CONTRAST SENSITIVITY TESTING

Senior Research Project

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INTRODUCTION

The fact that visual acuity declines as one moves progressively away from the fovea into the periphery has been well established.[1] The basis of this gradient has been attributed to neural factors such as increase in receptor field size and decline in cone density.

Previous studies have shown that contrast sensitivity decreases with increasing retinal eccentricity.[2] This phenomenon has been attributed to the same factors as those determining visual acuity.

Visual acuity and contrast sensitivity function are two methods of examining the integrity of the human visual system. Snellen visual acuity has been the clinician's standard for a long time. But it tests only a small portion of the visual system. Contrast sensitivity function provides an additional source of information.

In this study, I examined the relationship between contrast sensitivity and retinal eccentricity in order to determine how changing spatial frequency and temporal frequency would affect contrast sensitivity function. I also hoped to establish normal values for the equipment and testing conditions at Ferris State College. These values of ranges and averages for normal subjects will yield standard values to be used to analyze test results of clinic patients. Clinical uses for contrast sensitivity testing include:

(1) to screen glaucoma suspects
(2) to determine preferred eye in low vision patients
(3) early detection of multiple sclerosis

(4) detection of early macular disturbances

(5) screening for beneficial cataract surgery

(6) contact lens evaluation

(7) amblyopia- functional verses organic.[3]

METHODS AND APPARATUS

Vertical sinusoidal gratings generated on an Optronix Series 200 Vision Tester were used as the visual stimuli in this experiment. Subjects viewed the screen which subtended a $.91^{o}$ x 1.15^{o} field at a testing distance of three meters. All subjects were tested binocularly and wore their habitual correction for refractive error if any was present. No compensation was made for radial astigmatism induced when patients looked off-axis. Milldot, Johnson, Lamont, and Leibowitz (1975) showed that off axis refractive error induced by oblique ray astigmatism does not effect peripheral visual acuity at retinal eccentricities from 0^{o}-60^{o}.[4]

Each subject is presented a series of gratings varying in spatial frequency from .5 cycles/degree to 22.4 cycles/degree, and with varying temporal frequencies of .5 degree/second, 1.0 degree/second, and 2.0 degree/second, at retinal eccentricities of 0^{o}, 5^{o}, 10^{o}, 20^{o}, and 25^{o}. The 25^{o} eccentricity value testing was discontinued due to the fact that it too closely approximates the 20^{o} retinal eccentricity curve. The testing sequence is controlled by the computer. The contrast of the sinusoidal grating could be varied while maintaining a mean luminance over the screen. Contrast was defined as the ratio of the difference between maximum and minimum luminance of $(L_{max} - L_{min})/(L_{max} +$

L_{min}). This can be expressed as a percentage by multiplying the ratio by 100.

The method of adjustments was used as the psychometric procedure. Consecutive gratings were presented at various subthreshold levels. The subject increases contrast to first visibility of the gratings and then pushes a button connected to the computer. Each pattern is presented three consecutive times and then the computer computes an average threshold for that pattern. Between stimuli the subject looks away from the target to prevent afterimage contamination.

Subjects were all college students with best corrected acuity of 20/20 and normal visual fields. A case study on one low vision patient with macular degeneration, OD 10/600, OS 10/80, is also presented for interest.

RESULTS

Tables A, B, C, D, E, and F show the data for the normals while retinal eccentricity was varied. The velocity of the gratings was 1 degree/second. Standard deviation was greatest at the fovea and decreased with increasing retinal eccentricity. Figure 1 shows the curves for the average values obtained. The contrast sensitivity function decreases with increasing retinal eccentricity at all spatial frequencies presented. The maximum peak begins to shift from 3 cycles/degree to 1 cycle/degree at approximately 10°.

In Figure 2 are the curves of the averages of one person's repeated contrast sensitivity testing from tables G, H, I, and J. Standard deviation again is greatest at the fovea and decreases with increasing retinal eccentricity. In both Figure 1 and 2, the decrease is slower for low spatial frequencies verses high spatial frequencies.

