Table 1. Similarities and differences among epochs scored as REM (night and day), W-REM, and W according to EOG and EMG tracings. The plus signs show the presence of the indicated phenomenon in the scored epoch. For abbreviations, see text.

Presence of	Epoch score			
	REM night (10 p.m.–7 a.m.)	REM day (7 a.m.–10 p.m.)	REM W-	W
Rapid eye movements*	+	+	+	−
REM (single and bursts) in groups	+	+	+	−
Periodicity of REM groups	+	+	+	−
Muscle tonus block out or marked decrease	+	+	(+)	−
Slow eye movements	−	−	−	+
Eye blinks	−	−	−	+

* Aserinsky criteria (*1*).

Table 2. REM-stages W and 1 and their preceeding EEG stages during first and second 12 hours of recording time.

REM stage	EEG stages before onset of REM				
	W	1	2	3	4
	Hours 1 to 12				
W	0	0	0	0	0
1	2	4	27	27	6
	Hours 13 to 24				
W	15	3	2	1	0
1	4	3	17	16	0

in depth of sleep (*7*), occurred periodically over all 24 hours. Under condition (iv), in which we disturbed the subjects after 3 minutes of stage 2 sleep, only subject 2 showed very rapid changes of EEG pattern, going sometimes within 3 minutes from stage W to 3 and 4.

Events possessing the characteristics of REM occurred in the EOG during EEG stage 1 and sometimes, after 12 to 16 hours of recording, in stage W. We scored such events as REM phenomena, regardless of whether they occurred during EEG stage W or 1. The justification for this approach lies in the similarity of appearance between tracings of such events occurring under both W- and 1-EEG (Fig. 2) and the tendency for episodic and periodic occurrence of such events (Table 1) (*8*). Figure 2 further points out the distinctions between this REM phenomenon, slow eye movements, and voluntary eye movements (that is, eye movements performed by the subject at the command of the experimenter) (*9*). In interviews, we found that when W-REM was accompanied by a decrease in muscle tonus the subject reported a dramaturgic daydream and active subjective involvement. When W occurred without REM, the subject reported a more abstract, nondramaturgic thought content. It should further be noted here that none of our subjects were "eye-rollers."

During the first 12 hours of any trial, REM occurred only during stage 1; during the second 12-hour period of some trials, however, REM was found during stage W (*10*). Muscle tonus often decreased during stage W with REM but did not disappear completely as during stage 1 with REM. The EEG stage occurring over the 6-minute period immediately before the onset of a stage-1 REM period was usually stage 2 or 3; for W-REM, the immediately preceding EEG stage was generally stage W or 1. Table 2 shows the relative frequencies of occurrence of the various EEG stages immediately preceding REM periods.

The continuation of REM periods during daytime indicates that there is no saturation of REM, as seemed to be indicated by some findings in REM-deprivation experiments (*11*). Rather, there exists a continuing alternation of these two kinds of central brain activity, measurable by changes in peripheral physiological variables, such as EEG, EOG, and EMG (*12*). The lack of regularity in the occurrence of REM periods indicates that timing of cycles may be a function of such variables as subject-identity, environmental influences, and absolute time, all of which have observable influence in other cyclic biological phenomena.

Our results indicate that REM occurs at intervals throughout a 24-hour period and not solely during the usual periods of sleep and thus that the sleep-dream cycle is too limited a concept in that it constitutes only one manifestation of an overall cyclic activity, the significance of which has yet to be established.

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4. The Washington University Computing Facilities are supported through NSF grant G-22296.
5. Each set of 18 20-second samples were averaged to give a 6-minute aggregate index of EEG activity.
6. E. Hartmann, *Arch. Gen. Psychiat.* **18**, 280 (1968).
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8. REM has previously been observed during "wakefulness," but no mention was made about periodicity (*3*, p. 4).
9. In Fig. 2A the muscle-tone decrease during stage-W REM is nearly the same as during stage-1 REM. Our sample is particularly emphatic; in other cases the decrease is less impressive.
10. Where a delay occurred in the onset of REM [subject 1, condition (iii), and subject 3, conditions (ii) and (iv)], there was no stage W with REM observable.
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12. Muscular relaxation under sitting condition caused subject 1 to fall forward in the EEG chair, preventing the onset of the REM period. Under the awakening condition, subject 1 was erroneously disturbed by the operator before she finished 3 minutes of stage 2. She reported that she was interrupted several times during the onset of dreaming.
13. Supported by National Institute of Mental Health grants MH-07081 and MH-19247.

