (Prossor and Brown, 1965). Data here would agree with these general conclusions with maximum sensitivity of 7000 Hz observed for sheep. Wollack (1963), using three ewes, found a similarly shaped audiogram but reported a minimum threshold at 10,000 Hz. Several reasons may be responsible for these observed differences. First is the number of sheep used, since significant differences ($P<.05$) in individual responses were noted in the present experiment (table 2). Second, the use of training techniques as used by Wollack (1963), can lead to presumption or vibrative (non-audio) stimuli which result in animal response. Our data suggests that the auditory threshold curve for sheep is shifted to a higher frequency than reported for man and that sheep are more sensitive to higher frequency sounds than are humans being capable of detecting higher frequency sounds.

Summary

Three hundred thirty observations were made on 10 Suffolk ewe lambs to determine the auditory thresholds for sheep. Tests were conducted using

a free field technique in a soundproofed room (background 25 dB). EEG pattern changes and behavioral responses were used to determine hearing thresholds with a high degree of correlation (r=0.95) between techniques. Sound power levels necessary to elicit a response were significantly ($P<.05$) different at each frequency studied. Animals tested were most sensitive (lowest threshold) at 7000 Hz. The resulting audiogram was similar in shape to that of humans but occurred at a higher frequency.

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Chapter IV

PHYSIOLOGICAL RESPONSES OF LAMBS TO THREE TYPES OF NOISE AT TWO LEVELS OF INTENSITY

Reports relating auditory stimuli to physiological responses of farm animals are scarce. Bond (1963) reported increased heart rate in swine when subjected to jet aircraft noise. Davis (1932) indicated noise resulted in a decrease in galvonic skin response in man. Geber (1966) reported increased fetal death rate in rats subjected to noise stress. Loud noises have been found to increase blood pressure and to alter adrenal gland weight (McCann *et al.* 1948; Anthony, 1959; Sackler *et al.* 1959, 1960; Rosecrans, Watzman and Buckly (1966). The literature indicates that auditory stimuli results in physiological responses yet the effects of different types and intensities of sound have not been reported. The following experiment was conducted to determine some physiological responses of lambs subjected to three types of noise at two intensities.

Experimental Procedure

Experiments were conducted involving 25 early weaned lambs (25.3 kg) subjected to three types of noise [United States of America Standard Institute (USASI), instrumental music, and Intermittent Loud Sounds (IMS) at two levels of intensity--75 and 100 dB[1]]. All experiments were conducted in an environmentally controlled room 21° C.

[1]Decibels, logarithmic ratio of power or intensity level used here, it is the sound pressure with respect to a reference of 0.0002 dynes per cm^2.

Heart rate, respiration rate and oxygen consumption were monitored before each sound treatment, immediately after treatment began, and at 15 minutes, 1, 4, and 8 hours of the first day then daily during a 12-day test period. Heart rate (EKG) was determined using a telemetry system (E & M Physiograph). Needle electrodes were placed at the anterior portion of the throacic cavity lateral to the heart. Respiratory rates were determined by counting flank movements. Oxygen consumption was measured with a paramagnetic type continuous flow Oxygen Analizer (Type OA150) using a ventilated hood technique. The hood measured 60 cm in length and 45 cm in diameter and was ventilated at a rate of 15 liters per minute. Oxygen consumption was expressed as milliliters per minute.

<u>Trial I - USASI Noise</u>. The USASI noise spectra was produced by a Random Noise Generator (General Radio, Type 1381) and is obtained by selectively discriminating against low and high frequencies in accordance with certain equal loudness contours (Peterson and Gross, 1967). USASI noise was played continuously during test periods.

<u>Trial II - Music</u>. The music (instrumental Mantovani) was recorded on an 8-track recording tape and played continuously during test periods.

<u>Trial III - IMS Noise</u>. The IMS noise was recorded on an 8-track, 70-minute recording tape. The sound consisted of an electric train, diesel engines, jet and B47 airplanes, roller coasters, noise at football games, foghorns, firecrackers, machine guns and cannons, rain and band marches. The sounds were recorded in a manner such that the noise would occur for intervals of 15 seconds to 3 minutes followed by quiet periods lasting from 1 to 15 minutes.

The tape recorded in this manner furnished 11 hours of noise and 13 hours of quiet (background noise 45 dB). Above sounds were amplified to the desired intensity levels by a Randlan-Borg Amplifier (Model SA51A2S-70), and adjusted to the appropriate sound intensity using a sound level meter (General Radio, Model 1551C).

Lambs in the above trials were subjected to the following treatment regime: (1) 21-day control period with background noise at 45 dB; (2) 12-day test period at 75 dB; (3) 2-day adjustment period [45 dB]; and (4) 12-day test period at 100 dB. During the two-day adjustment period prior to the 100 dB test, 3 lambs which had not previously been exposed to any sound treatment were brought into the environmental room. This procedure allowed the evaluation of the role of climatization to sound.

Means and standard deviations were calculated. Analysis of variance and Duncan's new multiple range test (Kramer, 1956) was used to compare treatment means.

Results

Trial I - USASI Noise. Heart rate of lambs subjected to intensities of 75 dB increased above control values (109 to 114 beats per minute). Heart rate increased from 128 to 145 beats per minute during the first 15 minutes in non-acclimatized animals subjected to 100 dB intensity. It then declined to 135 beats per minute by the fourth hour (figure 1). During the first 8 hours of treatment animal variability was high as indicated by standard deviations ranging from 2.0 to 13.4 (Appendix Table A). Acclimatized lambs did not significantly ($P<.05$) increase heart rate during 12 days of 100 dB treatment although during the initial stages of 100 dB intensity, heart rate increased to 130 beats per minute during the first hour. Heart rates for non-acclimatized lambs subjected to 100 dB intensity sound was significantly higher ($P<.01$) than either the 75 dB or 100 dB acclimatized lambs throughout the 12-day test period (table 1).

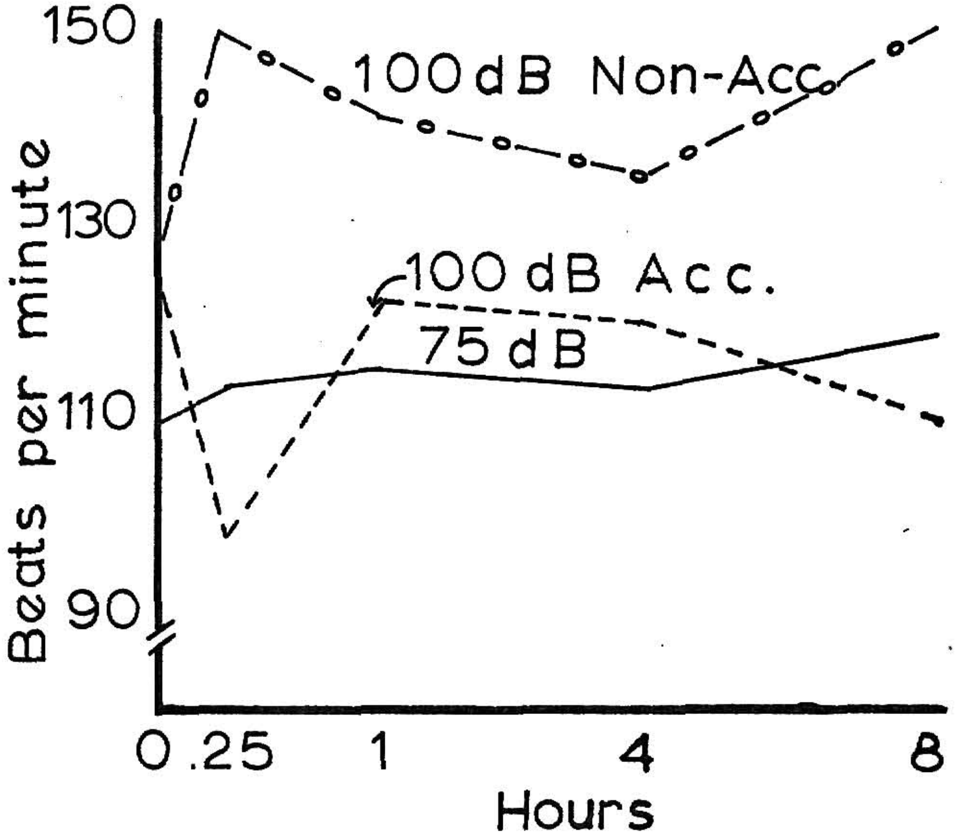

Figure 1. Effect of USASI noise on heart rate

TABLE 1. EFFECT OF THREE TYPES OF NOISE AT TWO INTENSITIES ON HEART AND RESPIRATION RATE AND OXYGEN CONSUMPTION[1]

