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Absolute and relative caloric responses

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Abstract

THE stability and pathological sensitivity of both percentage-based and absolute-based post-caloric electro-oculographic response measures were investigated in ten normal subjects, one of whom was tested ten times, and in twenty neuro-otological patients.

Using the method that we adopted, it was shown that the percentage-based measures were statistically more variable than the absolute-based measures. The mean interbeat interval showed higher sensitivity for the detection of abnormal electro-oculographic records. Criteria for the best electro-oculographic measure are presented in the form of an answer to the question: Why is the interbeat interval the measure of choice in the clinical evaluation of vestibular function?

Introduction

The post-caloric EOG (electro-oculographic) response has been widely accepted as a means for evaluating vestibular function. The quantification of the response has been subject to extensive studies since Bárány introduced the caloric test over seventy years ago. Several response measures have been used: response duration, total number of beats, total amplitude, maximum amplitude, maximum frequency and maximum speed of the slow phase of nystagmus. In the absence of electrical recordings, the duration of nystagmus (the duration of nystagmus following each thermal stimulus) is commonly used because it is the most readily identifiable response measure. Considerable information can be gained by this method, but there are some drawbacks. In particular, vestibular nystagmus is suppressed by optic fixation. The latter must inevitably occur whenever the eyes are open and there is at least moderate illumination. However, although optic fixation invariably reduces the 'intensity' of vestibular nystagmus, it frequently enhances abnormal caloric test patterns, or even makes such abnormal patterns apparent when they would not otherwise be so (Hood and Dix, 1973).

With the advent of EOG other measures of nystagmic response to caloric stimulation were made possible. At the same time the problem of optic fixation was in some ways resolved. Extensive studies led to general agreement that the maximum speed of the slow phase of the nystagmus was the most suitable measure of the post-caloric EOG response (Barber and Stockwell, 1976; Coats, 1965; Henriksson, 1956; Jongkees *et al.*, 1962). The use of the maximum slow phase speed had been supported by

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the introduction of direct read-out velocity channels (Henriksson, 1955). Almost invariably the maximum slow phase speed has been measured by averaging the speed of three or four beats selected around the peak response. It has been thought that this peak response occurs at about one minute post-stimulus time. Selection criteria are based upon individual judgements.

The terms 'canal parèsis' (CP) and 'directional preponderance' (DP) have been used to quantify particular abnormal caloric test patterns, and usually as a percentage of the total response. Percentage canal paresis (percentage CP) and percentage directional preponderance (percentage DP) are calculated from the following formulae:

$$\text{Percentage CP} = \frac{A+B-C-D}{A+B+C+D} \times 100$$

$$\text{Percentage DP} = \frac{A+D-B-C}{A+B+C+D} \times 100$$

where A, B, C, and D are the nystagmic responses to irrigation of the left ear with water at 44°C, the right ear with water at 44°C, the left ear with water at 30°C and the right ear with water at 30°C respectively.

The dispersion of normal caloric canal paresis and directional preponderance measures have been investigated by several workers (Aschan *et al.*, 1956; Brookler and Pulec, 1970; Coats, 1965; Henriksson, 1956; Jongkees *et al.*, 1962; Preber, 1958). Various values have been suggested (see Table I). However, there has been a prevailing view that the normal limits (defined as twice the standard deviation; this corresponds approximately to the 95 per cent confidence level) of 'canal paresis' and of 'directional preponderance' should be set at ± 20 per cent and ± 30 per cent respectively.

It is the purpose of the present study to investigate the statistical behaviour of percentage-based and absolute-based measures of speed and interval-based response measures. The interval-based measure used in this study is the mean interbeat interval (Hamid, 1979). The interbeat interval is the time difference between the onset or end of successive slow beats in the EOG response.

Materials and Methods

Data were collected from ten normal subjects. There were ten successive trials on one of these subjects. Each subject was tested in the supine position with the eyes open but covered and in a partially illuminated room. Left and right ears were irrigated successively with water at 44°C and 30°C, each for a period of 30 s.

Horizontal eye movements were recorded onto FM magnetic tapes for computer analysis. An IBM-1800 and a CDC-6400 computer system were

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used not only to process responses but also to produce results and illustrations for this study. Each EOG response was processed under visual control to select the start and end of each slow phase beat. The time of occurrence (measured at the middle of the beat with respect to the start of irrigation), and the slow phase speed (determined by linear regression) of each beat were computed and stored.

