later learn to make use of secondary, context-dependent cues (e.g., the direction of formant transitions or the formant frequencies of the following vowel) to discriminate place contrasts in unstressed or non-syllable-initial environments or in prestressed syllables for which the invariant spectral properties were not available. The adult's ability to reliably identify synthetic two- and three-formant CV stimuli would be a result of this learning process. The present data appear to support a model such as this in that the strongest evidence for place discrimination was obtained for stimuli which best exhibited the desired spectral properties.

It should be emphasized, however, that the results of this study provide only tentative evidence in support of this model. Further research is needed to determine the contribution of various acoustic-phonetic properties, such as release bursts, to early discrimination of speech sounds.

ACKNOWLEDGMENTS

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Frequency dependence of ultrasonic absorption in mammalian testis

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The earlier report that the frequency dependence of ultrasonic absorption of mammalian testis mimicked a single relaxation process is explained as an effect of ultrasonic beam width upon the transient thermoelectric technique. More detailed measurements show that the frequency dependence of the ultrasonic absorption in testis is much the same as the attenuation in other soft tissues, viz., α proportional to $f^{1.1}$. The earlier finding that testis exhibits an ultrasonic absorption coeffieient significantly lower than reported for other tissues is confirmed.

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INTRODUCTION

In a previous study by Brady *et al.*,[1] it was reported that ultrasonic absorption measurements on mammalian testis, using the transient thermoelectric technique, appeared to exhibit a frequency dependence of absorption resembling that of a single relaxation process. This relatively simple frequency behavior is discussed herein in the light of further analysis of the measurement technique.

The transient thermoelectric technique involves first imbedding a small thermocouple in a tissue sample and then irradiating the ensemble with a temporally rectangular ultrasonic pulse of known intensity. The absorption coefficient α of the imbedding medium is then given as

$$\alpha = \frac{\rho C}{2I}\left(\frac{dT}{dt}\right)_0, \tag{1}$$

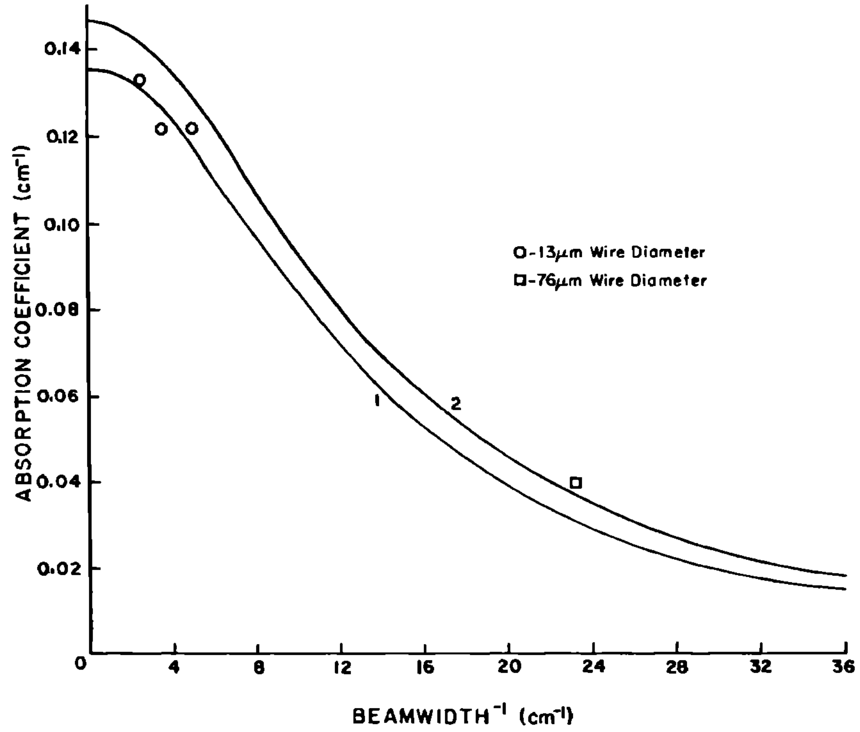

FIG. 1. Ultrasonic amplitude absorption coefficient in mouse testis at 7 MHz and 37°C as a function of the reciprocal of the half-power beamwidth. The circles and square represent measurements with 13 and 76-μm-diam-thermocouples, respectively. The lines represent the theoretical analysis of the effect of diffusion plus the added heating due to the presence of a 13-μm-diam (curve 1) or a 76-μm-diam (curve 2) thermocouple wire.