Levels	Types	Heart Rate	Respiration Rate	Oxygen Consumption
		beats/min.	breaths/min.	ml./min.
75 dB	USASI	121 ± 10.8^{ax}	43.3 ± 5.4^{ax}	272.1 ± 40.0^{ax}
	Music	111.7 ± 5.6^{ay}	61.0 ± 6.3^{by}	224.0 ± 31.4^{y}
	IMS	119.0 ± 15.9^{x}	65.0 ± 20.4^{by}	207.0 ± 24.1^{by}
100 dB Acclimatized	USASI	122.0 ± 10.4^{ax}	62.4 ± 15.5^{bx}	242.5 ± 31.1^{b}
	Music	116.0 ± 8.6^{by}	44.0 ± 4.9^{a}	252.0 ± 21.5
	IMS	123.0 ± 14.6^{x}	49.0 ± 13.3^{a}	222.0 ± 62.8^{a}
100 dB Non-acclimatized	USASI	130.6 ± 13.2^{b}	39.0 ± 5.9^{a}	
	Music	124.0 ± 8.3^{c}	45.0 ± 5.2^{a}	
	IMS	121.0 ± 11.3	46.8 ± 8.3^{a}	

[1]Mean and SD of 3 observations during 12-day tests

^{a,b,c}All letters within column with different subscripts are significantly different (P<.05) for intensity levels

^{x,y} All letters within columns with different subscripts are significantly different (P<.05) for types of sound

In acclimatized lambs respiration rate remained constant (39 breaths per minute) for lambs subjected to 75 dB intensity. Respiratory rate increased rapidly after the first hour, peaking at 64 breaths per minute by the eighth hour (figure 2). Non-acclimatized lambs showed little change until the fourth hour when respiratory rate increased rapidly from 37 to 60 breaths per minute. Following 8 hours of 100 dB intensity sound, respiration rate for both acclimatized and non-acclimatized lambs was significantly higher ($P<.01$), than controls or lambs exposed to 75 dB. This increase was 64 and 60 breaths per minute respectively, as compared to 39 breaths per minute for lambs subjected to 75 dB intensity. Respiration rate for 12-day period continued significantly ($P<.01$) higher at 100 dB test periods for lambs acclimatized by the 75 dB intensity (table 1).

Average oxygen consumption was higher during the 12-day period for lambs subjected to 75 dB intensity sound compared to controls and 100 dB intensity (figure 3, table 1).

Trial II - Music. During the first 8 hours at intensity levels of 75 dB, heart rate increased to values ranging from 114 to 125 beats per minute, stabilizing at 122 beats per minute (figure 4). Acclimatized lambs subjected to 100 dB intensity music had decreased heart rate during the first 8 hours of treatment compared to 75 dB treatments, but over the 12-day period were significantly higher ($P<.05$). The non-acclimatized lambs heart rate dropped from 107 to 96 beats per minute with the onset of treatment, but lambs exhibited the highest ($P<.01$) heart rate during the 12-day test (124 beats per minute) being significantly ($P<.05$) higher than both 75 dB and 100 dB (acclimatized) groups.

Lambs subjected to 75 dB intensity sound had higher respiration rates than both 100 dB acclimatized and non-acclimatized groups of control lambs, (figure 5, table 1).