The speed and the interbeat interval (measured as the time difference between each two successive beats) were the measures adopted in this study. Fig. 1 shows these two measures and how they were evaluated. These two measures were sufficient to quantify both the amplitude and the time characteristic of the EOG response. Moreover, while the slow phase beat can be regarded as a measure of the process generating the slow phase only of nystagmus, the interbeat interval can be regarded as a measure of the processes generating both the slow and the quick phase. It is to be emphasized that the interbeat interval is essentially different from the frequency measure. Frequency has always been expressed as an average of the number of beats per unit time. However, the choice of this unit time is arbitrary and difficult to standardize in view of the nature of the EOG

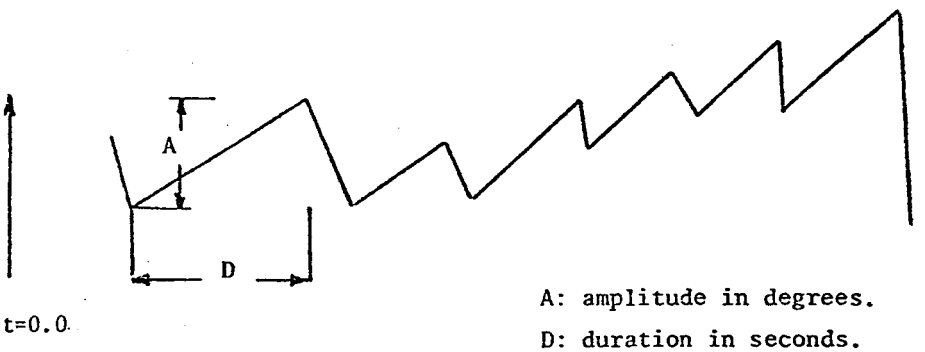


FIG. 1*a*
Part of an ideal EOG signal.

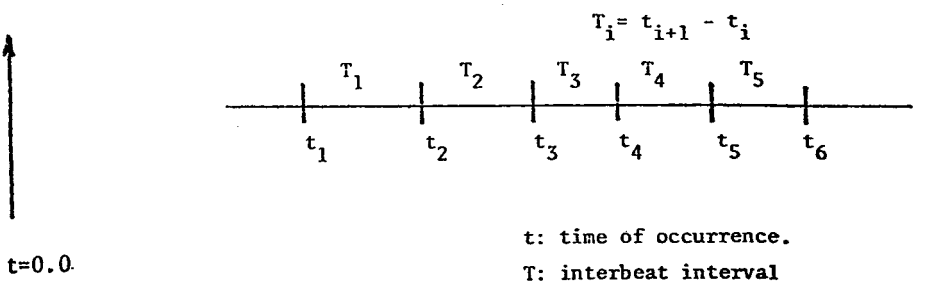


FIG. 1*b*
Point event version of signal shown in Fig. 1*a*.

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signal. It can also be argued that the term frequency implies periodicity, such as the frequency of a sine wave. Periodicity is difficult to observe in the EOG signal. However, one can use what can be termed 'instantaneous frequency' as an alternative; this is essentially the same as the interbeat interval.

Two sets of sequences were formed from each caloric response, i.e. eight sequences for each caloric test, as shown in Fig. 2. The maximum slow phase speed, mean slow phase speed and mean interbeat interval were computed and stored for each caloric response.

Results

Inter-subject response, i.e. responses drawn from ten different subjects, and intra-subject responses, i.e. responses drawn from the ten trials on the same control subjects, were processed as described above and two ensembles were formed, as shown in Figs. 3 and 4. The responses were also evaluated in terms of the following measures:

(a) Percentage canal paresis: $\frac{A+C-B-D}{A+B+C+D} \times 100$

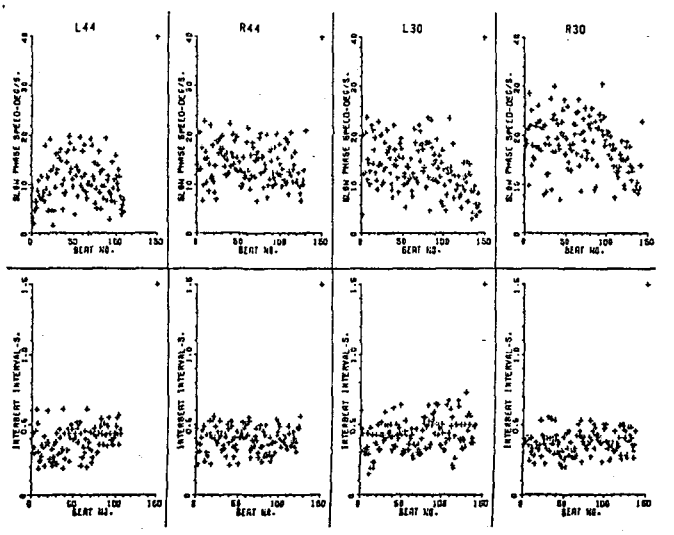


FIG. 2
Slow phase speed and interbeat interval sequences of subject F.M.