When varying the temporal frequency, looking at Figures 3, 4, 5, 6, 7, 8, 9, and 10, the retina was found to be most sensitive to 2 cycles/degree at all eccentricities. At 15° eccentricity, temporal frequency did not affect the contrast sensitivity function. All three frequencies have the same pattern of decreasing sensitivity as spatial frequency varies from 3 cycles/degree. For all three temporal frequencies the fovea had the highest sensitivity and it decreases with increasing eccentricity. At 10° the retina was more sensitive to 1 degree/second which evidences contrary to the belief that the peripheral retina has greater sensitivity to moving targets. The average of one subject's contrast sensitivity testing while varying the temporal frequency gives similar results. The decline in contrast sensitivity for varying temporal frequency was approximately equal at all spatial frequencies for all eccentricities. This finding agrees with existing neurophysiological data. Cell types which are thought to differ in their spatiotemporal tuning characteristics co-exist in approximately constant proportion across the visual field.[5]

A case study of a low vision patient, Figures 11, 12, 13, and 14, shows that contrast sensitivity decreases with increasing retinal eccentricity. At the fovea, varying the temporal frequency appears to have some effect but exactly what this effect is cannot be determined from this single case study. At 5°, the 2 degree/second temporal frequency yields the highest contrast sensitivity function consistent with trend in the normals (Fig. 14).

CONCLUSIONS

In this study the contrast sensitivity function was maximal at the fovea for all spatial frequencies with constant velocity and varying eccentricity. It was proposed that there are many more central than peripheral cells per unit area of retina, either pooling of signals at higher levels of the visual pathway or probability summation could improve the sensitivity of the central retina relative to the periphery.[6]

Varying temporal frequency, contrast sensitivity was found to be maximal with velocity of 2 degree/second at all retinal eccentricities.

The case study of one low vision patient shows some interesting results. Since the patient with macular degeneration is forced to use peripheral retina for fixation, the question arises as to whether there are any changes that occur within the peripheral retina following continued use. Does the sensitivity increase or does the patient learn to use signals that are ignored when central vision is intact? In this case study, there is no increase in contrast sensitivity on peripheral retina as compared to normals. Overall the contrast sensitivity curve is depressed more than would be predicted on the basis of eccentricity alone. This may be due to the inability of the patient to fixate upon and localize a point. More extensive testing of low vision patients should be carried out in this area.

The data definitely demonstrates, however, that the sine wave patterns are preferentially detected at the fovea regardless of coarseness or drift velocity.

ea

Spat freq cycles/deg	Cook	Fred	Gentile	Sleezak	Hafner	DiMartino	Ave	STD Deviation
3.0	656.9	229.1	876.0	780.7	378.0	310.8	538.6	268.3
11.4	83.2	43.2	43.9	75.4	30.0	61.7	56.23	20.66
0.5	212.6	84.1	66.1	115.5	71.2	31.4	96.81	62.92
6.0	340.8	184.1	344.7	416.9	208.9	290.1	297.6	88.46
22.8	29.2	9.9	26.0	20.7	11.2	6.0	17.17	2.45
1.0	512.9	96.9	186.2	329.2	172.8	147.9	240.98	154.14

Table A.