where $(dT/dt)_0$ is the initial time rate of change of temperature (°C/s), I is the sound intensity (W/cm^2) at the junction, and ρC is the heat capacity per unit volume at constant pressure (J/cm^3/°C). However, the temperature thus measured by use of the thermocouple junction is a true measure of the ultrasonic absorption of the surrounding medium only (1) if the ultrasonic beamwidth is broad enough to eliminate the effect of heat conducted away from the junction by the medium, and (2) if the size of the thermocouple is sufficiently small such that the heat generated by the ultrasonically produced relative motion between the viscous medium and the thermocouple wire may be neglected.[2,3] These effects were considered theoretically by approximating the bulk heating due to absorption as being produced by ten concentric cylinders, each with a different, but uniform, heat generation rate proportional to the intensity of the ultrasonic field in the corresponding portion of the beam.[4-6] The viscous heating at the wire surface due to relative motion between the wire and surrounding fluid medium was modeled in a similiar manner and added to the bulk heating. Analyses and measurements by Goss *et al.*[3] for a variety of beamwidths, frequencies, viscosities, and wire size combinations has experimentally verified the model, and shown that tolerable systematic measurement errors (< 10%), in the transient thermoelectric technique as applied to biological tissues, are achieved using half-power beamwidths larger than about 0.3 cm and thermocouple wire diameters on the order of 13 μm. These findings have now been employed in further measurements on mouse testis to minimize the errors associated with heat conducted away from the junction by the embedding medium and heat produced due to relative motion between the viscous imbedding medium and the thermocouple junction.

I. METHOD

The transient thermoelectric technique was the same as that employed previously[1] with the exception that broader ultrasonic beams, and reduced thermocouple wire sizes were employed. The specimens were adult mouse testes, removed surgically with all surrounding tissue dissected away, leaving the tunica albuginea in-

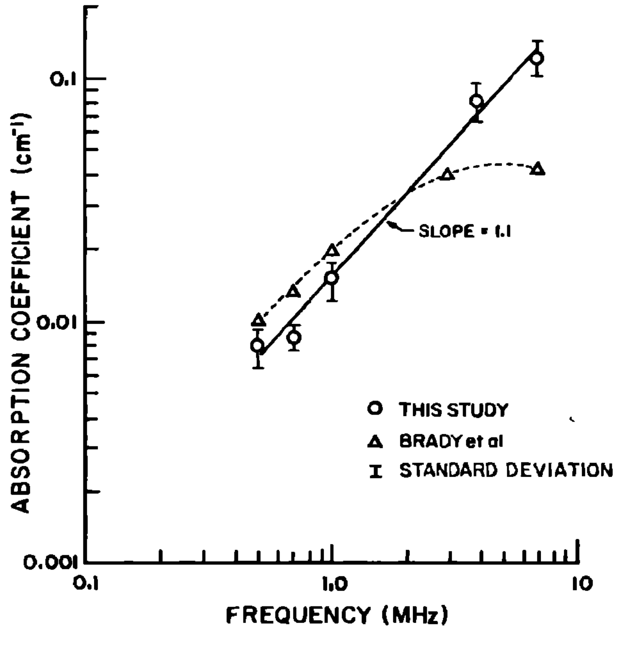

FIG. 2. Measured ultrasonic amplitude absorption coefficient in mouse testis (open triangles: data of Brady *et al.*[1]; open circles: data of present study). The straight line represents a least-squares fit to the data of the present study.

TABLE 1. Ultrasonic amplitude absorption coefficient of mouse testis: tabulated comparison of experimental results.

f(MHz)	Brady *et al.*[1]		This Study	
	$\alpha(\mathrm{cm}^{-1})$	No. of specimens	$\alpha(\mathrm{cm}^{-1})$ ± s.d.	No. of specimens
0.5	0.01	3	0.0078 ±0.0014	5
0.7	0.013	6	0.0085 ±0.00098	4
1	0.019	3	0.015 ±0.0026	6
3	0.040	5	---	
4	---	-	0.079 ±0.015	6
7	0.042	5	0.12 ±0.022	2

tact. Measurements were performed immediately after excision (within 2 hours) using degassed Ringer's solution maintained at 37° ± 0.5 °C as the acoustic coupling medium.

II. RESULTS AND DISCUSSION

Figure 1 shows the results of measurements of the ultrasonic absorption coefficient in mouse testis, at 7 MHz and 37 °C as a function of reciprocal beamwidth, made with two substantially different diameter thermocouples. Also shown are two curves which represent the results of the theoretical analysis using 0.135 cm^{-1} as the "true" value for the absorption coefficient (chosen for best fit to data) and a tissue viscosity of 5 cP.[3,7] Each curve illustrates, in addition to the effect of diffusion, the effect of added viscous heating due to the presence of a 13-μm (curve 1) or a 76-μm-(curve 2) diam thermocouple wire, respectively. These curves exhibit a vivid dependence of the apparent ultrasonic absorption coefficient upon the half-power beamwidth of the irradiating ultrasonic field. For example, increasing the half-power beam width from 0.043–0.4 cm (a change in the reciprocal of beamwidth from 23–2.5 cm^{-1}) increases the "apparent" absorption coefficient yielded by the transient thermoelectric technique by more than a factor of 3, at 7 MHz in mouse testis. The agreement between theory and experiment exhibited is consistent with results of the more complete study on a siloxane and various tissues.[3]