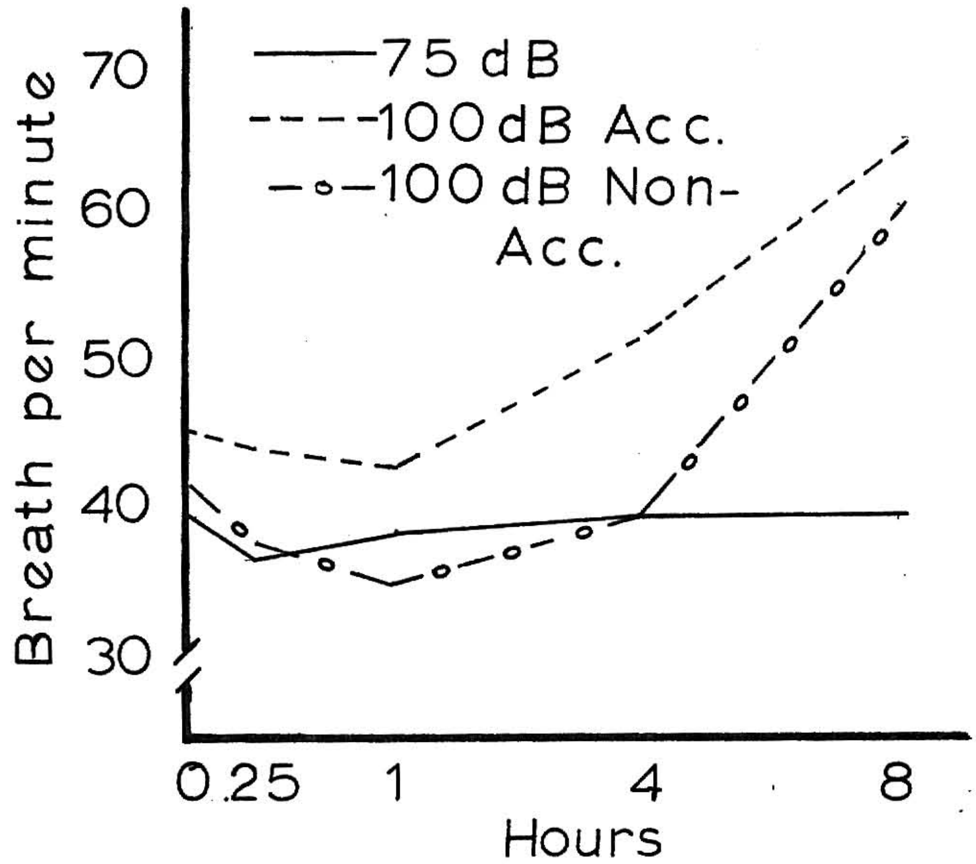

Figure 2. Effect of USASI noise on respiration rate

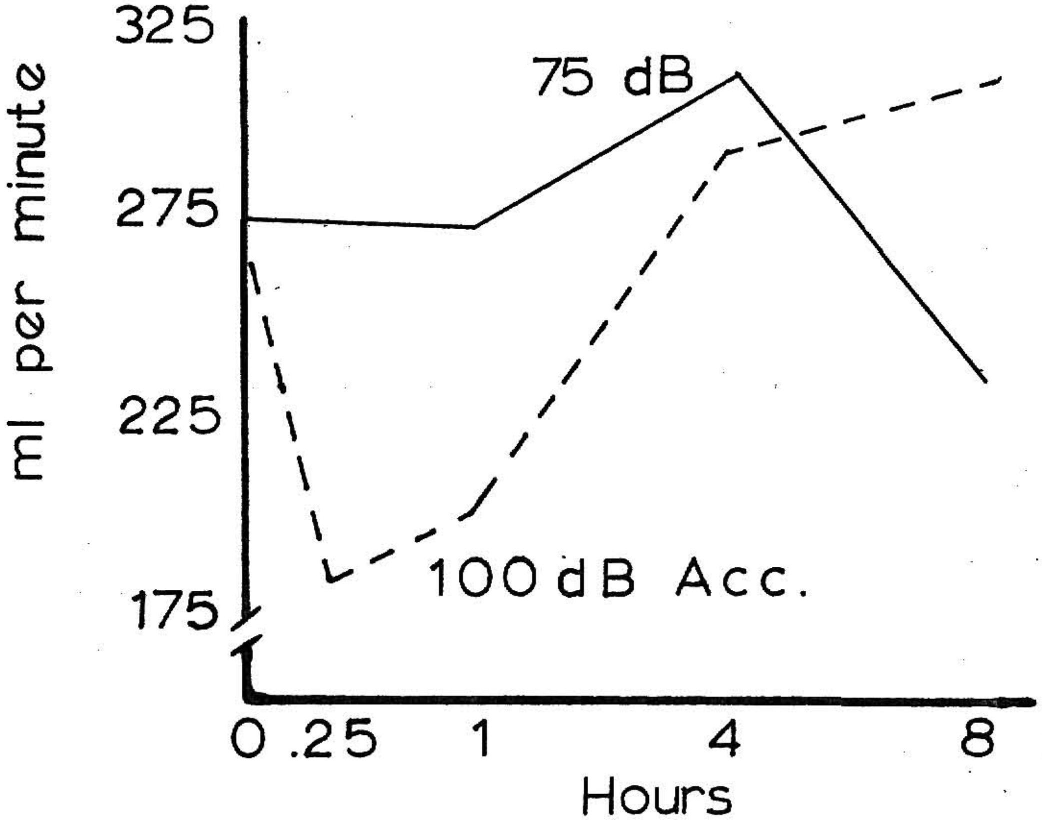

Figure 3. Effect of USASI noise on oxygen consumption

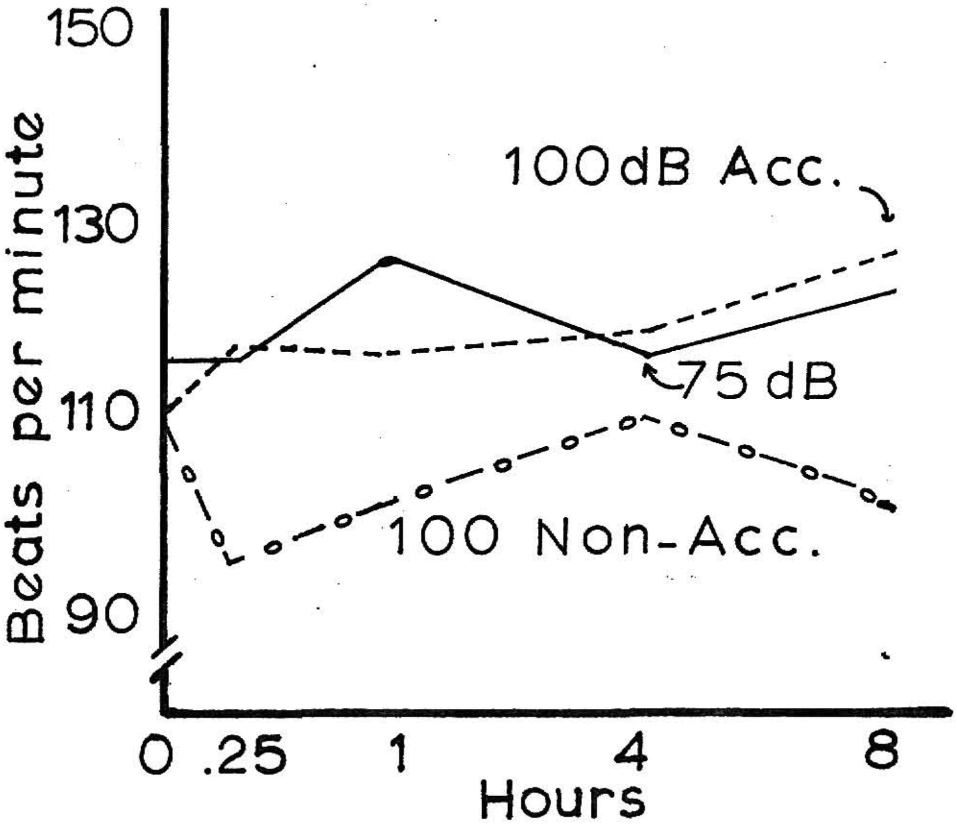

Figure 4. Effect of music on heart rate

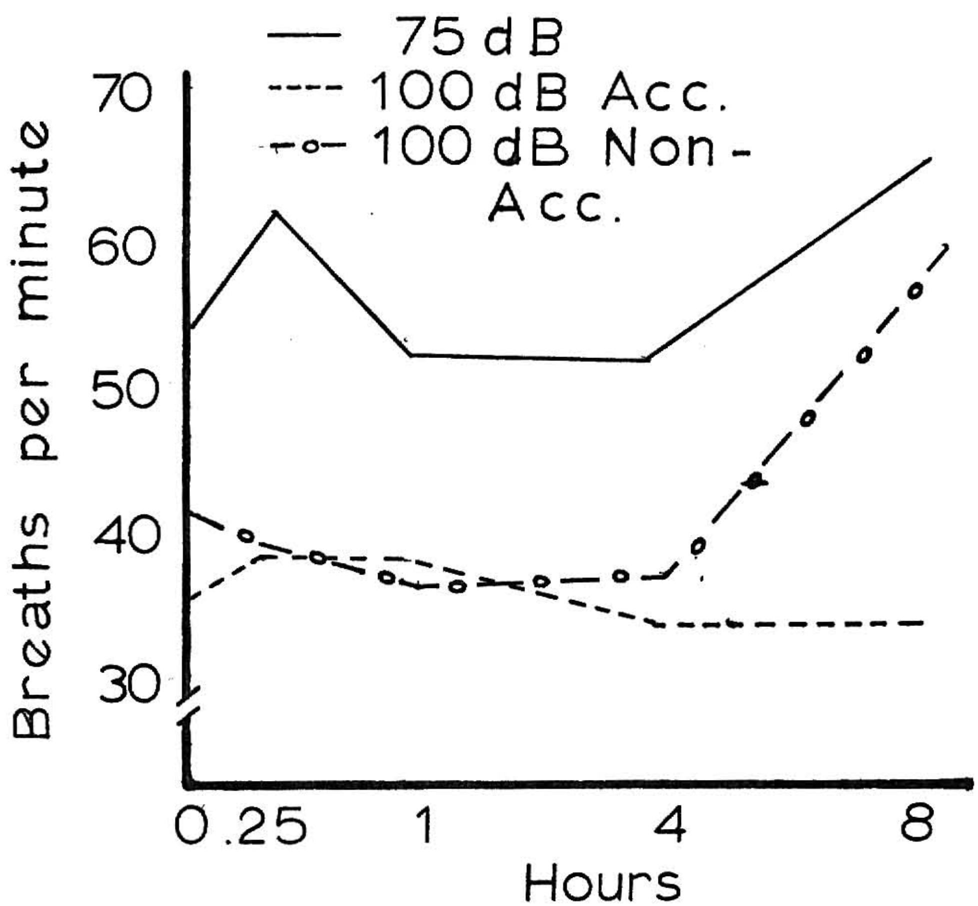

Figure 5. Effect of music on respiration rate

Oxygen consumption was variable throughout the trial. These data indicate that oxygen utilized at intensities of 100 dB was higher as compared to 75 dB treatment during the 12-day trial (224 vs 252 ml/min.), (figure 6).

Trial III - IMS Noise. During the 12-day test period there was no significant difference ($P<.05$) in heart rate at the intensity levels studied. However, heart rate did remain higher for the non-acclimatized lambs subjected to 100 dB intensity compared to those at 75 or 100 dB acclimatized during the first 8 hours (Fig. 7). Acclimatized lambs increased heart rate at the fourth hour from 112 to 128 beats per minute.

Respiration rate was highest at 75 dB levels, during the initial phases of the test and remained significantly higher throughout the 12-day trial when compared to the controls and lambs exposed to 100 dB intensity levels (figure 8, table 1).

Oxygen consumption increased from 207 to 222 ml/min. and was significantly higher ($P<.05$) when lambs were subjected to intensities of 100 dB for the 12-day period of testing.

Discussion

McDonald (1969) stated that external stressors profoundly affect regulatory systems but many contradictions render it difficult to unravel each physiological response. He indicates that both epinephrine and norepinephrine are powerful stimulants of the heart and increase its force, frequency and amplitude of contraction. Further, administrations of either hormone could increase respiratory rate, oxygen consumption and basal metabolic rate.