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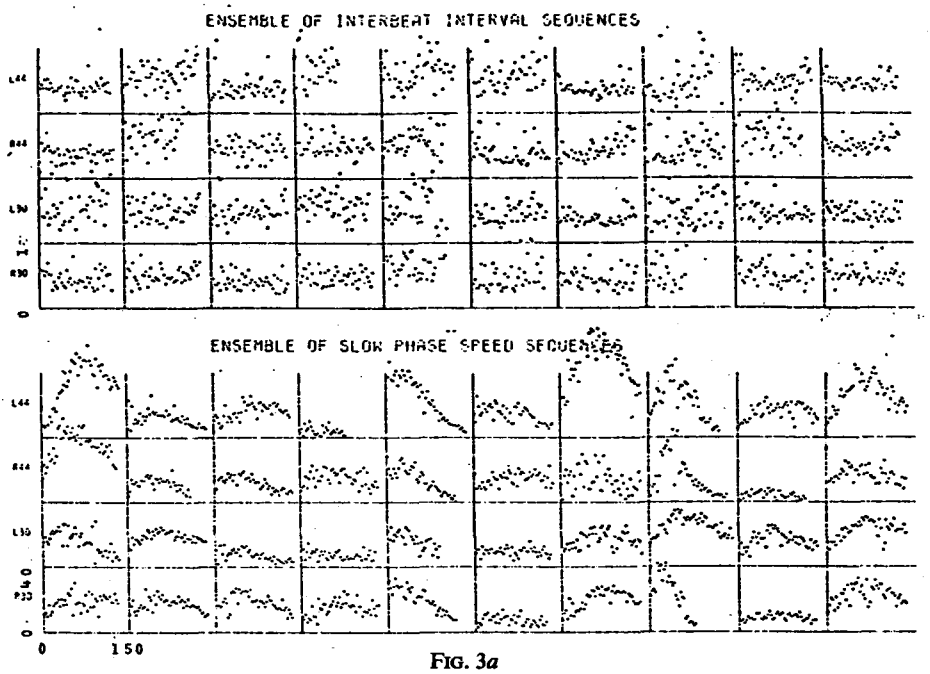


FIG. 3*a*

Inter-subject ensembles. Each vertical column represents one normal control subject.

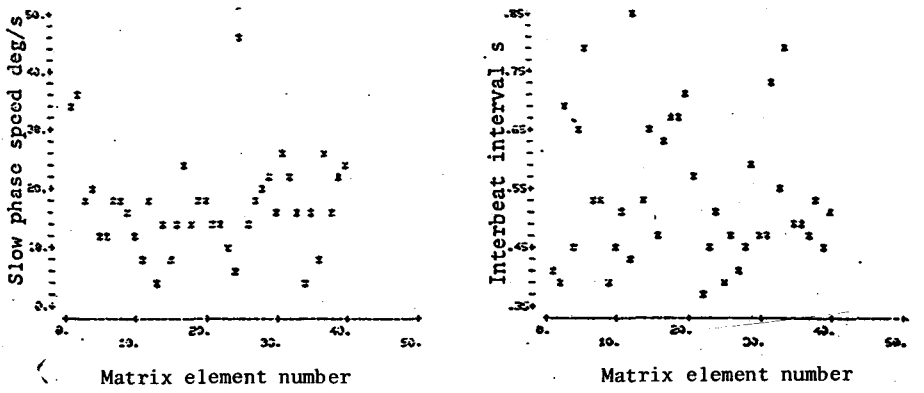


FIG. 3*b*

Ensemble means. Each value represents the average of the observations of the corresponding response in Fig.

