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The Evolution of Human Hearing

[redacted]

Department of Psychology, Florida State University, Tallahassee, Florida 32306

Five descriptive parameters of hearing—high-frequency and low-frequency sensitivity, lowest threshold, best frequency, and area of the audible field—are compared statistically, first, among mammals in general, and, then, among seven animals selected to approximate a phylogenetic sequence of man's ancestors. Three [redacted]

FIG. 1. Phylogenetic re-

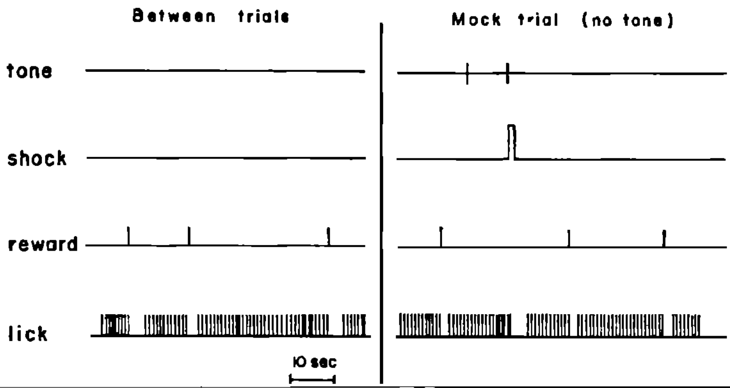

Between trials
Mock trial (no tone)
tone
shock
reward
lick
10 sec

TABLE I. Population and sample distributions of living mammals in genera per order.

[redacted]

	True distribution (after Simpson, 1945)		Sample distributions											
			[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		Area of [illegible]	
Order	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Monotremata	3	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Marsupialia	57	6.1	1	5.3	1	5.9	1	6.3	1	5.6	1	5.6	1	8.5
[redacted]														
Dermoptera	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chiroptera	118	12.7	2	10.5	2	11.8	0	0.0	2	11.1	2	11.1	2	17.0
Primates	59	6.3	6	31.6	6	35.3	6	37.5	6	33.3	6	33.3	3	25.5
Edentata	19	2.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Pholidota	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lagomorpha	10	1.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rodentia	344	36.9	3	15.8	2	11.8	3	18.8	3	16.7	3	16.7	1	8.5
Cetacea	35	3.8	1	5.3	1	5.9	0	0.0	0	0.0	0	0.0	0	0.0
Carnivora	114	12.2	2	15.8	3	11.8	3	18.8	3	16.7	3	16.7	2	17.0
Tubulidentata	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Proboscidea	2	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Hyracoidea	3	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

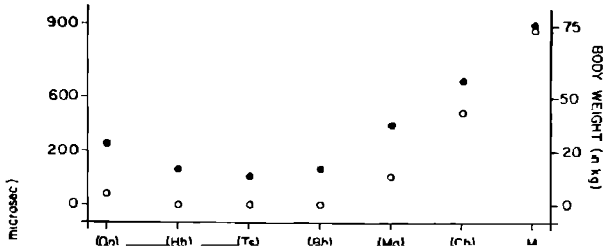
[redacted]

the method of estimating specific values for cases with incomplete audiograms are discussed within the appropriate sections.

D. Ancestral and Morphological Dimensions

analysis of the five auditory characteristics included here do not depend on the accurate affinition of tree shrews and, conversely, the auditory characteristics analyzed here provide no important information on the affinities of tree shrews.

only one pair is correlated in the comparisons among the 22 different mammals included here: Ancestry and Maximum Δt ($r = 0.69$, $p < 0.01$). But in the phyletic sequence, that is, among the seven mammals selected from the total of 22 for their close approximation to successive ancestors of Man (Fig. 1), all three pairs of potentially explanatory parameters are correlated (Fig. 5). This close interrelation of alternative explanations has been in the past, and still is, the primary ...



toward better general sensitivity is not unreasonable — that obviously approach an upper limit ...

This feature is analyzed in Sec. II C.

they do not reach it. In these cases, the upper limit their middle ear (malleus, incus, and stapes) and only one in their lower jaw (dentary) (Young, 1962). This

quences yield a correlation between High Frequency Sensitivity and Ancestry or Phyletic Level and also of a brief sound. One cue is the difference in the time of

3. *Evolution of High-Frequency Cutoff*

answer to this question is that some mammals have lost their high-frequency sensitivity in order to gain low-frequency sensitivity (von Békésy, 1960). This idea implies that high-frequency sensitivity and low frequency sensitivity are incompatible, or at least conflicting, characteristics. It is tenable because *Threshold at 1 kHz* is negatively correlated with High-Frequency Cutoff ($r=-0.58$, $p<0.05$); therefore, a conflict between the two characteristics may indeed exist. Thus, it

● In the evolution of Man, high-frequency sensitivity was retained until its benefits for sound localization were replaced by the benefits of wide set ears. From the early Eocene onward, progressively wider set ears (and the more effective interaural sound shadows that are their consequence) released man's ancestors from selective pressure for high-frequency hearing and resulted in regression of the upper limit to a point that is now so low that man bears artificial resemblance to nonmamkHz is high enough to be effectively shielded by most sound chambers now in use. At the same time, it is low enough to be a truly "low" frequency, in the sense that 1 kHz is far beneath the best frequency in 16 out of the 18 mammals included in the comparison (cf. Sec. II-D, on best frequency).