24 September 1968; revised 3 February 1969

Cochlear Distortion: Effect of Direct-Current Polarization

Abstract. *Intermodulation components (combination tones) appearing in microphonic potentials were measured from guinea pig cochleas with and without polarizing direct currents passing through the cochlear partition. At moderate intensities of stimulus the polarization had a qualitatively different effect on the distortion components than on their eliciting primaries or on pure tones simulating the distortion products. At high intensities, the primaries and the combination tones were similarly influenced by the polarizing current. It is concluded that cochlear distortion is a two-stage process, mechano-electrical at low levels and mechano-hydraulic at high levels.*

Some manifestations of distortion by the ear were noted as early as the beginning of the 18th century, but even today there is disagreement about the mechanism by which distortion is generated. Studies of distortion components in the cochlear microphonic potential proved that, at least up to extremely high intensities, the distortion originates in the cochlea and not in the middle ear (*1*). While the cochlea is implicated as the major source of distortion, there are two apparently conflicting views concerning the mechanism of generation of usual components of distortion (overtones and combination tones). Some maintain that the site of nonlinearity is in the final, mechano-electrical transduction process (*1, 2*), whereas others contend that the principal nonlinearities are to be sought in the mechanical vibration of the cochlear partition, or in the hydrodynamic properties of the cochlear fluids (*3*). Some of our results (*4*) as well as those of deBoer and Six (*5*) showed promise that the two contradictory views could be reconciled. We now hope to show that, depending on the intensity of the primary stimulus, either the mechano-electrical or the mechano-hydraulic mechanism of distortion generation can predominate.

Twenty young guinea pigs (300 to 500 g) anesthetized with urethane were used as experimental animals. The auditory bulla was approached ventrolaterally, all soft tissue from the bony auditory meatus was removed, the bulla was opened, and recording and stimulating electrodes were placed in the cochlea through small holes drilled in the bony cochlear wall. Our results were obtained by recording microphonic potentials from the basal turn with a pair of differential electrodes (*6*) consisting of 24-μm tungsten wires. The microphonic potentials were amplified ($\times$ 1000)—individual frequency components were monitored with a harmonic wave analyzer, the output of which was written out on a chart recorder. Direct currents (d-c) were passed through the cochlear partition with the aid of a second pair of electrodes (one placed in scala tympani, the other in scala vestibuli of the basal turn) made of glass pipettes (tip diameter approximately 20 μm) filled with Ringer solution, which were connected to the current source by Ag-AgCl wires. The method of d-c polarization was patterned after that of Tasaki and Fernandez (*7*). The sound stimuli were delivered to the bony meatus in a closed system, and the magnitude and purity of the sound were monitored at the eardrum with a calibrated probe-tube microphone. Special care was taken to assure insignificant influence on the measurements by distortion generated in the sound system (*8*).

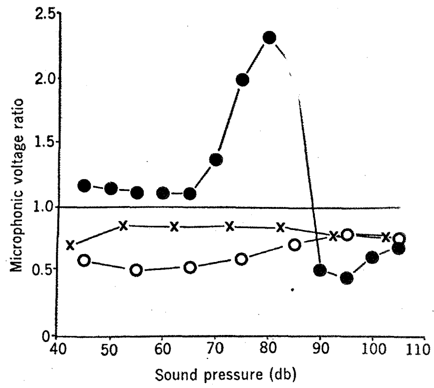

Fig. 1. Ratio of magnitude of microphonic potential with and without polarization. The primary frequencies are 4000 and 4500 hz presented at equal sound intensity; the distortion component is the 500-hz difference tone. The effect of polarization upon a 500-hz pure tone is also shown. The polarizing current is 100 μa, scala vestibuli negative. ○, 4000-hz primary; ●, 500-hz difference tone; x, 500-hz pure tone. Sound pressure reference, 0.0002 dyne/cm^2.

