This latter is seen to be independent of the power output per talker. If this signal to noise ratio were to be in excess of the minimum S_m required for intelligible conversation, the party would remain quiet; *otherwise it will become loud.* Requiring S to exceed S_m is equivalent to requiring N to remain less than a certain critical number N_0 which from (4) is calculated readily as:

$$N<N_0=K\left(1+\frac{(aV/4\pi h)+d_0^2}{d_0^2S_m^2}\right). \tag{5}$$

Hence, it is seen that for $N<N_0$ each talker will use only the small acoustic power P_m, but if $N>N_0$ each talker, in trying to override the background, will increase his acoustic power in small increments, which we see by (4) will be of no avail. When the loud level P_M is reached, each talker will finally decrease his talking distance to a new d less than the conventional minimum d_0 and thereby restore the possibility of conversation even though by unconventional means.

III. ACOUSTICAL DYNAMICS

Suppose that at $t=0$, $P=P_m$ and $d=d_0$, although $N>N_0$. Such a condition can prevail monentarily even at a loud party by the intervention of the host who may just have finished directing all attention toward the guest of honor. The ensuing quiet is ephemeral however, since an impossible signal-to-noise ratio will prevail, but the loud state will be reattained only after a finite time. For instance the dialogue: "I really don't know what she sees in him."—"Beg your pardon?"—"I say, I REALLY DON'T KNOW WHY SHE GOES OUT WITH HIM," will consume a time interval τ and result in an increase in speaking power by a ratio of say ρ.

Making the approximation of using differentials for finite differences, we would hence get the following equation describing the acoustic dynamics of the party following the momentary quiet:

$$dP/dt=(P/\tau)(\rho-1),$$

which integrates by separation of variables to:

$$\int_{P_m}^{P}\frac{dP'}{P'}=\frac{\rho-1}{\tau}\int_0^t dt$$

or

$$P=P_m\exp[(\rho-1)t/\tau].$$

The power of each talker thus increases exponentially, reaching the maximum P_M and re-establishing the noisy character of the party in a time T given by:

$$T=[\tau/(\rho-1)]\ln(P_M/P_m). \tag{6}$$

IV. CONCLUSION

The foregoing calculations are admittedly rough and proceed merely from first approximations. Certain refinements are clearly indicated—for instance account might be taken of the variation of the average absorption coefficient a and the mean free path h as the number of guests increases. Expressing h and a in terms of N would make (5) not explicit for N but merely implicit and possibly transcendental. However, by making some allowance for the absorption and obstruction of the guests, the formula can be used explicitly as it stands.

We see therefore that, once the critical number of guests is exceeded, the party suddenly becomes a loud one. The power of each talker rises exponentially to a practical maximum P_M after which each reduces his or her talking distance below the conventional distance d_0 and then maintains, servo fashion, just the proximity, tête à tête, required to attain a workable signal-to-noise ratio. Thanks to this phenomenon the party, although a loud one, can still be confined within one apartment.

On the Acoustics of Cocktail Parties

WILLIAM R. MACLEAN
Polytechnic Institute of Brooklyn, Brooklyn, New York
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Parties are classified as loud or quiet, and the distinction is shown to depend often upon a critical acoustic relationship rather than upon the guests themselves. An explicit formula is found for the maximum number N of well-mannered guests compatible with the quiet party. When this number is exceeded, the party will become a loud one within a calculable time T.

I. PRELIMINARY CONSIDERATIONS

ONLY parties of well-mannered guests will be considered. More specifically, if there is a guest A who, in talking to a listener X, tries to outshout another guest B, talking to the same listener, A is called ill-mannered and the case is not considered. In the cases studied, therefore, a guest A, talking to a listener X, merely tries to outshout the general ambient background of all other talkers not talking to X.

In the presence of a sufficiently weak background of noise, including other conversations, a well-mannered guest will talk with an average small acoustic power output[1] P_m to one or more listeners X, Y, . . ., and, if necessary, will adjust his talking distance to a minimum conventional distance, d_0. This power P_m is not necessarily the amount required to override a background, but may be merely the minimum comfortable level for proper articulation. In the presence of a gradually increasing background of noise however, the average guest A will increase this talking power to a much larger value without being consciously aware of any strain or even of the existence of the background, but at a certain maximum value of acoustic output P_M the strain will become apparent to A who, rather than overtax himself, will reduce the talking distance d to a distance less than the conventional minimum d_0 until conversation again becomes possible.

If a single symmetrical sound source were operating in a moderately live room such as a social room, the mean energy density w at a distance x from the sound source is known to consist,[2] to a first approximation, of two parts: the direct energy falling off as the square of x, and a second part, the diffuse energy, constant throughout the room. At a certain distance D known as the critical distance, these two parts will be equal. D is expressible in terms of the geometry and acoustic properties of the room by the formula

$$D=(a\sigma/16\pi)^{\frac{1}{2}}=(aV/4\pi h)^{\frac{1}{2}}, \qquad (1)$$

wherein σ is the exposed surface and a (presumed$\ll 1$) is the average (over the room, the guests, and the frequency) sound absorption coefficient (energy basis). In the alternate expression, h is a properly weighted mean free path (between the walls, etc.) of a ray of sound through the room of volume V.

This formula can be developed independently, but follows readily from an expression[3] for the reverberation time, together with one for the diffuse energy throughout the room.[4] More accessibly, Beranek[5] gives an expression for the total energy (pressure squared) at a distance from a source in a room, from which the above formula can also be derived by equating the direct and indirect contributions.

In case the sound source considered is a person, the formula (1) can be refined by considering the directivity factor Q of the human head,[6,7] whence we have the better formula

$$D=(Qa\sigma/16\pi)^{\frac{1}{2}}=(QaV/4\pi h)^{\frac{1}{2}}. \qquad (2)$$

II. CRITICAL RELATIONSHIP

Consider a party of N guests broken up into conversational groups containing on the average K guests. In each group there will be only one talker (well-mannered guests) and hence a total of N/K talkers. We presume that at $t=0$ each talker is, on the average, delivering the minimum confortable acoustic output P_m and is distant from his listeners by the minimum conventional distance d_0. The time-averaged energy density w of his direct speech will be related to the density w_0 of his diffused speech by:

$$w/w_0=(D/d_0)^2. \qquad (3)$$

Since there are N/K simultaneous talkers each creating the same diffuse energy level (conversational groups are presumed spaced in excess of D—which is the usual case) at the listeners, the signal to noise ratio (energy basis), S^2, for the listeners will be:

$$S^2=\frac{(w+w_0)/w_0}{(N/K)-1}=\frac{(D/d_0)^2+1}{(N/K)-1}. \qquad (4)$$

[1] In cgs units, although the equations will be identical for mks units.

[2] A. Sturmhoefel, *Akustik des Baumeisters* (G. Kuehtmann, Dresden, 1898), p. 40.

[3] I. Katel, *Les bruits dans les bâtiments—comment les éviter?* (C. Beranger, Paris, 1929), p. 94.

[4] *Handbuch der Experimentalphysik* (Akademische Verlagsgesellschaft, Leipzig, 1934), Vol. 17, Part 2, p. 476.

[5] Leo L. Beranek, *Acoustics* (McGraw-Hill Book Company, Inc., New York, 1954), p. 314, Eq. (10.59).

[6] See reference 5, p. 317, Eq. (10.65).

[7] Leo L. Beranek, *Acoustic Measurements* (John Wiley and Sons, Inc., New York, 1949), p. 394, Fig. 9.11.