Table 2. Intercorrelations and centroid factor loadings.

Test	1	2	3	4	5	6	7	I	II	h^2
1) Critical flicker frequency		.37	.23	.23	.12	−.49	−.12	.47	−.38	.36
2) Digit Symbol			.43	.65	.55	−.53	−.27	.78	.08	.61
3) Porteus Maze				.44	.48	−.45	−.20	.61	.07	.38
4) PMA Reasoning (untimed)					.67	−.40	−.18	.73	.39	.69
5) Raven Progressive Matrices						−.38	−.32	.72	.39	.67
6) WCST, perseverative errors							.34	−.71	.35	.62
7) Age								−.40	.16	.19

bined samples. The results with the male sample generally confirm those of the earlier study, the most striking exception being the failure of the Raven Progressive Matrices to correlate with flicker-fusion frequency. When the data from the two studies are pooled to provide a larger sample, all the tests except the Progressive Matrices correlate significantly with critical flicker frequency. A centroid factor analysis of the correlations from the combined sample is presented in Table 2. The analysis yielded only one significant factor, a general intellectual one in which both critical flicker frequency and age have significant loadings.

In the combined sample the perseveration score on the Wisconsin Card Sorting Test correlated the highest with critical flicker frequency. This test measures rigidity in concept formation, and it is tempting to draw similarities between conceptual perseveration and the neurophysiological perseveration reflected in flicker-fusion. However, the failure of the factor analysis to uncover a perseverative factor somewhat inhibits such speculation.

More than 20 percent of the variance in conceptual perseveration can be accounted for by flicker-fusion, presumably because both functions are sensitive to alterations in cerebral physiology. This relationship in the elderly might be explained by the comparative absence in some, and presence in others, of varying degrees of subclinical cerebral dysfunction. The relationship was probably attenuated by the exclusion of subjects with ophthalmological and neurological diseases and those in poor health. It is likely that these latter groups contained a disproportionate number of individuals with both low critical flicker frequency and severe intellectual impairment.

The results of the present study indicate the desirability of including measures of the flicker-fusion in longitudinal studies of aging. Repeated measurements throughout the life span of an individual would elucidate with less ambiguity the precise relationship between an individual's decline in intellectual ability and his decline in critical flicker frequency—and (presumably) in neural functioning.

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7. George McDonald performed the ophthalmological examinations. We are indebted to the officials of the following institutions in New York City for providing the subjects for this experiment: the Mary Manning Walsh, Josephine Baird, and St. Patrick's homes, and the homes of the Little Sisters of the Poor in Manhattan, the Bronx, and Brooklyn; and also the Hodson, Sirovich, and Forest Community Day Centers. This research was supported by grant No. M-1283 from the National Institute of Mental Health, U.S. Public Health Service.

29 May 1961

Humming: A Vocal Standard with a Diurnal Variation

Abstract. The process of humming can be used as a basal vocal measurement which can be repeatedly obtained with an accuracy comparable to that of other physiological variables. Studies have shown a diurnal fluctuation of the hum frequency. Data were collected by employing automatic telephone-answering equipment.

Various studies have been made in an attempt to find correlations between vocal response and physiological change. A review of these studies suggests that one possible obstacle in this field has been the difficulty in establishing a standard vocal response which can be repeated with some consistency.

In order to achieve a vocal base line, it is important to reduce the number of variables associated with the functioning of the vocal mechanism. For example, during phonation the vocal cavities are altered by the relative positions of the tongue, mouth, and lips and also, to some extent, by the facial expression. In the study reported here, vocal samples were recorded in the laboratory and over the telephone to test the hypothesis that the process of humming can be used as a vocal standard. Subjects were asked to hum—while seated in a relaxed position with the mouth and lips closed—one continuous note for up to 10 seconds. The response was recorded on a continuous loop of tape. This procedure insured that the positions of the oral and nasal cavities at the time the vocal samples were taken were relatively constant.

The fundamental frequency was measured in the following way. The hum sample was played back on the tape recorder. The output of the recorder was displayed on the vertical axis of a cathode ray oscilloscope, while the output of the audio oscillator was fed to the horizontal axis, the two curves forming a Lissajous figure. Because vocal samples fluctuate, in some cases by a few cycles per second, about a mean frequency, the average hum frequency was determined when the oscillator was adjusted so that the twisting Lissajous figure turned approximately one way for half the duration of the cycle and in the reverse direction for the remainder of the cycle. To determine the relative intensity for each recorded sample, the average signal level was read from the standard VU meter.

Statistical analysis of the results (from 33 subjects) showed that when samples of the fundamental hum frequency were taken over periods up to 179 days, the coefficient of variation of the hum frequency ranged from 3 to 18 percent. Intensity readings for the same group over the same period gave coefficient-of-variation values of 32 to 300 percent. Table 1 shows the means and the standard errors for coefficients of variation of these results as compared with the calculated coefficients of variation of biochemical determinations; the data indicate that a basal vocal hum frequency can be repeatedly established with accuracy comparable to that obtainable for biochemical determinations.

The coefficient of variation for hum

Table 1. Means and standard errors for coefficients of variation of oral temperature, hum frequency, hum intensity, and the sodium and potassium concentrations in urine, sweat, and saliva.