Our experiment was guided by the following hypothesis. If the relative change in a distortion component as the result of d-c polarization is the same as seen for primaries and for pure tones simulating the distortion component in question, then it is reasonable to assume that the distortion is mechanical or hydraulic in origin. This is so, for mechano-hydraulically generated distortion components would be transduced into microphonic potentials by the hair cells through the same mechanism as would be pure tones. Thus, there is no reason to assume that a change in the biasing (*9*) of the mechano-electric transducer would differentially affect the transduction of mechanically generated nonlinear components and pure tones.

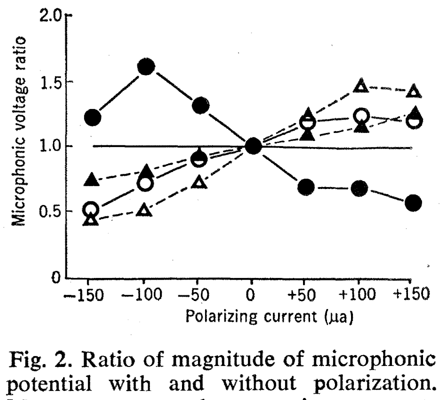

Fig. 2. Ratio of magnitude of microphonic potential with and without polarization. Measurements made at various currents and at two sound pressures of primary tones (67 and 97 db; reference, 0.0002 dyne/cm^2). The two primaries (4000 and 4500 hz) are presented at equal sound levels. The distortion component of interest is the 500-hz difference tone. ▲--▲, primary at 67 db; △--△, primary at 97 db; ●——●, difference tone at 67 db; ○——○, difference tone at 97 db.

If, however, the distortion originates in the mechano-electric transducer, then any change in the transducer's operating point brought about by polarization should differentially affect pure tones and nonlinear components. In general, one would expect that the distortion components would be more sensitive to such biasing than the pure tones. In Fig. 1 the relative change in microphonic potential due to d-c bias is shown as the function of stimulus intensity for a difference tone, for one of its eliciting primaries and for a pure tone simulating the difference tone. The plots for the pure tones confirm the results of Tasaki and Fernandez (*7*) in that a fairly uniform reduction of the microphonic results from the biasing procedure.

In contrast, at low intensities the difference tone increases as a result of polarization—it decreases at high intensities. At around 80 db of sound pressure (referred to 0.0002 dyne/cm^2) profound changes are seen. First, the difference tone increases over twofold; then it decreases to about 0.4 before approaching the value typical for pure tones, that is, 0.7. This plot shows a fairly general pattern. However, both qualitative and quantitative differences in response to polarization are seen from animal to animal depending on electrode location, frequency, and type of distortion component (*10*).

Nevertheless, the results are confirmatory in that three zones of behavior are usually discernible. At low intensities the pure tones and the distortion component react in opposite sense to polarization; at high intensities they react the same way; and within the transition zone some rather bizarre behavior is often seen. Direct comparisons between a high frequency primary, a low frequency pure tone, and a difference tone of low frequency are legitimate for the following reasons. (i) With differential electrode recording the pickup is well localized, thus the potentials in question all originate in the vicinity of the recording electrodes. (ii) We have shown (*4*) that at moderate intensities the distortion component is most prominent in the region where the primaries are located. (iii) Relative magnitude differences between the potentials that are compared are not significant because, as the plots indicate, the biasing causes the same relative change in the magnitude of the response to a pure tone, no matter what its absolute size might be.

Another demonstration of contrasting behavior of difference tones at low and high primary intensities under polarization is shown in Fig. 2. Here two pairs of curves are seen for one of the primaries and for the difference tone, at moderate and at high intensities. The relative change in microphonic component is plotted as the function of the magnitude and polarity of the biasing direct current. The functions for the primary at both sound intensities and also for the difference tone at high levels are like those reported (*7, 11*). There is a roughly proportional increase in microphonic with current strength when the scala vestibuli is positive, and similar proportional decrease when the scala vestibuli is negative. In contrast is the curve for the difference tone at the moderate sound level (67 db). The behavior is exactly reversed, positive polarity creates a decrease whereas negative polarity creates an increase in this nonlinear component.