(b) Absolute canal paresis: $A+C-B-D$

(c) Percentage directional preponderance: $\dfrac{A+D-B-C}{A+B+C+D} \times 100$

(d) Absolute directional preponderance: $A+D-B-C$

(e) Mean response measure

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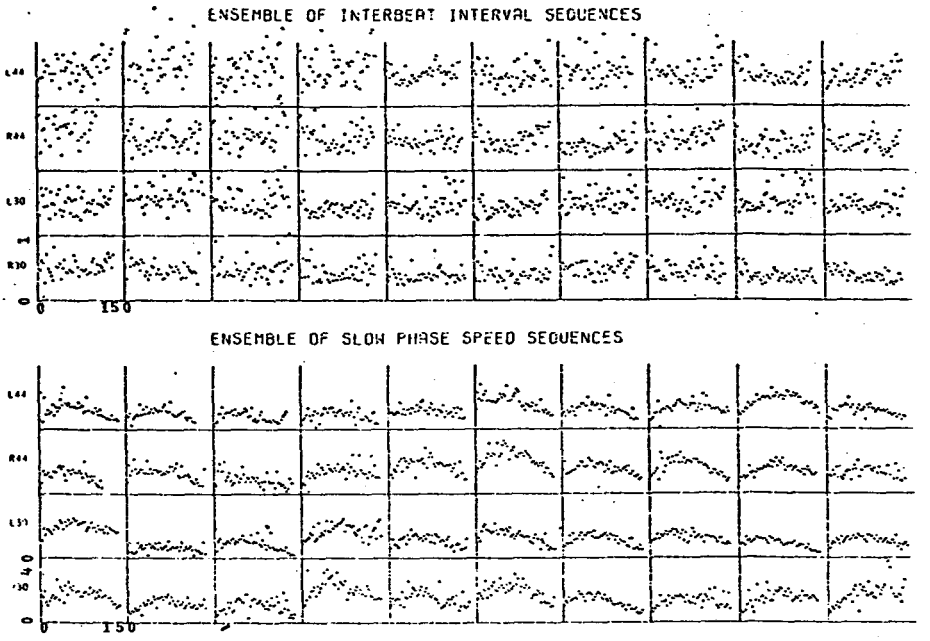


FIG. 4*a*

Intra-subject ensembles. Each vertical column represents a single trial on the same control subject.

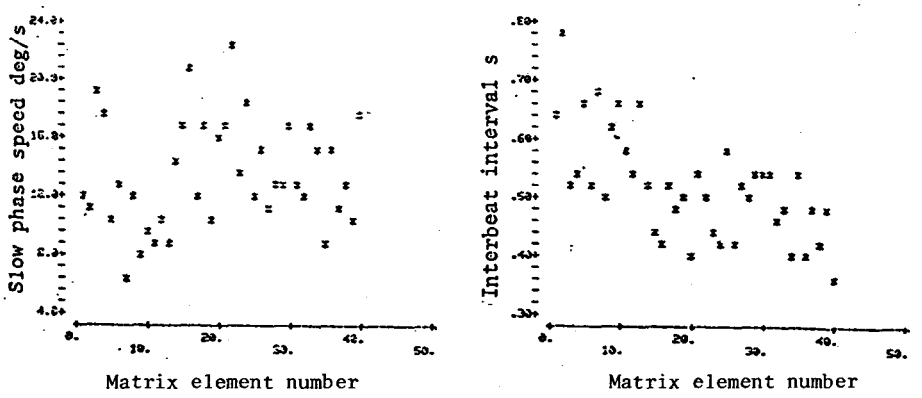


FIG. 4*b*

Ensemble means.

The above measures were calculated for both speech and interval measurements; the results are listed in Table II to V. The percentage speed-based values were computed using the maximum slow phase speed while the absolute-based values were computed using the mean of each response measure.

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TABLE I

NORMAL LIMITS OF CALORIC CP AND DP (MEASURED BY MAXIMUM SLOW PHASE SPEED AND BASED ON ±2 SD)

Reference	*CP*	*DP*	*Eyes*
Aschan *et al.*	16%	18%	Closed
Brookler and Pulec	24%	28%	Closed
Coats	18%	26%	Closed
Hamid *et al.*	47%	28%	Open and covered
Henriksson	18%	16%	Open and covered
Jongkees	16%	18%	Closed
Preber	10%	12%	Closed