Item	Coefficient of variation (%)
Urine (Na)*	9 ± 3
Urine (K)*	11 ± 3
Sweat (Na)*	33 ± 7
Sweat (K)*	20 ± 5
Saliva (Na)*	22 ± 2
Saliva (K)*	8 ± 1
Oral temperature†	0.6 ± 1
Hum frequency‡	8 ± 1
Hum intensity‡	101 ± 27

*From 6. †As evaluated from readings or oral temperature studies (see 5). ‡As calculated from readings from 33 female subjects taken over periods up to 179 days.

intensity (101 ± 27 percent) is much higher than that for frequency (8 ± 1 percent), and this suggests that the relatively large fluctuations of intensity tend to mask subtle changes brought about by physiological mechanisms.

In a study to explore the diurnal fluctuation of the hum frequency, 18 female subjects telephoned the laboratory at three specified times during the day—(i) in the early morning, immediately after awakening (6:30 to 7:45 A.M.); (ii) at 12 noon, before lunch; and (iii) at the end of the day, before retiring for the night. The telephone calls were answered automatically and recorded on a Western Electric telephone-answering set, type I-BA, which made the following prerecorded announcement: "Please be seated; when you hear the beep tone at the end of this announcement please say your telephone number, the time, then hold the telephone close to your mouth, keep your lips pressed together in a comfortable way, and hum one note continuously for about 5 seconds. Thank you."

An analysis of variance of the data obtained for these 18 subjects showed that a definite diurnal fluctuation of the hum frequency occurred ($P < .001$). Subsequent tests revealed that the hum frequency was significantly higher at noon (241 ± 11 cy/sec) than it was in the early morning (208 ± 7 cy/sec; $P < .001$). Moreover, the noon reading was significantly higher in frequency than the night reading (212 ± 8 cy/sec; $P < .001$). No significant difference was found between the night reading and the early morning reading ($.70 > P > .60$). This finding is undoubtedly influenced by restricting the various vocal parameters so that the acoustical signal is modulated solely by physiological change.

The diurnal fluctuation of the hum frequency suggests that this variable is associated with the sleep-wake cycle, as are many other physiological funtions. This can be deduced from studies by Carhart (*2*) who concluded that the increased breath pressure and increased tension on the vocal cords produce a rise in laryngeal frequency. Mitchinson's x-ray studies (*3*), showed that in humming the vocal folds become elongated with an increase in vocal pitch, while Sonninen (*4*) showed that a lengthening of the external laryngeal muscles and the cricothyroid muscle occurs when there is a rise in the pitch of the singing voice.

From the studies of Mitchinson and Sonninen and from those reported here it can be assumed that during the day there is a rise in breath pressure, with a consequent rise in tension of the vocal cords. There is also a lengthening of the laryngeal muscles and the cricothyroid muscle, all this resulting in a rise in the hum frequency (*7*).

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9 June 1961

Localized Cooling in the Brain

Abstract. A slender refrigeration probe for the production of reversible discrete lesions within the central nervous system of man and experimental animals is described. Cooling, in the region of the third nerve nucleus in cats, produced pupillary dilatation which was quickly reversed when the temperature around the third nerve nucleus returned to normal.

Localized cooling of structures deep within the brain is a relatively easy, inexpensive, and effective method of producing reversible brain lesions. The widespread use of stereotactic surgical techniques for the treatment of Parkinson's disease in man has made it imperative to find a safe, effective method of producing reversible brain lesions to guide the surgeon in placing his permanent therapeutic lesions in the thalamus and basal ganglia. A refrigeration probe seems to be one answer to this problem. Furthermore, this probe could give animal neurophysiologists a dramatic new tool for the investigation of the central nervous system. This is particularly true if it could provide the experimenter with one probing electrode that could record information, stimulate the brain, and make both reversible and permanent lesions. It was with both clinical and experimental objectives in mind that we designed a long, slender refrigeration probe.

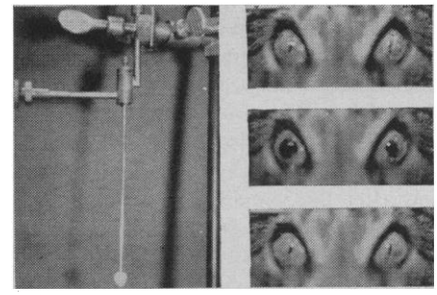

Fig. 1. (Left) Refrigeration probe with ice sphere around its tip. (Right) Pupillary size of the cat's eyes before (top), during (middle), and after (bottom) cooling produced by the refrigeration probe, 4 mm from the third nerve nucleus.

The probe (Fig. 1, left) made for us by John Chato of Massachusetts Institute of Technology (*1*) consists of two stainless-steel needles. The outer needle is 125 mm long with an outside diameter of 1.6 mm. Its distal tip, containing a 5-mm-long cooling chamber, is rounded for insertion into the brain. Its proximal end is attached to a small chamber which serves as an inlet for the liquid refrigerant (Freon 12). A smaller needle of 1 mm outside diameter lies within the larger needle; its distal tip has a beveled shoulder, which is elevated and lowered against the inlet to the cooling chamber by a knurled thumb screw at its proximal end. This device controls the inflow of refrigerant from the outer needle into the cooling chamber. The inner needle also serves as an exit for the expanded gas from the cooling chamber; it carries this cold gas up to the center of the probe and thus prevents cooling of the outer walls of the probe which carry down the uncooled refrigerant.

Our next problem was to see whether this probe would produce reversible lesions under experimental conditions. For this purpose, we did a series of ex-