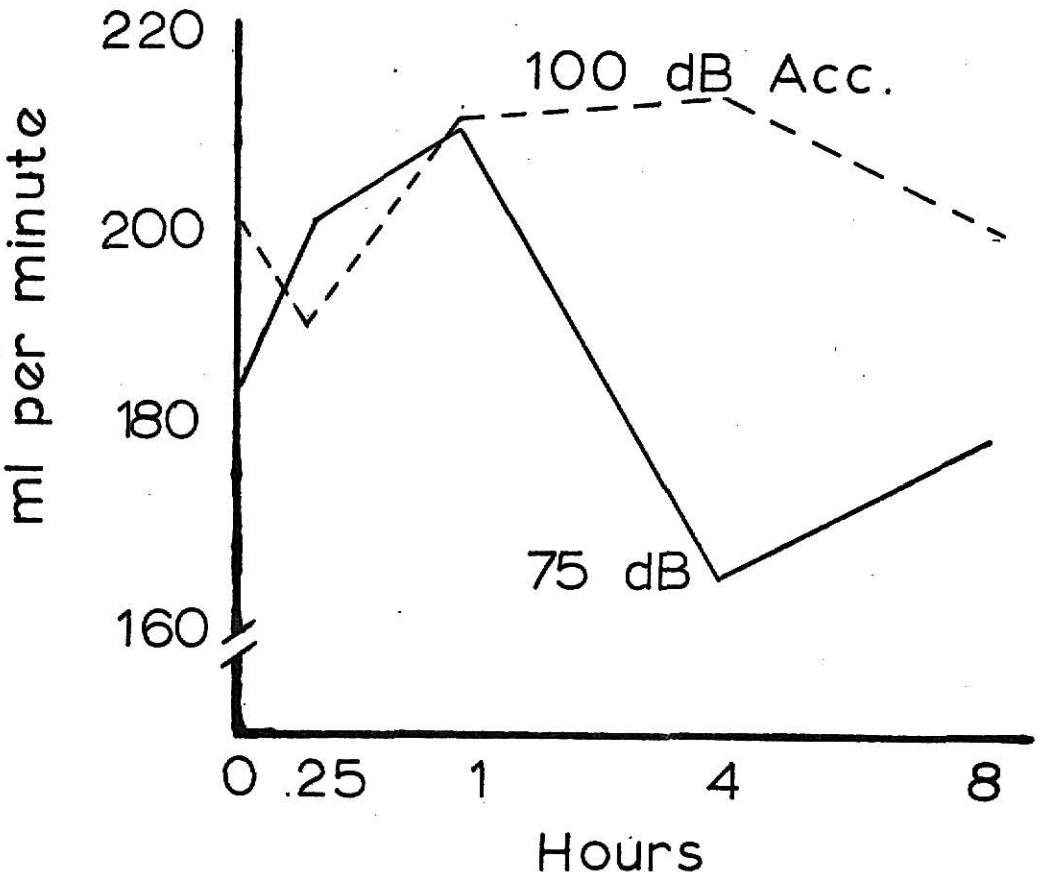

Figure 6. Effect of music on oxygen consumption

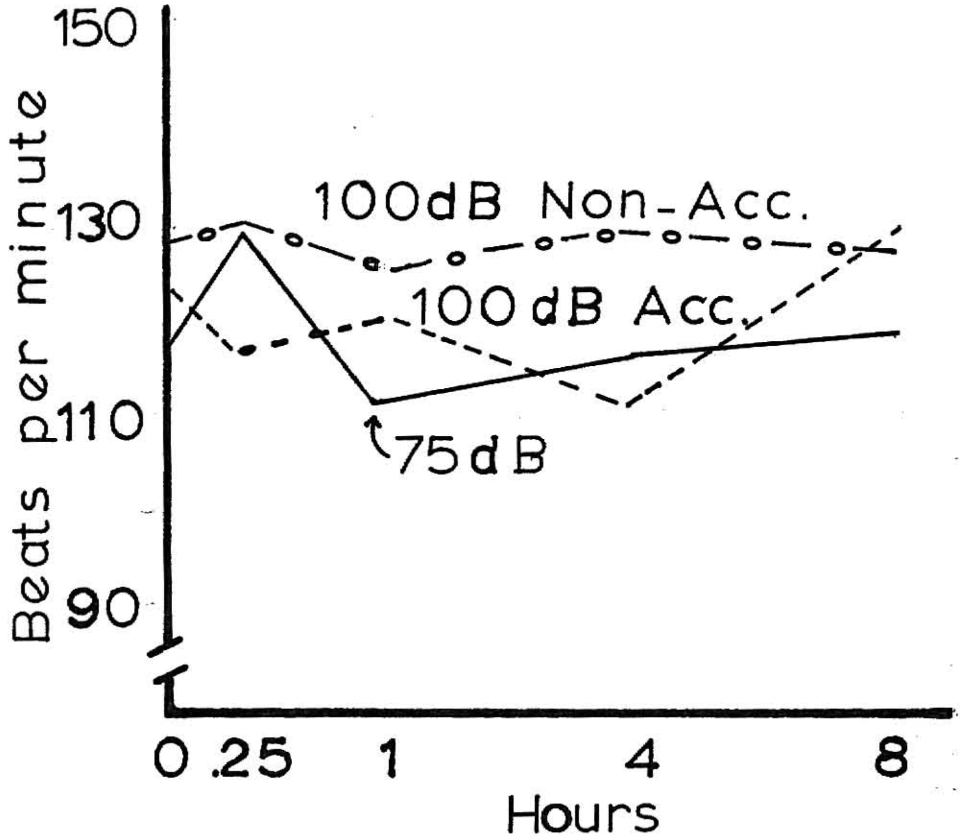

Figure 7. Effect of IMS noise on heart rate

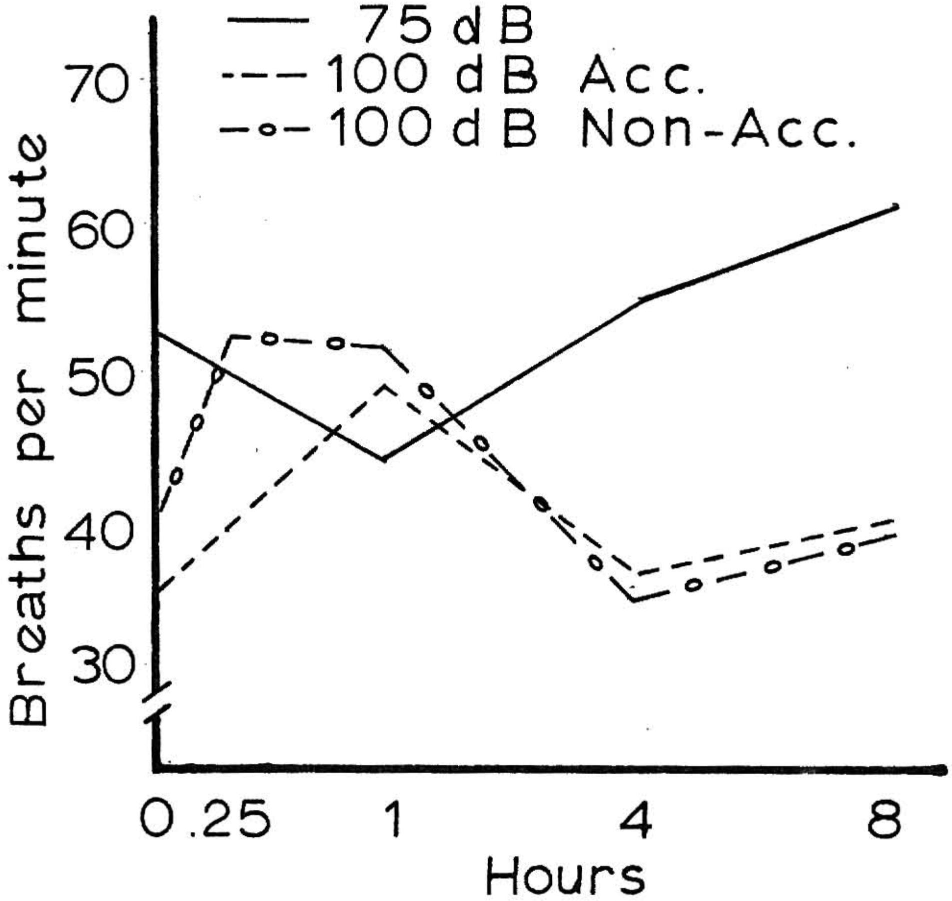

Figure 8. Effect of IMS noise on respiration rate

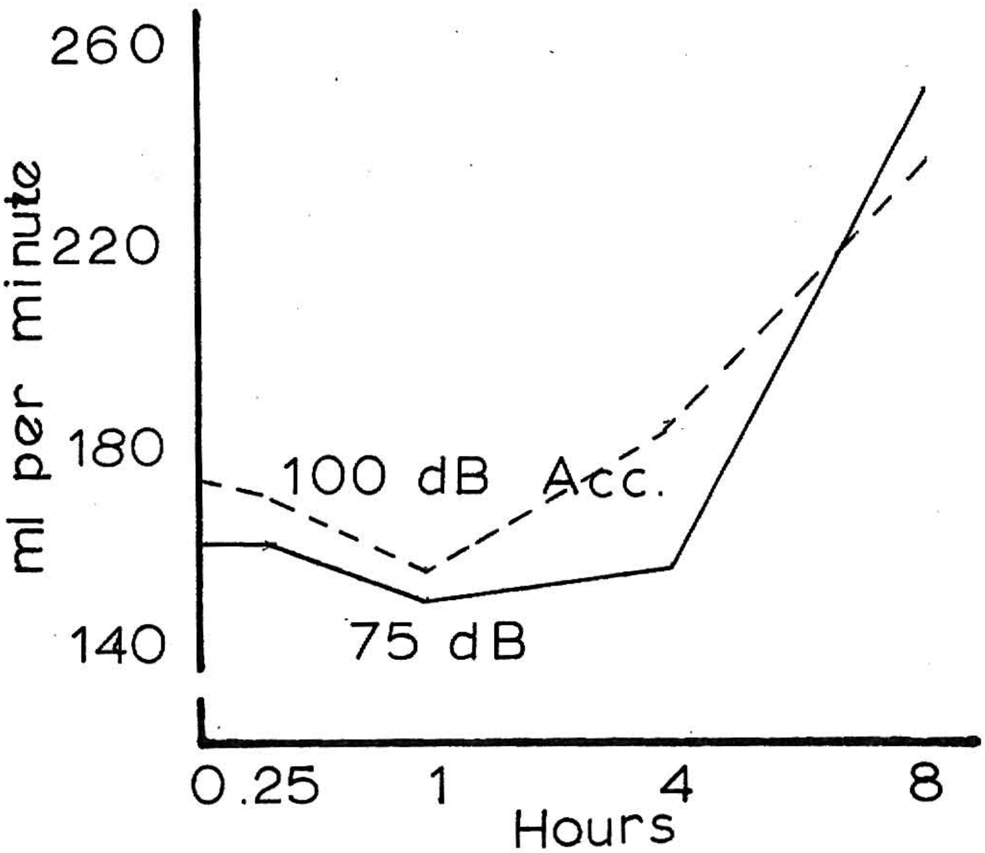

Figure 9. Effect of IMS noise on oxygen consumption

As shown in figures 1-9 and table 1, physiological responses of lambs to noise was evident. Information reported here shows that lambs respond to auditory stress by increased heart rate, respiration rate and oxygen consumption. Heart rate responses of the non-acclimatized lambs to 100 dB intensity sounds is an example of the expected, i.e., initial increase in beats per minute over control values. In three groups of lambs (acclimatized 100 dB, USASI; non-acclimatized 100 dB, music; and acclimatized 100 dB, IMS), a noticeable decrease in heart rate was observed during the initial phases of each trial. This occurence was not expected because of the anticipated effect of the catecholamines but may be explained by vagal inhibition. The observed decreased heart rate initially does not agree with the findings of Bond (1963), Bernard and Sontag (1947) and Geber (1966) who reported increased heart rate in animals under sound treatments. Apparently over extended periods of time auditory stress has cardio-acellatory properties after initial treatment with sounds since heart rate remained significantly ($P<.05$) higher in lambs exposed to 100 dB intensity. Consequently, it is assumed that stress did exist in all trials where intensity levels were 100 dB.

The data also suggests (table 1) that sound type may cause cardiac responses. Lambs had higher heart rates during the 12-day test in trials 1 and 3 compared to trial 2, at intensity levels of 75 dB and 100 dB (acclimatized). Chapter III supports the hypothesis that lambs are more sensitive to the higher frequencies (7000 to 10,000 cps) represented in USASI spectra. The startling effect of the IMS noise is a reasonable explanation for continued high heart rate over a 12-day period in trial 3 (table 1). At loud intensities (100 dB or higher) the data suggests no significant ($P<.05$) difference in heart rate response to different types of noise.

Respiration rate responded differently compared to heart rate. Many additional factors other than those affecting heart rate dictate respiration rate. Examples of such factors are body size, age, exercise, environmental temperature, and degree of fill of the digestive tract, especially the rumen. It is apparent from these data that respiration rate is not a reliable measure of auditory stress in lambs.

Oxygen consumption data was not consistent. Oxygen consumption is a direct measure of metabolic rate. The data (table 1) indicates that metabolic rate was higher at 75 dB intensity compared to controls and 100 dB in trial 1, whereas, the reverse was true in trials 2 and 3. Variations between trials and within trials were extremely high. This is apparently due to size of lambs, fill in digestion tract, excitement in placing lambs in hoods, etc., as well as sound types and intensities. It is concluded that the technique involved in determining oxygen consumption under these conditions do not provide consistent results.

Summary