TABLE II

INTER-SUBJECT RESULTS, SPEED-BASED MEASURES

Subject number	*Mean response measure*				*Percentage CP*	*Abs. CP*	*Percentage DP*	*Abs. DP*
	L44	*R44*	*L30*	*R30*				
1	33·6	35·1	17·3	19·3	− 3·0	− 3·4	0·0	0·5
2	12·1	11·5	18·8	17·3	3·0	2·1	− 1·0	− 0·8
3	16·4	11·7	7·5	18·1	−11·0	− 6·0	28·0	15·3
4	4·1	14·9	7·6	14·6	−43·0	−17·8	− 9·0	− 3·8
5	23·5	13·4	17·0	19·0	11·0	8·1	16·0	12·0
6	14·4	14·1	9·8	7·0	6·0	3·1	− 5·0	− 2·6
7	46·1	14·3	17·1	19·5	30·0	29·4	35·0	34·2
8	22·8	15·8	25·7	21·8	13·0	10·9	4·0	3·2
9	15·9	4·1	16·4	8·2	45·0	20·1	8·0	3·6
10	26·4	16·8	22·7	23·1	10·0	9·2	11·0	10·0
Statistics of each response measure:								
Mean	21·1	15·2	16·0	16·8	6·1	5·6	8·6	7·2
SD	11·9	7·8	6·1	5·4	23·6	13·2	14·0	11·5
CV	·6	·5	·4	·3	**	**	**	**
Normal limits based on ±2 SD:								
Lower limit	**	**	3·8	6·0	−47%	−26·4	−28%	−23·0
Upper limit	44·9	30·8	28·2	27·6	+47%	+26·4	+28%	+23·0

SD, standard deviation; CV, coefficient of variation; **, not applicable.

Discussion

The normal limits of percentage canal paresis and percentage DP are different from those reported by other workers (see Table I). Using the methods adopted here, the data used in this study show that percentage CP is more variable than percentage DP. It is, however, in agreement with the limits of normality reported by Henriksson in 1956. This is perhaps because of the criterion used for determining the maximum slow phase speed. Previously, the maximum slow phase speed has been calculated by averaging the speed of three or four beats around one minute post-stimulus time (this is the currently used criterion in many clinical practices). The inter-subject slow phase speed ensemble shown in Fig. 2 clearly

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TABLE III

INTER-SUBJECT RESULTS, INTERVAL–BASED MEASURES

Subject number	Mean interbeat interval				Percentage CP	Abs. CP	Percentage DP	Abs. DP
	L44	R44	L30	R30				
1	·42	·38	·69	·46	14·0	·3	− 9·0	− ·2
2	·64	·78	·53	·54	− 6·0	− ·15	− 0·4	− ·13
3	·39	·45	·51	·43	1·0	0·02	− 7·3	− ·14
4	·85	·53	·66	·48	20·0	·5	6·0	·14
5	·63	·66	·66	·7	− 2·6	− ·1	0·0	0·01
6	·58	·37	·45	·52	7·2	·14	14·5	·30
7	·39	·47	·41	·44	− 6·0	− ·11	− 2·9	− ·05
8	·59	·48	·47	·73	− 6·6	− ·15	16·3	·4
9	·55	·78	·48	·50	−10·8	− ·2	− 9·0	− ·25
10	·47	·52	·45	·51	− 5·0	− ·1	0·5	0·01
Statistics of each response measure:								
Mean	·55	·54	·53	·53	1·0	·01	·6	·01
SD	·14	·15	·10	·10	9·8	·20	8·9	·20
CV	·30	·30	·20	·20	**	**	**	**
Normal limits based on ±2 SD:								
Lower limit	·27	·24	·33	·33	−20%	− ·4	−18%	− ·4
Upper limit	·83	·84	·73	·73	+20%	+ ·4	+18%	+ ·4

SD, standard deviation; CV, coefficient of variation; **, not applicable.