Figure 2 depicts the markedly different frequency dependence of the ultrasonic absorption coefficient of mammalian testis which results when the above criteria for ultrasonic beamwidth and thermocouple size are considered (refer to Table I for numerical data). The open triangles are the data from fresh mouse testis specimens[1] using 76-μm-diam thermocouples and focused ultrasonic fields, for which the beamwidth varies inversely with frequency. The open circles are fresh mouse testis data of the present study, wherein 13-μm-diam thermocouple wires were used, and the irradiating beamwidth was in all cases, greater than 0.3 cm. Since viscous heating due to relative motion between the wire and the surrounding fluid medium is less dependent upon frequency, than is the bulk heating due to absorption, the error due to this effect is expected to be more pronounced at the lower frequencies and this seems to be manifested in Fig. 2. The dependence of focal beamwidth on frequency leads to increasing error due to heat diffusion with increasing frequency as is evident at 4 and 7 MHz. The frequency dependence of the absorption coefficient determined in this study (α proportional to $f^{1.1}$ as determined from a least-squares straight-line fit to the data) is in sharp contrast to that previously reported for mouse testis.

Another source of error in determining the absorption coefficient by the transient thermoelectric technique is associated with the determination of the ultrasonic intensity at the site of the thermocouple junction, as it is a finite depth from the tissue surface of exposure and some procedure must be employed to correct for loss of energy over that distance. For low-absorbing, low-attenuating media, such as testis,[6] the correction is small and has been made in the data reported herein (max. of 5%) by employing a simple iterative method involving the absorption coefficient.[8] However, it is more correct to use the appropriate attenuation coefficient, rather than the absorption coefficient, to obtain an estimate of the intensity at the thermocouple junction. For this example, if it is assumed that the attenuation coefficient is twice the value of the absorption coefficient, the corrected absorption coefficient is only approximately 5% greater than reported herein, for testis at 7 MHz for a thermocouple junction depth of 2 mm. As this is considered to be a high value for the attenuation coefficient, the actual error is less, making the use of the absorption coefficient justifiable in this case. However, in highly attenuating media the situation is considerably different. For example, Dussik *et al.*[9] have reported the attenuation coefficient in beef tendon at 3 MHz and room temperature to be 1.25 cm^{-1} while the absorption coefficient, at 3 MHz and 37 °C determined by the transient thermoelectric technique and using an iterative method to correct for absorption, is found to be 0.46 cm^{-1}.[3] If the Dussik *et al.* attenuation coefficient is used to correct the intensity at a depth of 2 mm, the value computed for the absorption coefficient becomes 0.63 cm^{-1}, which is 37% higher than that calculated by the previous method, i.e., using the absorption coefficient in the correction procedure. Note also that the error increases at higher frequencies since the attenuation and absorption coefficients are believed to increase similarly with increasing frequency.

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A new principle for the design of condenser electret transducers

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In this paper we describe a new principle which can be used to design condenser electret transducers. Contrarily to previously described systems, it does not require an air gap between the moving element (electret or electrode) and the back electrode. It utilizes the relative displacement of electrical charges imbedded in the electret during a nonhomogeneous deformation of the system, with respect to the electrodes of the condenser. This inhomogeneous deformation is obtained through the use of superimposed layers of different tensile moduli. We first describe this general principle and present some preliminary sensitivities.

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During the last few years electrets have been intensively used in the field of electrostatic transducers. In these transducers, a thin metallized foil is stretched over a back electrode. This condenser contains an air gap and an electret which is used to produce a static electric field in the air gap. When a mechanical or acoustical excitation is applied, the displacement of the foil in the air gap produces a modulation of the static electric field, which in turn induces an electrical current or voltage in the external circuit, which can be amplified. This very simple principle, which has led to numerous applications (electret microphones,[1] hydrophones,[2] transducers), can be quite difficult to apply for many applications. Indeed, if the static pressure in which the transducer operates is too large, or if the amplitude of the signal to be detected is also too large, the foil tends to come against the back electrode. This can produce a change of sensitivity or nonlinearities in the operation of the transducer. It may even damage the system irreversibly.

Various principles have been proposed to overcome these problems. As to large-amplitude signals, many designs have been proposed. They all use the idea introduced by Sessler and West,[3] to support the foil not only at its periphery but also along lines, curves, and points. This technique operates fairly well up to rather high dynamic pressures. As to the static pressure, its influence can be drastically reduced in aerial applications by making a thin channel connecting the air gap to the external part of the transducer. This channel has a high acoustical impedance at high frequencies and a low acoustical impedance at low frequencies. It may thus equalize the internal and external static pressure. It is clear, however, that this principle cannot be applied to transducers which operate in media which could produce

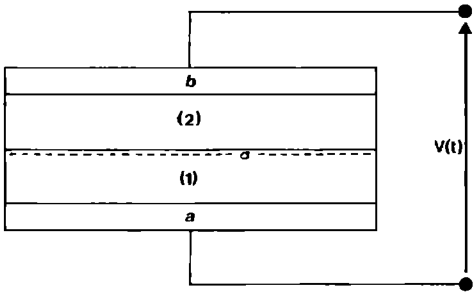

FIG. 1. Basic design of a no-air-gap electret transducer.