Three experiments were conducted involving 25 early weaned lambs (25.3kg) subjected to three types of noise at 2 intensity levels, to determine the effects of noise on heart and respiration rate and oxygen consumption. Heart rate is the best indicator of live animal evaluation of noise stress. In all cases heart rate responded significantly ($P<.05$) to intensity levels of 100 dB. Non-acclimatized lambs had significantly ($P<.05$) higher heart rate using USASI and music. There was no significant difference in heart rate of acclimatized and non-acclimatized lambs at intensity levels of 100 dB indicating acclimatization does take place. Respiration rate and oxygen consumption were not consistent in all trials and do not appear to be acceptable as factors for measuring direct sound stress factors on live animals.

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Chapter V

THE EFFECT OF TYPE AND LEVEL OF SOUND ON GROWTH AND FEED EFFICIENCY OF EARLY WEANED LAMBS

Increasing intensities of ambient sounds in the modern world may affect livestock performance. Questions arise as to how this present noise level is tolerated by animals and if high intensity noise will affect performance and/or production. Information is needed to determine the relationships of ambient noise with growth, feed efficiency and reproduction of livestock, for several reports indicate the existence of such relationships (Farris, 1945; Galin, 1964; and Cohen, 1968). Zondek and Tamari (1969) suggested that sound stimuli increases the secretion of steroid hormone in rats. Anthony (1959) observed convulsions and depressed gains in rats subjected to sound stress, yet Bond and Winchester (1963) found no change in rate of growth, feed intake, or efficiency of swine subjected to loud aircraft sounds. This study was conducted to determine the effect of sound type and intensities on growth and feed efficiency of early weaned lambs.

Experimental Procedure

The three trials involved 60 early weaned Hampshire x Southwestern whiteface lambs averaging 25.7 kg in weight. Each lamb was given ovine ecthyma vaccine and clostridium perfringens Type D bacterin before each study. All were maintained shorn (biweekly shearing) during the trials.

All trials were conducted in an environmentally controlled room maintained at 21° C. Individual stalls were 1 m x 1.25 m on concrete and bedded with straw. Individually maintained animals were allowed a 10% refusal of their daily feed intake. Group-fed lambs were penned (5 lambs per lot) in a

4 m x 5 m area and self-fed a pelleted ration containing 55% roughage and 45% concentrate (table 1). The lambs were subjected to three types of noise: 1) United States of America Standard Institute (USASI) - white noise; 2) Instrumental music (Mantovani); and 3) Intermittent Miscellaneous Sounds (IMS). Each sound type was studied at two levels of intensity (75 and 100 dB).[1/]

Trial I - USASI White Noise. This trial was conducted in December using the USASI Spectra produced by a Random Noise Generator (General Radio Co. Type 1381) by selectively discriminating against low and high frequencies in accordance with previously established loudness contours (Peterson and Gross, 1967). During this trial, the USASI noise was played continuously during test periods.

Trial II - Instrumental Music. This trial was conducted in February using instrumental music from Mantovani. The music was recorded on an 8-track 70-minute tape and played continuously during test periods.

Trial III - IMS. This experiment was conducted in May. The IMS noise, recorded on an 8-track, 70-minute tape, consisted of electrical and diesel engines, jet and prop airplanes, roller coasters, stadium noise, foghorns, firecrackers, machine guns and cannons, rain, and band marches. The sounds were recorded in a manner such that the noise would occur at intervals of 15 seconds to 3 minutes with intermittent quiet periods lasting from 1 to 15 minutes. The IMS tape furnished 11 hours of IMS noise and 13 hours of quiet during a 24-hour period.

