Human neonatal cardiac responses to sound: a power function¹

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Abstract

Human newborns were each presented with four intensities of a 1000-cps tone in 5 complete cycles of ascending and descending series. An approximately linear relation was observed between cardiac responses plotted on a log scale and stimulus intensity in decibels. This is consistent with the power law relation between stimulus and response shown by Stevens (1961) to hold for a large number of sensory systems.

Problem

Data on human adults indicate an approximately linear relation between the logarithm of the galvanic skin reaction (Tarchanoff potential method) and decibel level of a 1000-cps tone (Hovland & Riesen, 1940), which agrees with Stevens' (1961) power law based on psychophysical data. There does not appear to be any published study of this relation in human newborns. Such data are of theoretical interest with regard to the contributions of maturation and early sensory experience to the power function observed between response magnitude and stimulus intensity. They may also be helpful for subsequent more detailed studies of absolute and differential sensitivity in human newborns.

Previous studies with human newborns have demonstrated reliable cardiac acceleration to auditory stimuli (Bartoshuk, 1962a, 1962b); cardiac responses were significantly greater to 91 than to 80 db (Bartoshuk, 1962b).

The purposes of the present study were to examine whether the relation between the magnitude of the cardiac response (i.e., increase in heart rate) and stimulus intensity was consistent with Stevens' power law, and whether the exponent is similar to that observed for adults.

Method

The Ss were 39 full-term human newborns between 24 and 100 hours of age, and without any known abnormalities. Nine Ss did not complete the test because variations in baseline activity did not permit the presentation of 40 trials within the available testing time of about 75 min. The principal results are based on the remaining 30 Ss.

Electrocardiograms were recorded from an electrode on the left leg and an EEG electrode at the left frontal area (the latter gave less movement artifacts than arm electrodes). Cardiometer tracings were used to determine when the heart rate was steady (i.e., least variable), which was one of the primary criteria for presentation of the stimuli. Ancillary recordings were used as well to check the steadiness of baseline activity before presentation of a stimulus. These recordings

consisted of surface electromyograms from the right forearm extensors, bipolar EEGs from electrodes at the left frontal and parietal areas, respiration, and bodily movements recorded by a stabilimeter.

The stimuli were produced by a speaker inside a sound-proof room, on the newborn's right side and about 2 ft away from its head. The frequency was 1000 cps and the stimulus lasted 1 sec. Intertrial intervals were variable; they depended on the time required to get a steady baseline of activity with a heart rate of about 120 beats/min. or less. These intervals were never less than 20 sec. and they averaged about 45 sec. A Bruel & Kjaer sound level meter with an octave filter was used to measure the sound level at the location normally occupied by the newborn's head. The resting sound level, measured in an octave band centered at 1000 cps, was 10.5 db re 0.0002 microbar. This value was obtained under experimental conditions with all the recording apparatus in operation. Sound levels of the four stimuli used were 48.5, 58, 62.5, and 78 db. The resting level of 10.5 db was subtracted from these levels in order to derive the stimulus increments of 38, 47.5, 52, and 67.5 db. These stimuli were presented in 5 complete cycles of alternatively ascending and descending series, so that each intensity was presented 10 times. This sequence of stimulation should tend to equate the degree of habituation to the different intensities.

Heart rates were determined from measurements of the duration of the 6 beats immediately before stimulus onset and the 6 beats immediately after stimulus onset. Subtraction of the former from the latter gave the response measure used in Fig. 1.

Results

As seen in Fig. 1, there is an approximately linear relation between heart rate response plotted on a logarithm scale and stimulus intensity in decibels. A straight line can be fitted to the data to within one standard error of the mean. This finding is consistent with the power function between sensory magnitude and physical intensity demonstrated by Stevens. In our data, the exponent is 0.53 which is reasonably close to the exponent of 0.6 reported by Stevens (1961).

One prerequisite for our principal finding may be adequate control for variations in heart rate immediately before the stimulus. Earlier studies (Bartoshuk, 1962a; 1962b) demonstrated a significant negative correlation between cardiac response and prestimulation heart rates. In the present study, median prestimulus heart rates did not differ significantly for the four intensities. The means of Ss median prestimulation heart rates for

Fig. 1. The cardiac response is the mean for 30 Ss of their median response on 10 trials for each intensity used. Each mean is bracketed with plus and minus one standard error of the mean.

the four stimuli in order of increasing intensity were: 113.2, 112.9, 112.1 and 111.8 beats/min. Moreover, response magnitude was not significantly related to pre-stimulation heart rates in this study, perhaps due to the latter's restricted range. Present mean heart rates were also between 10 and 20 beats slower than the means in the earlier studies (Bartoshuk, 1962a; 1962b). Nevertheless, most Ss had EEGs which were more similar to our published awake than asleep samples (Bartoshuk & Tennant, 1964).

Present data also provide some indication of the weakest intensity capable of producing a reliable response. On control trials, when the speaker was disconnected from the stimulator, a mean "response" of 1.2 beats/min. was observed; this was not significantly different from zero and it was due to fluctuations in baseline heart rates. Responses on the 38-db trials were greater than on control trials in 67% of the Ss which was not statistically reliable. However, responses to the 47.5-db stimulus were reliably ($P < .01$) greater than on control trials. This suggests that under present conditions the absolute threshold for neonatal cardiac acceleration

was between 38 and 48 db.

With regard to differential sensitivity, it should be noted that responses were reliably ($P < .001$) greater to 67.5 than 52 db, and to 52 than 38 db; only 67% of the Ss had larger responses to 52 than 47.5 db, and only 62% of the Ss had larger responses to 47.5 than 38 db.

Discussion

These results indicate that with improved techniques it is possible to demonstrate much finer sensitivity to sound intensities in human newborns than was generally demonstrable with earlier techniques (Zubek & Solberg, 1954). At present there apparently are no published data on human newborns for any response measure which is as finely graduated with respect to stimulus intensity as the present data on cardiac acceleration. This study also suggests the general feasibility of using cardiac acceleration in human newborns to scale the activation effects of stimuli as a function of intensity, not only for audition but for other modalities as well. Reliable cardiac responses to photic stimulation have been demonstrated (Bartoshuk, 1962b). Such studies may provide systematic data which permit comparisons with psychophysical functions on adults.

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