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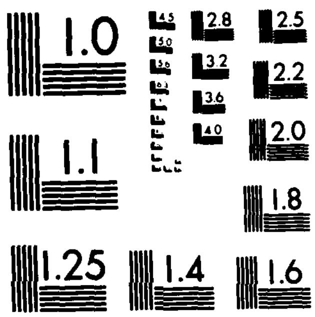
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REAL-TIME MONITORING OF THE VISUAL EVOKED POTENTIAL

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Subjects can experience loss of consciousness (LOC) during exposure to sufficiently high $+G_z$ acceleration. LOC is usually preceded by decreased visual sensitivity, dimming of the visual field, peripheral light loss (PLL) and central light loss. Real-time monitoring of PLL as a measure of $+G_z$ tolerance on the human centrifuge presently requires an active response by the subject.

In contrast, the visual evoked potential (VEP) also reflects the integrity of the visual system and requires only the passive response of viewing a visual stimulus.

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A preliminary evaluation of the Steady-state VEP for real-time monitoring of visual functioning was accomplished with a computer controlled dual-channel, Fast Fourier Transform (FFT) signal analyzer. Since significant degradation of visual functioning must be recognized in less than approximately four seconds, we required a previously unattained efficiency in producing and measuring the VEP. Using the Coherence Function and the expectation for the variance of a weighted sum of variables we developed analytic methods and instrumentation for reducing the results of the FFT processing to unidimensional measures having a known and maximal signal-to-noise ratio, with measures available at 1 1/2 sec. intervals.

Preliminary tests on six subjects indicate that the technique may have adequate stability as a measure of G-tolerance. Stimulus interruption produces a rapid loss of responses, with recovery somewhat slower. However, the measure is considerably more stable for some subjects than for others. Further testing is in progress.

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INTRODUCTION

Subjects can experience loss of consciousness (LOC) during exposure to sufficiently high +Gz acceleration. LOC is usually preceded by decreased visual sensitivity, dimming of the visual field, peripheral light loss (PLL) and central light loss. Real-time monitoring of PLL as a measure of +Gz tolerance on the human centrifuge presently requires an active response by the subject.

In contrast, the visual evoked potential (VEP) also reflects the integrity of the visual system and requires only the passive response of viewing a visual stimulus. (4)

A preliminary evaluation of the Steady-state VEP for real-time monitoring of visual functioning was accomplished with a computer controlled dual-channel Fast Fourier Transform (FFT) signal analyzer. Since significant degradation of visual functioning must be recognized in less than approximately four seconds, we required a previously unattained efficiency in producing and measuring the VEP. Using the Coherence Function (1) and the expectation for the variance of a weighted sum of variables (2) we developed analytic methods and instrumentation for reducing the results of the FFT processing to a unidimentional measure (which we label "Percent Vision"), having a known and maximal signal-to-noise ratio, with measures available at 1½ second intervals. (3)

METHOD

This approach was tested on six male Naval Enlisted and Officer volunteers under static (non-centrifuge) conditions. The subjects sat in front of a diffuse strobe light flickering simultaneously at 12.8 and 16.0 Hz. This was timed and controlled from the internal clock signal of an HP3582A low frequency spectrum analyzer which was set to retrigger every 1.5625 seconds and generated an FFT for each of these time frames in the frequency range of 0-100 Hz, with a spectral resolution of 0.8 Hz. Standard scalp electrodes (Oz, Cz, mastoid ref.) were used to monitor the EEG. Each subject sat through four runs lasting about one minute each on two different days. The first of each four runs was a parameter estimation run and the next three, taken less than two minutes apart, were used for determination of "Percent Vision". For these three runs the strobe light was occluded for about five seconds and then exposed again near the end of each run to simulate an episode of loss of vision.