50

3.0	226.5	127.4	380.2	158.5	192.8	229.1	219.08	88.18
11.4	23.3	11.2	24.4	5.3	14.9	6.3	14.23	8.22
0.5	102.9	46.0	66.1	33.3	51.3	34.1	55.67	26.14
6.0	98.3	89.1	89.6	73.3	109.6	84.6	90.75	12.32
22.8	4.7	3.6	3.3	2.2	—	2.0	3.16	1.10
1.0	117.5	85.6	222.6	89.1	216.3	86.1	136.2	65.6

Table B

100

3.0	109.6	63.8	148.8	66.8	82.2	65.3	89.42	33.87
11.4	4.0	7.1	3.5	2.0	3.4	2.0	3.67	1.87
0.5	(42.4) 42.4	32.2	42.4	26.6	25.9	14.2	30.62	10.85
6.0	62.0	34.9	43.2	14.0	41.9	7.0	33.83	2.45
22.8	5.0	can't see	can't see	can't see	can't see	can't see	2.5	1.22
1.0	123.0	37.8	125.2	62.0	72.4	61.7	80.35	35.75

Table C

Spatial freq cycles/deg	Cook	Felici	Gentile	Slezak	Hofner	DiMartino	Ave	STD Deviation
3.0	39.8	40.5	48.4	21.4	40.3	7.3	32.95	±2.45
11.4	2.7	2.0	2.0	—	—	—	2.23	±.40
0.5	15.9	15.3	32.9	18.2	18.5	6.3	36.0	±8.61
6.0	13.5	3.2	9.4	2.0	2.8	2.0	5.48	±4.82
22.8	2.8	can't see 2.0	can't see 2.0	can't see 2.0	can't see 2.0	can't see 2.0	2.13 ~~.467~~	.33 ~~±1.14~~
1.0	52.5	44.9	59.2	39.6	21.0	19.3	39.42	±16.35

15°

Table D

3.0	38.2	59.2	34.1	—	19.4	7.4	31.66	19.66
11.4	3.0	2.3	2.0	—	—	—	2.43	.51
0.5	43.7	15.8	20.2	—	10.0	7.9	19.52	14.36
6.0	5.9	5.0	3.3	—	3.5	2.1	3.96	1.50
22.8	2.3	—	—	—	—	—	2.3	0
1.0	83.7	39.6	45.2	—	35.1	28.9	46.5	21.64

20°

Table E

			Ave	STD Deviation
3.0	40.5	56.2	48.35	11.10
11.4	2.6	2.0	2.3	.424
0.5	18.2	11.7	14.95	4.60
6.0	2.0	3.6	2.8	1.13
22.8	2.0	—	2.0	0
1.0	31.1	30.9	31.0	.14