[1/] Decibels, logarithmic ratio of power or intensity levels, used here it is the sound pressure level with respect to a reference of 0.0002 dynes per cm^2.

TABLE 1. PROXIMATE ANALYSIS OF LAMB DIET
(Dry Matter Basis)

Dry matter %	88.68
Protein % (N x 6.25)	14.46
Ether extract %	2.63
Ash %	5.79
Crude fiber %	15.61
N - free extract %	50.19

Above sounds were amplified to the desired intensity levels by a Randlan-Borg Amplifier (Model SA51A2S-70) and adjusted to the appropriate sound intensity using a sound level meter (General Radio Model 1551C). Lambs in the above trials were subjected to the following treatment regime: (1) 21-day control period with background noise at 45 dB; (2) 12-day test period at 75 dB; (3) 2-day adjustment [45 dB]; and (4) 12-day test period at 100 dB. During the 2-day adjustment period prior to the 100 dB test, five lambs which had not previously been exposed to any sound treatment were included in the 100 dB treatment. This procedure allowed the evaluation of the role of acclimatization to sound under these circumstances.

Least square analysis of variance and Duncan's multiple range test (Kramer, 1956) were used to analyze the average daily gain and feed intake data.

Results

Trial I. USASI noise at intensity levels of 75 dB significantly ($P<.01$) increased average daily gain and feed efficiency (table 2). There was no significant ($P<.05$) difference in daily feed intake during the trial. The most efficient feed utilization and greatest average daily gain occurred at 75 dB increasing 38% above control values (table 2). When lambs were subjected to 100 dB (acclimatized and non-acclimatized) feed efficiency was significantly less ($P<.05$) than control values (8.04 vs 5.66) but remained significantly higher than at 75 dB (table 2). Feed efficiency of individually fed lambs was highly variable during the control period (SD 3.84) however, treatment values were less variable (SD 0.28 to 2.05).

TABLE 2. EFFECT OF TYPE AND LEVEL OF NOISE ON AVERAGE DAILY GAIN OF INDIVIDUALLY AND GROUP FED EARLY WEANED LAMBS[1]

		Means with S. D. (Kg)						
		Control Background Noise		Treatment Levels				
	Initial	45 dB		75 dB		75 & 100 dB		100 dB
Type	Weight	Individual	Lot-Fed	Individual	Lot-Fed	Individual	Lot-Fed	Individual
USASI	24.8±1.08							
No. animals		5	10	5	10	5	10	5
Ave. daily gain		0.23±0.11^{x}	0.23±0.07^{x}	0.42±0.06^{ay}	0.41±0.09^{ay}	0.30±0.02^{x}	0.30±0.04^{x}	0.27±0.08^{ax}
Kg feed/kg gain		8.04±3.84^{x}	4.23	3.47±0.28^{ay}	4.55	5.65±1.05^{y}	5.65±1.05	5.66±2.00^{y}
Feed intake/day		1.436^{a}		1.463^{a}		1.699^{a}		1.408^{a}
MUSIC	27.9±2.80							
No. animals		5	10	5	10	5	10	5
Ave. daily gain		0.23±0.08	0.23±0.04	0.21±0.10^{b}	0.24±0.13^{b}	0.18±0.14	0.24±0.12	0.12±0.06^{b}
Kg feed/kg gain		8.80±3.12^{x}	6.14	6.95±2.19^{by}	6.79	10.55±5.80^{x}	8.85	11.78±3.77^{x}
Feed intake/day		1.715^{a}		1.538^{a}		1.534^{a}		1.650^{a}
IMS	24.5±2.80							
No. animals		5	10	5	10	5	10	5
Ave. daily gain		0.16±0.22^{xy}	0.21±0.04^{x}	0.39±0.13^{az}	0.33±0.10^{ay}	0.22±0.05^{xy}	0.28±0.09^{x}	0.15±0.22^{xb}
Kg feed/kg gain		6.60±2.28^{x}	7.96	3.41±0.34^{ay}	4.49	7.06±1.84^{x}	5.79	6.45±1.34^{x}
Feed intake/day		.986^{bx}		1.312^{by}		1.120^{by}		1.280^{by}

[1]Comparison of individual and lot-fed lambs were made separately

^{a,b}All letters within columns with different subscripts are significantly different ($P<.01$)

^{x,y}All letters within rows with different subscripts are significantly different ($P<.05$)

Trial II. Music played continuously at either 75 dB or 100 dB (acclimatized and non-acclimatized) had no significant ($P<.05$) effect on performance (table 2). Gains were lowest (0.18 and 0.12 kg) for individually fed lambs subjected to 100 dB intensities compared to control value (0.23 kg) with non-acclimatized lambs having the lowest average daily gain (0.12 kg). There was no significant difference in feed efficiency although a high degree of variability with standard deviations ranging from 2.19 to 5.80 existed. This indicates that individual responses of lambs to music is different.

Trial III. Lambs subjected to IMS noise consumed less feed per day as compared to animals in trials I and II (table 2). Average daily gain of lambs were significantly higher ($P<.01$) at 75 dB intensity (0.33 - 0.39 kg) compared to controls and 100 dB tests. Non-acclimatized lambs had average daily gains of 0.15 kg whereas acclimatized lambs gained 0.22 kg. In trials II and III acclimatization appeared to affect performance.

Discussion

The data from this experiment indicates that sound affects performance of lambs. Reports are not consistent concerning the effect of sound on animal performance. Anthony, Ackerman and Lloyd (1959) concluded that sounds do not influence rat weights, while Sackler *et al.*(1959) reported decreases in rat gains. Bond and Winchester (1963) reported no growth response in swine. This data indicates that animals respond in terms of ADG and feed efficiency to auditory stimuli.

Pooled analysis of the data indicated a highly significant difference ($P<.01$) in growth and feed efficiency of lambs subjected to different types of sound (figure 1). Instrumental music had no significant (P<.05) effect on performance of lambs, whereas USASI (accumulation of frequencies) and IMS increased lamb gains significantly (P<.01). Chapter III indicates that lambs are most sensitive to frequencies of 7,000 to 10,000 cps. These frequencies were represented in the USASI spectra. Anthony *et al.* (1959), Sackler *et al.* (1959) used different types of sounds and achieved different responses in terms of growth with rats. Data from this study supports the hypothesis that animals respond differently to various types of sound.

Data here also indicate that levels of intensity precipitated significant (P<.01) growth effects. Pooled analysis of data indicated that intensity levels of 75 dB resulted in significantly higher ADG (0.31 kg) compared to 0.23 kg for control (figure 2). No significant response (P<.05) was observed when intensity levels were increased to 100 dB (acclimatized lambs). An intensity of 100 dB caused significantly lower (P<.05) gains in case of non-acclimatized animals. Jones and Cohen (1968) stated that noise levels are increasing at the rate of 1 dB per year. It appears that at high intensities, sounds stress animals initially. Sound intensities of 75 dB may be causing a stimulation effect rather than stress which was observed at 100 dB intensity.

Lambs submitted to both 75 and 100 dB intensity had an ADG of 0.27 kg compared to 0.18 kg for non-acclimatized lambs. Several workers in the field indicate that animals adapt to sounds and intensity (Bond *et al.* 1963; Parker and Bayley, 1960; Casady and Lehmann, 1956). Since acclimatization can be expected it is assumed that growth stimuli would decrease over extended periods (longer than 12 days). However, this short term experiment did not indicate such occurred. The experiment suggests that environmental sounds can act either as a stress or stimuli. Observations during the trials