During the parameter estimation runs, we collected 32 FFT's and estimated the copower, cross-power, phase angle, and coherence of the ensemble. These parameters were used to calculate a complex weighting function to be applied to single FFT's in real-time to produce the single variable, "% Vision". The weighting function performs magnitude normalization, rotation of axis such that the VEP component becomes positive real, and produces scalars which when summed result in a variable which has maximal signal-to-noise ratio. (This method assumes stationarity, normal distribution, uncorrelated "noise", correlated "signal").

RESULTS AND CONCLUSIONS

In all runs, a five second delay of the data collection, after turning on the strobe, was used to permit the response to reach a steady-state. In Figure 1, the first 2-3 plotted points indicate that a total delay of 8-10 seconds should be used in further applications. In the real-time runs, the strobe was occluded for three frame times beginning approximately at frame 34. In Figure 1, the values for Frames 35-38 indicate that a three frame loss of stimulus has a major effect on only four frames. Frames 36-37, clustering as they do at zero, indicate that coherent electronic noise was not corrupting the measurement.

Taking Frames 4-34 as quasi-stationary, Table 1 presents the summary results for each of the 36 real-time runs. The expected standard deviation, based upon the parameter estimation runs, ranges from 17.0 to 30.4, while the obtained values ranged from 15.4 to 36.8. The correlation between E[SD] and real-time SD was +.62.

Mean Percent Vision, ranging from 59.6 to 106.5, was not related to either expected or obtained SD ($r = +.12$ and +.07 respectively). *This reduced signal amplitude would seem to require a non-stationarity of the VEP's phase angles and/or relative magnitudes (magnitude as a function of frequency). Further data and analysis are required to estimate the source of this effect, and appropriate methods for dealing with it.*

Figure 2, in addition to showing that the monitoring method is useable with the "better" subjects, also shows the effectiveness and cost of using a "Two-Point Smooth": the displayed result at frame 24 is moved up substantially, but the zero vision point at frame 35 is delayed by one frame-time. Since we can not simply reject time-frames contaminated by eye-blink or other artifacts such smoothing provides a simple and reasonably effective method.

Overall, the results of this experiment indicate that while improvements in the method are required, if we are to have an effective real-time monitor for visual functioning, such improvements are not only possible, but feasible. Procedure modification, changes in stimulus parameters and provision of auditory or tactile feedback to the subject, all promise some improvement. Measurement of the separate responses at 01 and 02, instead of just 0z, should give a considerable improvement in detection.

TABLE I. THE EXPECTED STANDARD DEVIATIONS, OBTAINED STANDARD DEVIATIONS, AND MEAN PERCENT VISION FOR REAL-TIME RUNS (Frames 4-34).

SESSION-SUBJECT	EXPECTED SD	RT-1 SD	RT-2 SD	RT-3 SD	RT-1 MEAN	RT-2 MEAN	RT-3 MEAN
1-1	24.9	29.6	27.6	27.2	82.1	106.3	90.5
1-2	18.2	24.5	22.9	16.7	99.7	80.6	67.9
1-3	18.5	15.4	21.8	19.1	85.9	77.9	74.7
1-4	21.6	31.0	28.4	21.1	79.1	64.8	59.6
1-5	17.0	18.3	19.1	20.4	94.1	83.7	77.1
1-6	22.0	25.8	19.2	20.1	86.3	73.4	79.7
2-1	30.4	24.9	26.3	33.9	64.8	79.2	97.9
2-2	18.0	19.5	26.7	22.5	91.7	81.7	69.5
2-3	24.0	22.8	28.8	20.0	106.5	95.2	105.2
2-4	29.5	24.7	30.1	32.8	97.6	86.2	90.5
2-5	17.5*	21.0	18.6	17.5*	101.2	91.3	93.3*
2-6	21.8	23.8	22.5	36.8	80.9	89.0	79.7

*Shown as Figure 2, Specimen Real-Time Run.