25°

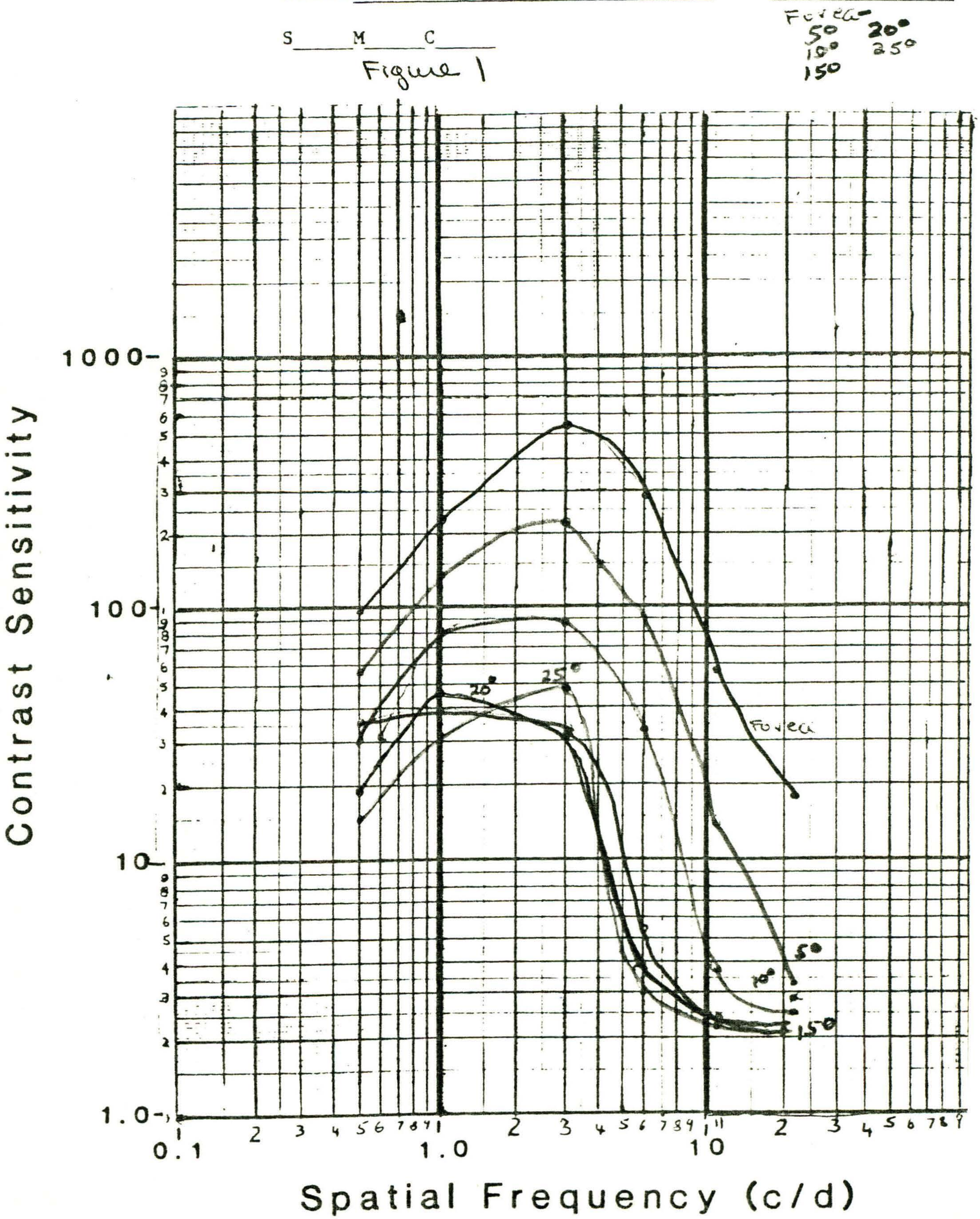
Table F

Patient Average curves of normal Age

Method Date

S M C

Figure 1



cycles/deg	7-27-83	5-2-84	5-3-84	Ave	STD Deviation
3.0	656.9	475.0	611.9	581.27	94.74
11.4	83.2	98.5	14.0	65.23	45.02
0.5	212.6	127.8	95.5	145.3	60.48
6.0	340.8	584.3	407.4	444.17	125.84
22.8	29.2	didn't	test.	29.2	0.0
1.0	512.9	265.4	300.0	359.43	134.03

Fovea

Average of One Person

C. Cook

Table G.

5°

3.0	226.5	386.1	407.4	340.0	98.87
11.4	23.3	22.0	25.3	23.53	1.66
0.5	102.9	104.7	103.9	103.83	0.90
6.0	98.3	230.9	236.2	188.47	13.73
22.8	4.7	didn't	test	4.7	0.0
1.0	117.5	299.7	250.0	222.4	94.18

Table H.

10°

3.0	109.6	243.6	239.0	197.4	76.07
11.4	4.0	3.85	4.3	4.05	0.23
0.5	42.7	77.0	44.3	54.67	19.36
6.0	62.0	80.0	85.1	75.7	12.14
22.8	5.0	didn't	test	5.0	0.0
1.0	123.0	286.2	130.0	179.73	92.27

Table I.