TABLE IV

INTRA-SUBJECT RESULTS, SPEED-BASED MEASURES

Test number	Mean slow phase speed				Percentage CP	Abs. CP	Percentage DP	Abs. DP
	L44	R44	L30	R30				
1	12·1	11·5	18·8	17·3	4·0	2·1	0·0	− 0·8
2	10·0	12·7	6·0	11·9	−20·0	− 8·6	8·0	3·2
3	8·1	9·4	9·0	10·7	− 7·0	− 2·8	1·0	·4
4	9·1	14·3	17·0	20·8	−14·0	− 9·1	− 1·0	− 1·3
5	11·7	17·0	10·6	15·9	−18·0	−10·6	0·0	− ·1
6	16·8	22·0	13·7	18·7	−13·0	−10·2	0·0	− ·2
7	12·3	15·0	11·5	13·0	− 7·0	− 4·2	− 1·0	− 1·1
8	12·7	16·7	12·6	12·4	− 6·0	− 3·8	− 7·0	− 4·2
9	16·9	15·1	8·7	14·9	− 7·0	− 4·3	14·0	8·0
10	11·5	12·9	10·5	17·6	−15·0	− 8·6	11·0	5·6
Statistics of each response measure:								
Mean	12·1	14·7	11·8	15·3	−10·3	− 6·0	2·5	·9
SD	2·9	3·7	3·9	3·3	7·1	4·1	6·4	3·6
CV	·3	·3	·3	·2	**	**	**	**
Normal limits based on ±2 SD:								
Lower limit	6·3	7·3	19·5	21·9	−14%	− 8·0	−13%	− 7·0
Upper limit	17·9	22·1	4·0	8·7	+14%	+ 8·0	+13%	+ 7·0

SD, standard deviation; CV, coefficient of variations; **, not applicable.

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TABLE V

INTRA-SUBJECT RESULTS, INTERVAL-BASED MEASURES

Test number	*Mean interbeat interval*				*Percentage CP*	*Abs. CP*	*Percentage DP*	*Abs. DP*
	L44	*R44*	*L30*	*R30*				
1	·64	·60	·53	·54	1·2	·05	− 4·0	·05
2	·67	·52	·64	·50	14·0	·3	0·0	·01
3	·61	·66	·57	·54	− 0·8	−0·02	− 3·4	− ·08
4	·66	·52	·43	·43	7·0	·14	6·0	·1
5	·53	·48	·49	·41	7·0	·13	− 1·6	− ·03
6	·53	·50	·44	·42	3·0	·05	1·0	·01
7	·57	·41	·53	·50	9·0	·19	7·0	·1
8	·54	·54	·54	·46	4·0	·08	− 3·0	·1
9	·48	·40	·54	·40	12·0	·22	− 3·0	− ·06
10	·47	·42	·48	·36	10·0	·17	− 2·0	− ·07
Statistics of each response measure:								
Mean	·57	·52	·52	·46	8·0	·13	− 0·3	·01
SD	·07	·08	·07	·06	4·70	·10	3·9	·06
CV	·1	·2	·1	·1	**	**	**	**
Normal limits based on ± 2 SD:								
Lower limit	·43	·36	·38	·34	− 9·40	− ·2	− 8·0	− ·12
Upper limit	·71	·68	·66	·58	+ 9·40	+ ·2	+ 8·0	+ ·12

SD, standard deviation; CV, coefficient of variation; **, not applicable.

demonstrates that the peak response is not always around the one minute post-stimulus time. The maximum slow phase speed calculated by this three beat average is, therefore, frequently different from the true maximum speed. Henriksson used the velocity channels apparatus in his study and was therefore able to calculate the exact maximum slow phase speed. In the present study, the maximum slow phase speed was computed by first filtering each slow phase speed sequence and, secondly, finding the average of the 15 maximum values in the filtered sequence. This criterion seems to give a more accurate estimate of a maximum slow phase speed, should this be required to quantify caloric responses.

The results in Tables II to V also show that the standard deviations of the percentage-based measures are higher than those of the absolute-based measures by a factor of at least 2. This is evident in both inter-subject and intra-subject results. The use of absolute-based measures is therefore indicated to quantify the post-caloric EOG response.

To investigate the pathological sensitivity of the percentage-based and the absolute-based measures, twenty neuro-otological cases were evaluated in terms of the two measures and the results are shown in Table VI. The results show that the sensitivity (number of pathological cases correctly identified) of the percentage speed-based measure is almost the same as that of the absolute speed-based measure. However, considering the interval-based measures, it is clear that the sensitivity of the absolute-based