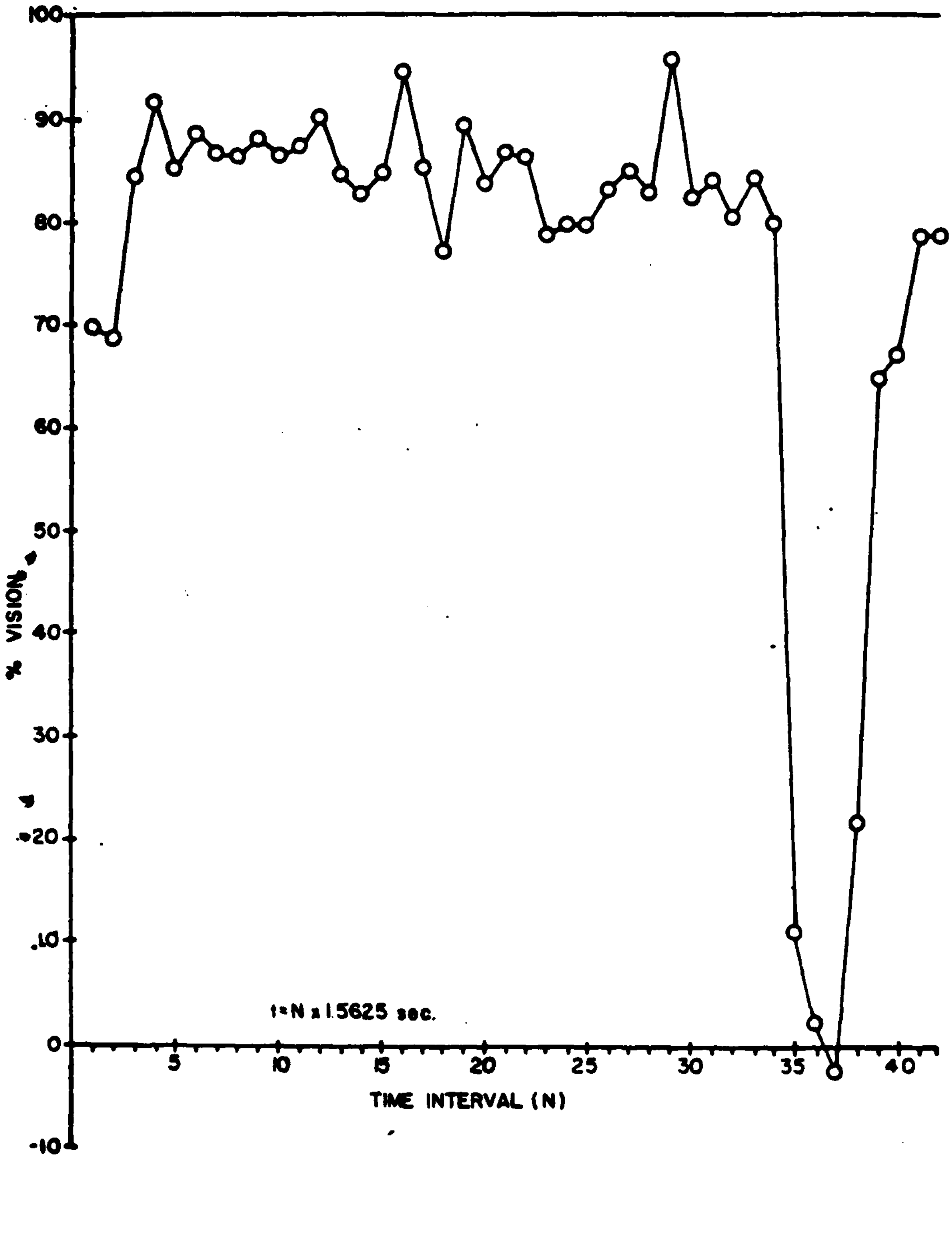

Figure 1 - Mean Percent Vision For All Real-Time Runs

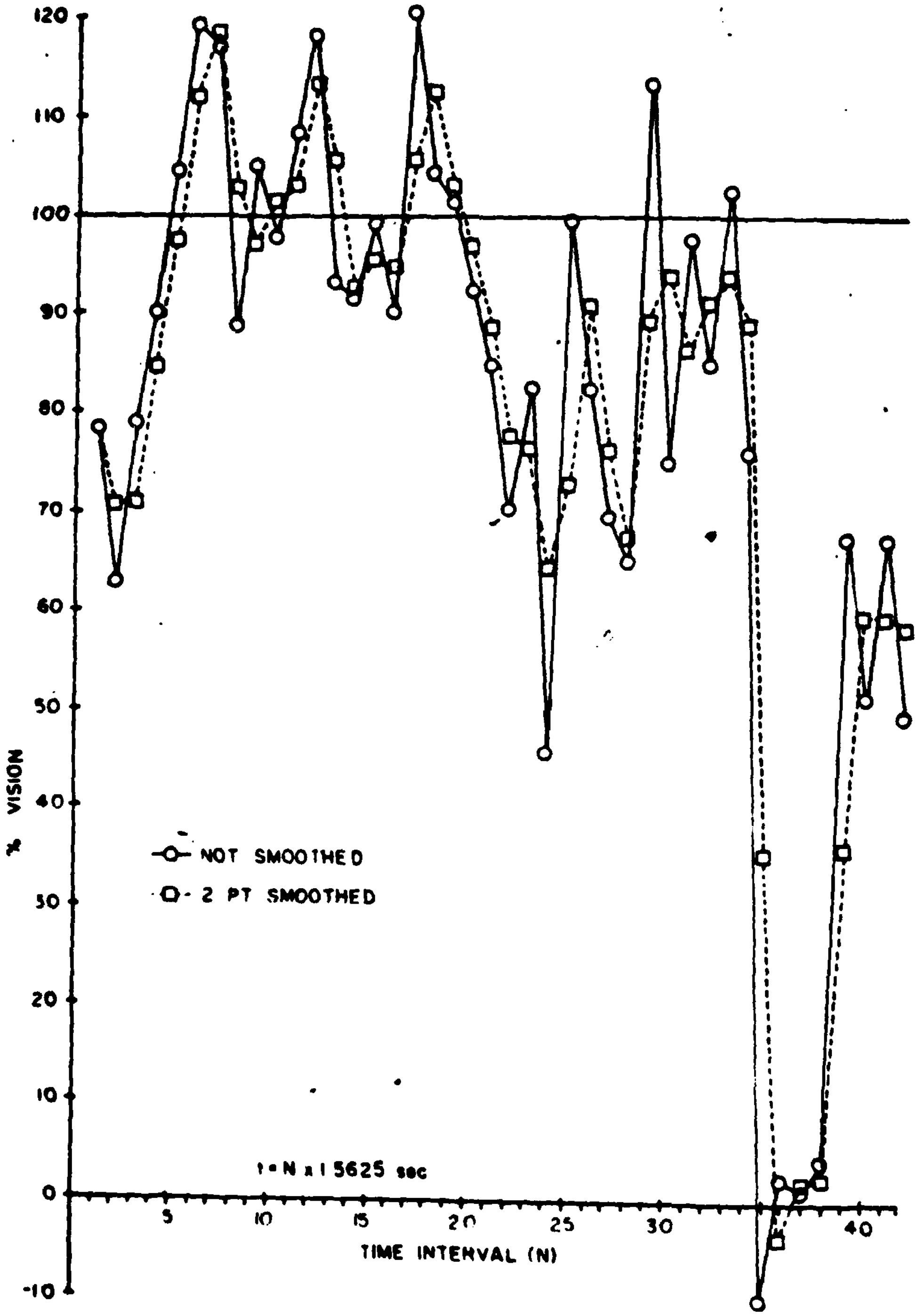

Figure 2 - Specimen Real-Time Run For Subject with Low Predicted and Obtained Standard Deviation (See Table I)

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