Spatial Freq	7-27-83	5-2-84	5-3-84	Ave.	STD Deviation
3.0	39.8	81.9	77.0	66.23	23.02
11.4	2.7	2.0	2.5	2.4	0.36
0.5	15.9	36.3	25.1	25.77	10.22
6.0	13.5	13.3	10.2	12.33	1.85
22.8	2.8	didn't	test	2.8	0.0
1.0	52.5	88.0	55.0	65.17	19.81

15°

Table J

Average of
One Person
C. Cook

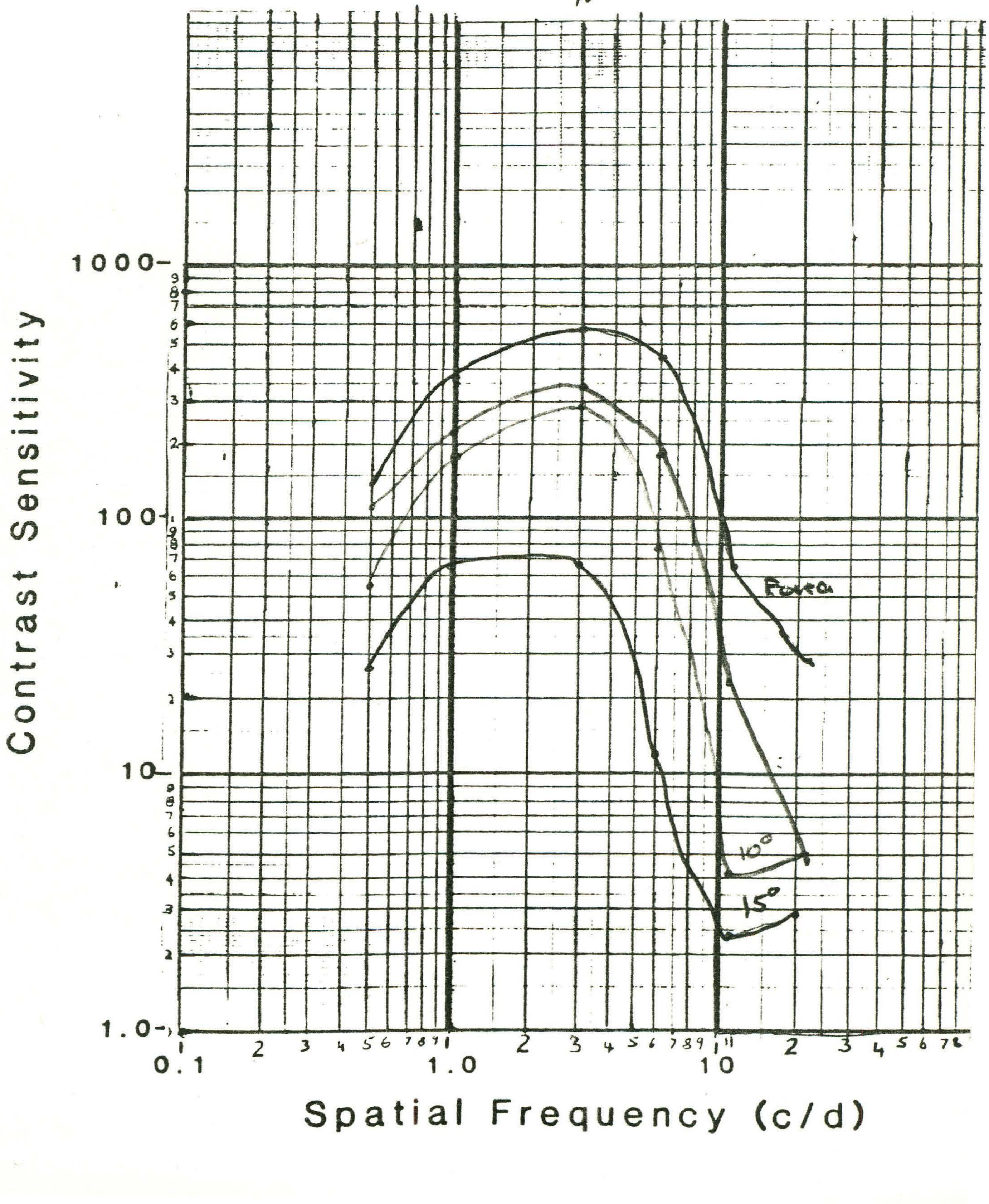
Patient Average of One Person Age Repeated Time