These results indicate that cochlear distortion is at least a two-stage process with signal intensity playing the critical role. At low levels the distortion is primarily a hair-cell phenomenon, and, as we demonstrated (*4*), it is most prominent at the location of the maximum primary microphonic potential. At high intensities a mechanical type of nonlinearity becomes predominant, and the distortion which is generated by this nonlinearity is manifested by components which are probably distributed within the cochlea by traveling waves.

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9. We assume that a large fraction of the current flowing between the two stimulating electrodes is shunted between the two perilymphatic scalae. A small fraction, however, traverses the organ of Corti and generates a voltage drop across the hair cells. This voltage drop adds to or subtracts from the resting polarization of these cells. The latter is presumably obtained as the sum of the endocochlear potential and the intracellular negative polarization of the hair cells.
10. A similar lack of exact repeatability was noted by T. Konishi and T. Yasuno [*J. Acoust. Soc. Amer.* **35**, 1448 (1963)] in their investigation on the effect of polarization upon the summating potential. This similarity is not surprising, because the summating potential is presumably the d-c distortion component in the microphonic potential. The repeatability of results on the effects of polarization on pure tones is excellent; it is the distortion components, irrespective of frequency, that show labile responses.
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Speech: Relation of Nonfluency to Information Value

Abstract. *In spontaneous speech and oral reading of stutterers, likelihood of nonfluency occurring on any word is not related to the amount of information carried by that word. The same is true for spontaneous speech of normal speakers. Previous contrary findings can be accounted for by the relationship between information value and word length.*

It has been suggested that stuttering is essentially similar to nonfluency in normal speech, and that a key factor underlying both is the information value of the word (*1*). Thus, the greater the amount of information transmitted by a word, the greater is said to be the probability that it will be uttered nonfluently. Information value is defined in terms of the probability of correctly guessing a word from those words preceding it: the more judges who correctly guess it, the less information it carries. Since most of the research reviewed has been performed on the oral reading of stutterers, I set out to confirm the nonfluency–information relationship in the spontaneous speech of stutterers, and also in the reading and the spontaneous speech of normal speakers (*2*). Since simple pauses are not counted as nonfluencies in the present work, it cannot be compared directly with Goldman-Eisler's work (*3*) demonstrating a relationship between hesitancy and information within normal speech. The importance of word length as a linguistic variable [see, for example, (*4*)] is taken into account, and also the relationship (*5*) of nonfluency incidence to sentence position and to initial sound of the word.

To examine the reading of stutterers, Quarrington's data (*6*) on 24 subjects reading a 95-word passage were analyzed. Stuttering had been defined by clinical judgments of two experienced listeners. Stuttering and information were significantly correlated (.32); but when the effect of word length was held constant, the partial correlation became nonsignificant (.16). Stuttering and word length were also correlated significantly (.43); with information held constant, the partial correlation remained significant (.36).

Next, the spontaneous speech of eight stutterers was recorded and transcribed. Subjects were asked to talk for 5 minutes about a job which they had held in the past. Nonfluencies were designated (here and in the following studies) according to the criteria of Johnson *et al.* (*7*). Thus, a word was marked as nonfluent if it was associated with one of the following categories: interjections, part-word repetitions, word repetitions, phrase repetitions, and prolonged sounds. A single judge was employed, and adequate reliability was demonstrated through independent judging of five of the passages after 1 month. The four variables, word length (short, medium, long), initial sound (vowel, consonant), fluency (fluent, nonfluent), and sentence position (initial, medial, final), allow 36 cells or categories of words; four words were selected per cell from the transcripts. Information value of each of these 144 words was determined by having 195 undergraduates attempt to guess them from the preceding context; the negatives of the logarithms of the number of correct guesses per word were used as the measure of the information transmitted by each word. Two three-way analyses of variance were performed, each with information as the dependent variable. In the first, the factors were nonfluency, sentence position, and