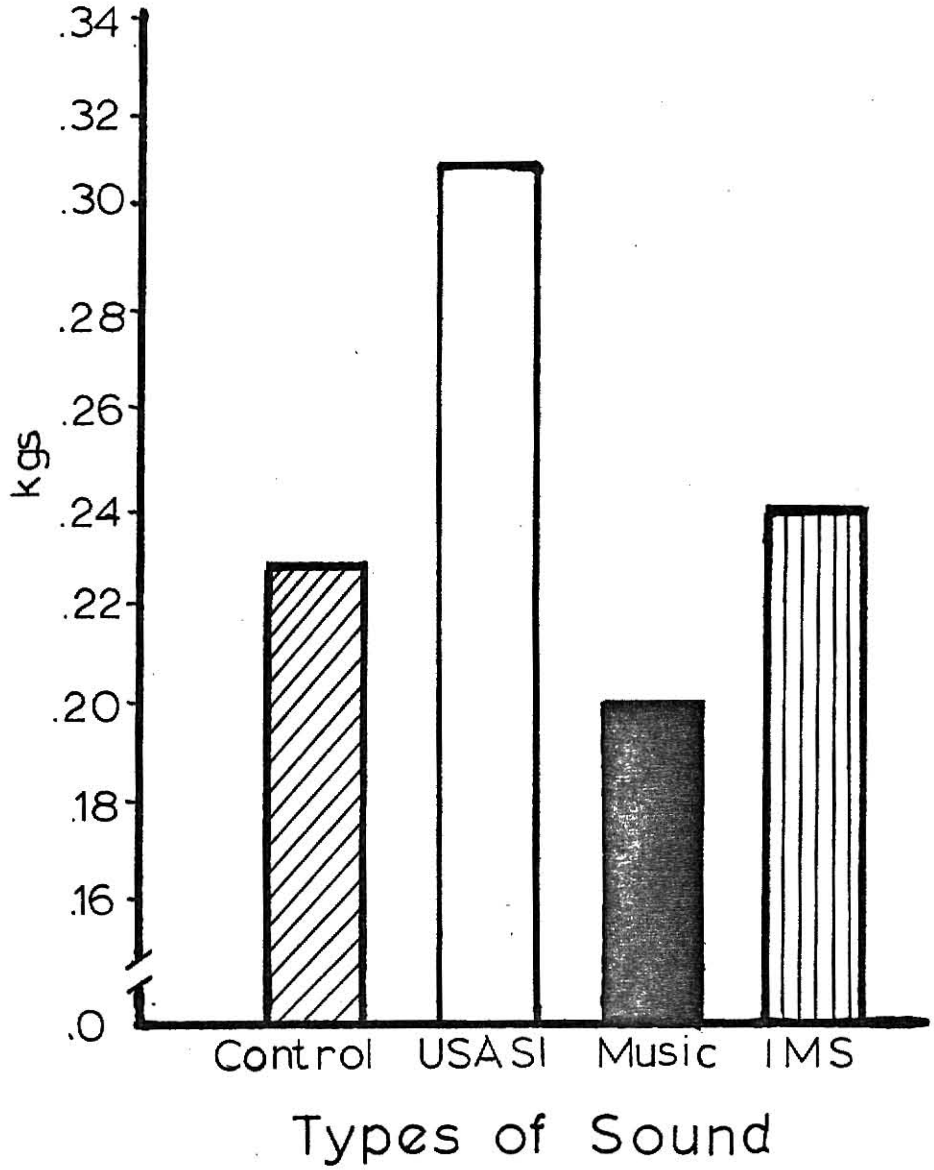

Figure 1. Effect of sound types on average daily gains of lambs

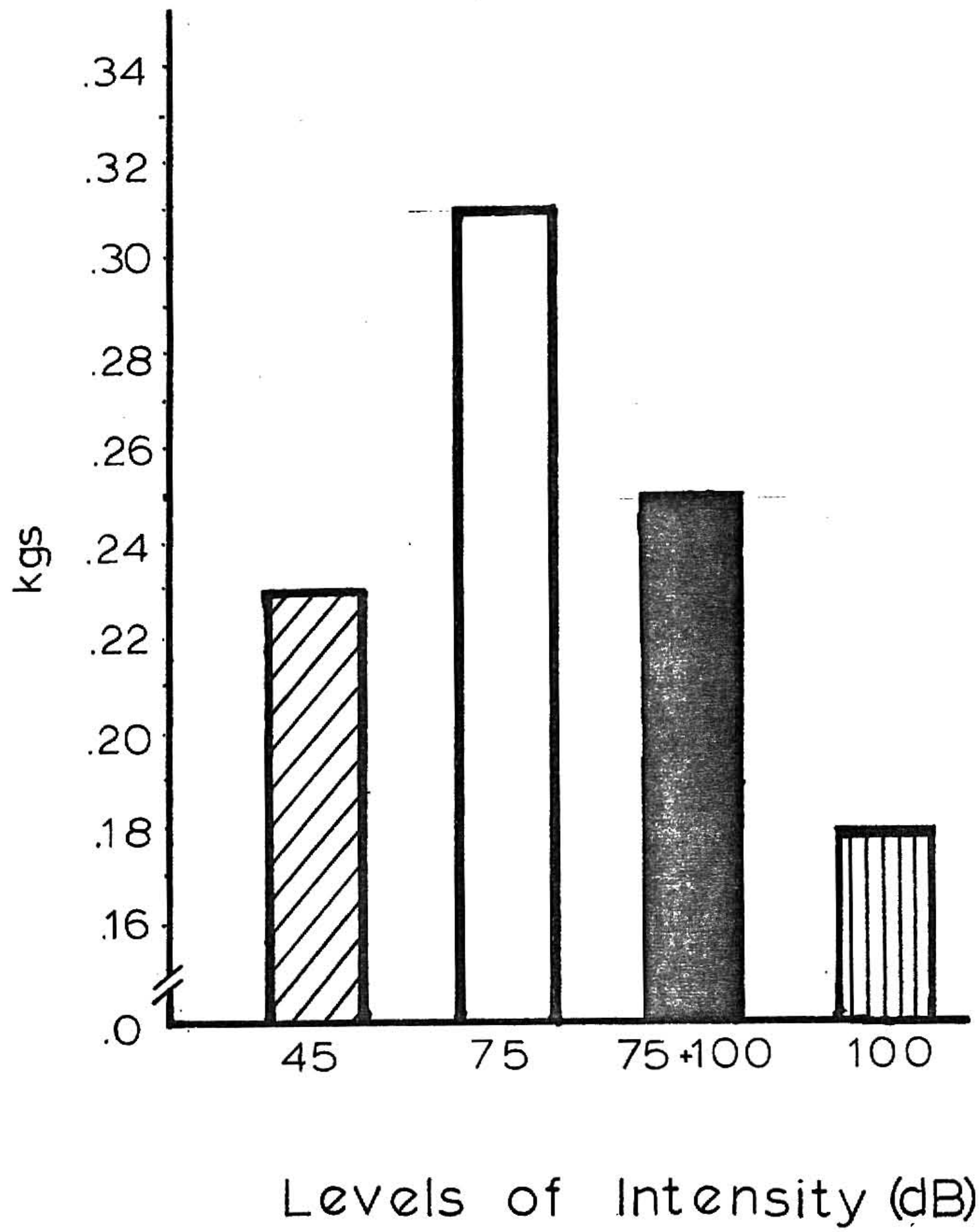

Figure 2. Effect of intensity levels on average daily gains of lambs

lead one to believe that sounds can be used as a masking effect against obnoxious background noises. Instrumental music appeared to have this effect. The lambs did not show the alertness or nervous energy observed in trials I and III. With controlled environmental conditions this experiment suggests that sound can be used as a means of stimulation. A great deal of research remains to be done on the influence of sounds on animals. Actually, the entire field of responses of animals to this environmental factor with particular reference to livestock production remains largely unexplored.

Summary

Early weaned lambs were subjected to three types of noise (USASI, instrumental music, and IMS), at 75 and 100 dB intensities. USASI and IMS noise at 75 dB intensity increased ADG significantly ($P<.01$) from 0.23 to 0.41 kg and 0.16 to 0.39 kg, respectively. Feed efficiency also increased under similar conditions. Pooled data from the 3 trials indicated that types and intensity levels of sound were significant ($P<.01$). Lambs appeared to acclimate to all 3 types of noise. Music did not affect lamb ADG or feed efficiency.