Method Constant vel. - 1°/sec Date

S_____ M_____ C_____

Fovea
5°
10°
15°

Figure 2



Fovea

Spat. freq cycles/deg	deg/sec	Stone	Felici	Cupal	Paveglio	Mollan	Ave	STD Deviat
0.5	0.5	80.4	74.6	87.62	42.0	38.6	64.64	22.73
0.5	1.0	74.1	66.1	97.76	42.0	29.7	61.93	26.87
0.5	2.0	156.7	130.3	221.16	74.1	64.6	129.37	64.08
3.0	0.5	106	236.7	535.34	286.2	130.8	259.0	171.35
3.0	1.0	465.1	348.7	644.7	420.1	281.8	432.08	137.82
3.0	2.0	546.4	382.4	809.92	392.0	223.9	470.92	221.19
11.4	0.5	124.5	68.4	167.74	85.8	46.1	98.51	48.17
11.4	1.0	98.6	35.1	112.66	87.8	36.6	74.15	36.06
11.4	2.0	53.7	19.3	59.5	43.7	26.9	40.62	17.17

Table K

5°

Spatial Freq cycles/deg	Temp Freq deg/sec	Stone	Felici	Cupal	Paveglio	Mollan	Ave	STD Dev.
0.5	0.5	79.4	37.6	59.98	27.3	18.9	44.64	24.78
0.5	1.0	62.4	38.7	96.74	46.8	25.3	53.99	27.42
0.5	2.0	110.3	56.9	116.44	50.5	40.1	74.85	35.74
3.0	0.5	207.7	119.5	267.84	124.9	80.0	159.99	76.12
3.0	1.0	124.5	193.9	333.92	186.2	81.9	184.08	95.58
3.0	2.0	227.8	200.7	309.26	124.0	139.1	200.17	74.49
11.4	0.5	17.9	5.8	16.06	6.0	5.1	10.17	6.26
11.4	1.0	5.6	6.8	14.92	29.3	16.5	14.62	9.51
11.4	2.0	6.0	4.4	8.98	26.9	6.1	10.48	9.33

Table L.

10°

spatial freq cycles/deg	Temp freq deg/sec	Stone	Felici	Cupal	Laveglio	Mollan	Ave	STD Deviation.
0.5	0.5	57.2	20.9	50.68	21.4	8.5	31.74	21.04
0.5	1.0	47.6	26.3	52.48	27.8	14.8	33.80	15.75
0.5	2.0	71.6	37.6	96.88	25.3	16.9	49.66	33.63
3.0	0.5	128.0	33.5	131.12	52.0	31.6	75.24	50.23
3.0	1.0	142.9	115.5	155.22	97.0	47.5	111.62	42.48
3.0	2.0	134.1	52.2	155.78	55.4	47.5	89.0	51.72
11.4	0.5	4.3	2.3	2.38	10.1	4.7	4.76	3.18
11.4	1.0	2.0	5.0	3.42	18.9	3.2	6.50	7.0
11.4	2.0	2.2	2.3	2.0	4.6	2.7	2.76	1.06

table M.

15°

spatial Freq cy/deg	temp freq. deg/sec	Felici	Ave Cupal	Ave	STD Dev.
0.5	0.5	14.4	31.25	22.83	11.91
0.5	1.0	10.0	34.45	22.23	17.3
0.5	2.0	25.4	54.7	40.05	20.72
3.0	0.5	19.0	52.43	35.72	23.64
3.0	1.0	14.9	60.4	37.65	32.17
3.0	2.0	17.3	53.23	35.27	25.41
11.4	0.5	2.1	2.0	2.05	.07
11.4	1.0	2.2	2.0	2.10	.14
11.4	2.0	2.4	2.0	2.2	.28

Table N