1. Low-Frequency Sensitivity in Mammals

kHz proves to be modestly correlated with Ancestry ($r=-0.49$, $p<0.05$) and Maximum Δt ($r=-0.50$, $p<0.05$) and it is not significantly correlated with Body Weight ($r=-0.34$).

The negative correlation of Threshold at 1 kHz with Ancestry means that there is a tendency for mammals with more recent common ancestry with man to have better low-frequency hearing. The reason for this apparent tendency among Mammals in general will be letic sequence ($r = -0.95$, $p < 0.01$). Further, when Maximum Δt and Body Weight are held constant, the partial correlation of Threshold at 1 kHz and Ancestry increases to -0.96 ($p < 0.01$). Therefore, among the

animals in the phyletic sequence "recency of common ancestry with man," by itself, accounts for more than 92% of the total variance in Threshold at 1 kHz. This relationship is shown in Fig. 10.

In the face of this strong relationship within the phyletic sequence, it is difficult to avoid the conclusion

sistent selective pressure for low-frequency hearing. Apparently, sensitivity to low-frequencies was achieved gradually during the earliest periods of mammalian

that was discussed in the Sec. II-A. If Fig. 10 (showing the decrease in threshold at 1 kHz) is compared to Fig. 8 (showing the decrease in the upper limit of hearing), it can be seen that the two curves are far from coinci-

dent, despite the fact that they each start high at opossum and end low at man. This lack of coincidence means that low-frequency sensitivity and lack of high-frequency sensitivity, though statistically correlated,

are not either a cause nor an effect of each other, at least among the animals within the phyletic sequence. Thus,

tivity in order to gain low-frequency sensitivity is not supported. At the same time, a similar comparison between Figs. 7 and 9 shows the validity of the observa-

Unlike high-frequency sensitivity, the biological sig- threshold is at the low end of the frequency scale must

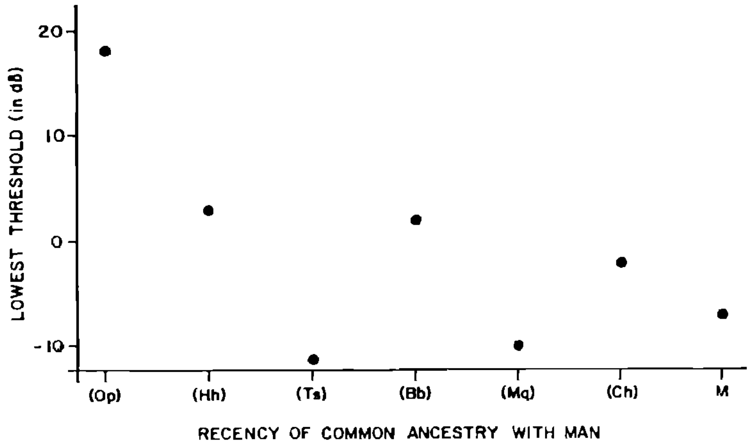


FIG. 12. Lowest Threshold in animals of phyletic sequence. Note large drop at lower levels.

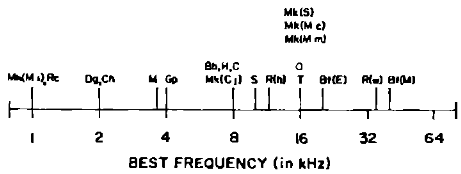


FIG. 13. Distribution of Best Frequency among 20 mammals.

keys (Mk) and rats (R).

sequently the chief effect of selective pressure for sound localization. But since Maximum Δt accounts for 69% of all the variance in High-Frequency Limit among mammals and only 30% of the variance in Best Frequency, it can be seen that there is at least one more factor influencing a mammal's best frequency than there is influencing its high-frequency limit.

significance of Best Frequency appears beyond the almost trivial observation that animals with a high

$p < 0.01$). Although this correlation is higher within the phyletic sequence than it is for mammals as a whole, no

800

than 0.05. Thus, the present state of knowledge provides in area from Monkey to Man is due mostly to a decrease panied the evolution of mankind, the Figures also allow Man's auditory capacities to be compared to those of other mammals. In the past, comparisons of this kind have typically concluded that human hearing is somewhat different from that of other animals, and

frequencies low enough to be in man's range of (possibly) superior sensitivity are truly *subsonic*, by the same argument that the bat's or dolphin's are *supersonic*. At the present state of knowledge, both capacities must be considered to be about equally aberrant—the result

example, most textbooks and popular periodicals, and

At present, human hearing can be *demonstrated* to be level during the Eocene. This change was most closely related to the drop in the upper frequency limit of hearing. (5) The total area of the audible field probably in-

while low-frequency sensitivity remained unchanged.

ACKNOWLEDGMENTS

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Simpson, G. G. (1949). [illegible]

[illegible]

[illegible] G. G. (1965). [illegible]

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