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APPENDIX

APPENDIX TABLE A

EFFECT OF USASI NOISE ON HEART AND RESPIRATION RATE AND OXYGEN CONSUMPTION OF LAMBS

Levels	Phy. Measures	Hours 0	.25	1	4	8	11 days
75 dB	H. Rate	109.0± 1.0	111.0± 4.2	112.0±12.7	111.0±13.4	114.0± 1.4	121.9±10.8[a]
	R. Rate	38.0± 4.2	36.0± 6.5	37.0± 4.2	38.0± 1.2	38.0± 3.0	43.3± 5.4[a]
	O_2 Cons.*	273.0	273.0	273.0	312.0	234.0	272.1±40.0[a]
100 dB Accl.	H. Rate	115.0± 1.0	107.0± 3.4	120.0± 3.6	112.0± 1.0	108.0± 0.0	122.0±10.4[a]
	R. Rate	45.0± 4.2	44.0±11.3	42.0±39.0	52.0±14.0	65.0± 2.8	62.4±15.5[b]
	O_2 Cons.*	265.0	178.0	195.0	288.0	312.0	242.5±31.1[b]
100 dB Non-accl.	H. Rate	128.0± 2.2	148.0± 7.0	140.0±14.1	135.0±35.0	150.0±10.6	130.6±13.2[b]
	R. Rate	41.0± 1.2	39.0± 4.2	35.0± 5.3	38.0±28.0	60.0± 5.6	39.0± 5.9[a]

[1]Mean and SD of 3 observations

*Measurement from 1 animal, no analysis

[a,b]All letters within columns with different subscripts are significantly different (P<.05)

APPENDIX TABLE B

EFFECT OF MUSIC ON HEART AND RESPIRATION RATE AND OXYGEN CONSUMPTION OF LAMBS[1]

Levels	Phy. Measures	Hours 0	.25	1	4	8	11 days
	H. Rate	114.0± 2.5	114.0± 6.4	125.0±16.0	116.0± 7.0	122.0± 6.8	111.7± 5.6[a]
75 dB	R. Rate	54.0± 2.4	62.0±22.5	53.0± 4.7	52.0± 0.0	66.0±15.8	61.0± 6.3[a]
	O_2 Ml/Min.	183.0±22.4	200.0±23.0	208.0±59.0	169.0±23.0	179.0±28.0	224.0±31.4
	H. Rate	110.0± 2.0	116.0±25.0	116.0±25.0	118.0±27.1	122.0±19.2	116.4± 8.6[b]
100 dB	R. Rate	36.0± 5.3	38.0±10.0	38.0±10.0	34.0± 5.8	34.0± 6.2	44.0± 4.9[b]
Accl.	O_2 Ml/Min.	200.0± 8.5	187.0±19.5	211.0±20.5	213.0±16.0	200.0±24.5	252.0±21.5
100 dB	H. Rate	107.0± 1.7	96.0± 0.5	104.0± 7.0	109.0±12.4	104.0±15.1	124.0± 8.3[c]
Non-accl.	R. Rate	39.0± 3.0	40.0± 1.6	40.0± 1.6	35.0± 4.2	33.0± 5.0	45.0± 5.2[b]

[1]Mean SD of 3 lambs

APPENDIX TABLE C

EFFECT OF IMS NOISE ON HEART AND RESPIRATION RATE AND OXYGEN CONSUMPTION OF LAMBS[1]

Levels	Phy. Measures	Hours 0	.25	1	4	8	11 days
75 dB	H. Rate	118.0± 8.8	123.0±10.8	112.0±13.1	117.0±18.2	118.0±13.8	119.0±15.9
	R. Rate	53.0±10.7	50.0±11.4	45.0±14.1	55.0± 6.2	61.0± 2.4	65.0±20.4^{a}
	O_2 Ml/Min.	161.0±11.9	161.0±11.9	148.0±12.4	151.0±16.6	254.0±17.9	207.0±24.1^{a}
100 dB Accl.	H. Rate	123.0±12.0	116.0±17.4	119.0± 4.7	112.0±13.8	128.0±13.8	123.0±14.6
	R. Rate	36.0± 0.0	39.0± 2.2	49.0± 6.1	37.0± 2.3	40.0± 7.0	49.0±13.3^{b}
	O_2 Ml/Min.	171.3± 6.2	169.0±59.6	158.0±35.5	184.3±48.5	234.0± 7.5	222.0±62.8^{b}
100 dB Non-accl.	H. Rate	128.0±15.1	129.0±16.1	126.0±18.3	128.0±18.3	126.0±13.8	121.0±11.3
	R. Rate	41.0± 3.0	52.0± 6.8	51.0± 4.5	34.0± 4.5	38.0± 1.7	46.8± 8.3^{b}

[1]Means and SD of 3 observations

^{ab}All letters within columns with different subscripts are significantly different ($P<.05$)

APPENDIX TABLE D

EFFECT OF THREE TYPES OF NOISE ON GLAND WEIGHTS OF LAMBS[1]

Type	Treatment	Glands (gm)			
		Pituitary	*Adrenal*	*Uterus*	*Ovary*
USASI	Control	$.375\pm0.08^{a}$	2.04 ± 0.12	9.6 ± 0.3^{a}	1.25 ± 0.48^{a}
	2 wk. (100 dB)	$.373\pm0.07^{a}$	1.99 ± 0.11	11.5 ± 2.8^{b}	0.82 ± 0.14^{b}
	4 wk. (75+100 dB)	$.304\pm0.06^{a}$	1.82 ± 0.22	11.1 ± 0.9^{b}	1.35 ± 0.83^{a}
MUSIC	Control	$.522\pm0.04^{b}$	1.79 ± 0.52	7.8 ± 0.9^{a}	1.08 ± 0.10^{a}
	2 wk. (100 dB)	$.477\pm0.02^{b}$	2.38 ± 0.07	9.6 ± 0.7^{b}	0.97 ± 0.27^{b}
	4 wk. (75+ 100 dB)	$.444\pm0.02^{b}$	2.00 ± 0.27	10.9 ± 0.3^{b}	1.11 ± 0.07^{a}
IMS	Control	$.544\pm0.07^{b}$	1.69 ± 0.36	7.4 ± 1.4	1.31 ± 0.11
	2 wk. (100 dB)[2]	$.451\pm0.04^{b}$	2.06 ± 0.36		
	4 wk. (75+100 dB)	$.441\pm0.06^{b}$	1.73 ± 0.36	7.9 ± 3.7	1.09 ± 0.03

[1]Mean and SD of 5 observations

[2]Male castrate lambs

[ab]All letters within columns with different subscripts are significantly different ($P<.05$)

APPENDIX TABLE E

EFFECT OF NOISE LEVELS ON ACTH, FSH, LH OF THE PITUITARIES OF LAMBS

	% AA/100 ug adrenal ACTH		ug/100 ug ovary FSH		ugAA/100 ug ovary LH
	Music	*IMS*	*Music*	*IMS*	*Music*
Controls	85.5±11.0[a]	58.9±13.0[a]	103.6±25.3[a]	32.6±11.9[a]	.644±.020[a]
2 wk. stress 100 dB Non-acclimatized	45.1±10.0[b]	75.5± 6.5[b]	74.6±20.2	97.0±10.2[b]	.738±.013[b]
4 wk. stress + 100 dB Acclimatized	94.6± 1.7[c]	62.3± 4.2[c]	86.8±10.5[c]	87.3± 8.2[c]	.749±.013[b]

[abc] All letters within columns with different subscripts are significantly different ($P<.01$)

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EFFECTS OF AUDITORY STIMULI ON LAMBS

by

LAURENCE ALVIN AREHART

B. S., Virginia Polytechnic Institute, 1965

AN ABSTRACT OF A MASTER'S THESIS

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KANSAS STATE UNIVERSITY

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ABSTRACT

EFFECTS OF AUDITORY STIMULI
ON LAMBS

by Laurence A. Arehart

The effects of sound on livestock have not been extensively studied. This experiment was designed to characterize the physiological responses and the performance of early weaned lambs subjected to different sound types (USASI Noise, Instrumental Music, and Intermittent Loud Sounds) at two intensities (75 dB and 100 dB). Initially, auditory thresholds for sheep were determined on ten Suffolk ewe lambs using a free-field technique in a soundproofed room. EEG pattern changes and behavioral responses were used to determine hearing thresholds. The resulting audiogram was similar in shape to that of the human but occurred at a higher frequency. Animals tested were most sensitive (lowest threshold) at 7000 Hz. Heart rate, respiration rate and oxygen consumption were determined for lambs subjected to the mentioned sound types and intensities. Heart rate appeared the best indicator of sound stress increasing significantly ($P<.05$) at intensity levels of 100 dB. Respiratory rate and oxygen consumption were more variable and responses could not be directly correlated to sound stress factors. These data indicated a significant ($P<.05$) role of acclimatization in lambs subjected to sound. Lamb performance was significantly ($P<.01$) changed when animals were subjected to sound treatments. Both average daily gain and feed efficiency increased significantly ($P<.01$) when animals were subjected to USASI and Intermittent Loud Sounds at 75 dB. Results indicated that

lambs respond differently to different intensities and types of sound. Acclimatization to sound type and intensity was evident. This research indicates that lambs respond to auditory stimuli.