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TABLE VI

RESULTS OF 20 NEURO-OTOLOGICAL CASES

	Speed-based measures				*Interval-based measures*			
Case no. *N.L.*	*Percentage (CP)* ±47	*Abs. (CP)* ±26	*Percentage (DP)* ±28	*Abs. (DP)* ±23	*Percentage (CP)* ±20	*Abs. (CP)* ±·40	*Percentage (DP)* ±18	*Abs. (DP)* ±·40
1	100 (+)	28 (+)	7 (−)	2 (−)	100 (+)	1·5 (+)	−16 (−)	−·3 (−)
2	3 (−)	1 (−)	− 7 (−)	− 3 (−)	7 (−)	·2 (−)	15 (−)	·5 (+)
3	−32 (−)	− 6 (−)	−12 (−)	− 3 (−)	16 (−)	·5 (+)	3 (−)	·1 (−)
4	−21 (−)	14 (−)	29 (+)	20 (−)	−17 (−)	−·5 (+)	−15 (−)	−·4 (−)
5	−22 (−)	−10 (−)	− 2 (−)	− 2 (−)	22 (+)	·4 (+)	−12 (−)	−·3 (−)
6	−28 (−)	− 9 (−)	− 1 (−)	− 1 (−)	18 (−)	·4 (+)	−15 (−)	−·4 (+)
7	−21 (−)	−10 (−)	0 (−)	0 (−)	16 (−)	·4 (+)	2 (−)	·1 (−)
8	− 6 (−)	− 3 (−)	14 (−)	6 (−)	13 (−)	·6 (+)	−18 (+)	−·8 (+)
9	−28 (−)	−32 (+)	12 (−)	13 (−)	14 (−)	·3 (−)	−·5 (−)	− 1 (−)
10	6 (−)	6 (−)	12 (−)	11 (−)	−10 (−)	−·2 (−)	− 3 (−)	−·1 (−)
11	4 (−)	2 (−)	− 6 (−)	− 4 (−)	− 2 (−)	−·1 (−)	10 (−)	·3 (−)
12	2 (−)	3 (−)	−36 (+)	−58 (+)	− 5 (−)	−·1 (−)	8 (−)	·1 (−)
13	5 (−)	6 (−)	−44 (+)	−54 (+)	− 1 (−)	0 (−)	− 5 (−)	−·1 (−)
14	− 7 (−)	− 3 (−)	−22 (−)	− 8 (−)	−14 (−)	−·7 (+)	−21 (+)	− 1 (+)
15	−·2 (−)	−·2 (−)	38 (+)	39 (+)	− 3 (−)	−·1 (−)	0 (−)	0 (−)
16	2 (−)	·8 (−)	23 (−)	10 (−)	1 (−)	·1 (−)	− 6 (−)	−·3 (−)
17	− 7 (−)	− 6 (−)	−15 (−)	−12 (−)	0 (−)	0 (−)	0 (−)	0 (−)
18	3 (−)	2 (−)	− 1 (−)	− 1 (−)	9 (−)	·1 (−)	− 7 (−)	−·1 (−)
19	42 (−)	20 (−)	19 (−)	9 (−)	− 6 (−)	−·1 (−)	− 8 (−)	−·1 (−)
20	1 (−)	1 (−)	− 4 (−)	− 2 (−)	10 (−)	·3 (−)	13 (−)	·4 (+)

N.L., normal limits; (−), inside normal limits; (+), outside normal limits.

measure is markedly higher than that of the percentage-based measure (factor of 4). This not only further supports the use of the absolute-based measure, but it also indicates the use of an interval-based measure. In this case it is the mean interbeat interval of each individual response.

The absolute mean interbeat interval clearly exhibits the lowest variability; it shows a markedly low coefficient of variation. These coefficients of variation can also be regarded as constant for the four different caloric stimuli conditions. This indicates an evident constant precision of the mean interval which is difficult to observe with speed measures.

To further investigate the sensitivity of the mean interval and the mean slow phase speed, the responses from twenty neuro-otological cases were evaluated in terms of the two measures and the results are shown in Table VII. The values in Table VII were tested to determine whether or not they lay within the confidence limits of each measure. The confidence limits were computed from the ensemble mean sequences shown in Fig. 3. A Kolmogorov-Smirnov test showed that these sequences are normally distributed at the 5 per cent level. However, the confidence limits were defined on the basis of two standard deviations considering (a) the small number (40) of observations, and (b) that no attempt was made to reject data from the ensemble mean sequences. Thus, on the basis of two stan-

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TABLE VII

RESULTS OF 20 NEURO-OTOLOGICAL CASES

Case no.	*Absolute slow phase speed deg/s*				*Absolute interbeat intervals*			
	L44	*R44*	*L30*	*R30*	*L44*	*R44*	*L30*	*R30*
1	15 (−)	NR (+)	13 (−)	NR (+)	·63 (−)	NR (+)	·87 (+)	NR (+)
2	8 (−)	9 (−)	9 (−)	7 (−)	1·02 (+)	·66 (−)	·70 (−)	·84 (+)
3	3 (−)	7 (−)	3 (−)	5 (−)	·75 (+)	·47 (−)	·99 (+)	·80 (+)
4	26 (−)	8 (−)	16 (−)	19 (−)	·48 (−)	·94 (+)	·60 (−)	·64 (−)
5	13 (−)	19 (−)	3 (−)	7 (−)	·41 (−)	·32 (+)	·81 (+)	·47 (−)
6	8 (−)	12 (−)	3 (−)	7 (−)	·48 (−)	·47 (−)	·80 (+)	·43 (−)
7	8 (−)	13 (−)	10 (−)	15 (−)	·74 (+)	·52 (−)	·63 (−)	·47 (−)
8	12 (−)	10 (−)	8 (−)	12 (−)	·78 (+)	·91 (+)	1·65 (+)	·96 (+)
9	21 (−)	30 (−)	18 (−)	34 (−)	·50 (−)	·43 (−)	·58 (−)	·39 (−)
10	34 (−)	27 (−)	14 (−)	16 (−)	·42 (−)	·57 (−)	·44 (−)	·50 (−)
11	35 (+)	62 (+)	45 (+)	15 (−)	·32 (+)	·31 (+)	·38 (−)	·49 (−)
12	24 (−)	48 (+)	40 (+)	10 (−)	·40 (−)	·48 (−)	·56 (−)	·52 (−)
13	7 (−)	12 (−)	8 (−)	5 (−)	·55 (−)	1·42 (+)	1·45 (+)	1·29 (+)
14	38 (+)	19 (−)	13 (−)	32 (−)	·37 (−)	·42 (−)	·58 (−)	·61 (−)
15	15 (−)	9 (−)	7 (−)	11 (−)	·93 (+)	1·07 (+)	1·40 (+)	1·20 (+)
16	18 (−)	27 (−)	18 (−)	14 (−)	·64 (−)	·63 (−)	·82 (+)	·77 (+)
17	21 (−)	18 (−)	14 (−)	13 (−)	·39 (−)	·38 (−)	·47 (−)	·36 (−)
18	22 (−)	22 (−)	16 (−)	14 (−)	·34 (+)	·33 (+)	·47 (−)	·34 (+)
19	21 (−)	7 (−)	13 (−)	7 (−)	·29 (+)	·39 (−)	·30 (+)	·29 (+)
20	9 (−)	9 (−)	9 (−)	8 (−)	1·07 (+)	·68 (−)	·74 (+)	·79 (+)

(−) indicates inside the normal range; (+) indicates outside the normal range; NR, no response.

dard deviations, the confidence limits of the mean slow phase speed and the mean interbeat interval are 1 deg/s–34 deg/s (17 mrad.s^{-1} to 593 mrad.s^{-1}) and 0·34 s–0·74 s respectively. The results of testing the values shown in Table VII are indicated in the same table, where '+' indicates outside the confidence limits, i.e. abnormal; and '—' indicates inside the normal limits, i.e. normal.

The ratio of responses identified by the mean interbeat interval to those identified by the mean slow phase speed was 38:9. In terms of the total number of cases, there were fifteen abnormal cases identified by the mean interbeat interval as opposed to five cases identified by the slow phase speed. It should be noted that the cases identified by the mean slow phase speed were also identified by the mean interbeat interval; the reverse was not true in 80 per cent of the cases. A higher sensitivity of the interbeat interval is therefore supported.

Criteria for the best EOG response measure

Criteria are postulated in the form of an answer to the question: Why the interbeat interval?

The mean interbeat interval can be regarded as the best EOG response measure for the following reasons:

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1. Higher stability (because of its small intra- and inter-subject variability).
2. Constant precision (because of its relatively constant coefficients of variation).
3. Higher sensitivity (because 75 per cent of abnormal cases used in this study were detected by the mean interbeat interval).
4. Simplicity. The interbeat interval is the simplest measure of the EOG response to use, with or without computational aids. It can be argued the the amount of hardware necessary for measuring the interbeat interval is substantially less than that required for measuring the slow phase speed or any other speed-based measure. Moreover, the problems associated with calibration signals are avoided.
5. It is drawn from a homogeneous and stationary population (Hamid *et al.*, 1979).

Summary

The statistical features of absolute-based and percentage-based post-caloric EOG response measures were investigated on ten normal and twenty pathological cases. Criteria for the best EOG response measure are introduced. It is concluded that, using the method adopted in this study, the mean interbeat interval can be regarded as the measure of choice for quantifying the post-caloric EOG response.

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