AD-A209 915

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFOSR-TR- 89-0964
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Suprathreshold Contrast Sensitivity Vision Test Chart: Annual Progress Report

5. TYPE OF REPORT & PERIOD COVERED
Annual Report
15Jun89

6. PERFORMING ORG. REPORT NUMBER
N/A

7. AUTHOR(s)
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8. CONTRACT OR GRANT NUMBER(s)
F49620-88-C-0083

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Vision Sciences REsearch Corp.
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10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
N/A

11. CONTROLLING OFFICE NAME AND ADDRESS
AFOSR/NL
Directorate of Life Sciences
Building 410, Bolling AFB, DC 20332-6448

12. REPORT DATE
15Jun89

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)
Same as 11

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

SDTIC ELECTE JUL 11 1989 H

18. SUPPLEMENTARY NOTES
None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Suprathreshold Contrast Sensitivity Test Chart
Vision Test Chart
Suprathreshold Vision, Visual Perception, (AUK)
Contrast Sensitivity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This research period concentrated on the further design and development of a suprathreshold contrast sensitivity test chart with which to create a family of contrast matching functions. Three different chart configurations were developed and tested for suitability. Preliminary test-retest, subject instruction, and chart configuration experiments were completed. The results show good test-retest reliability. Individual

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89 7 10 091 14 JUN 1989

19. Cont.

Contrast Matching
Vision Performance

20. Cont.

differences in contrast matching using previously developed suprathreshold contrast sensitivity charts are also evident in these new data. Different subject instructions having the subjects either make the contrast judgments using a global or local contrast analysis resulted in similar results. The spatial positioning of grating test patches appears to bias the contrast matches and warrants further investigation. Future research will finalize the suprathreshold contrast sensitivity chart configuration and compare the resulting contrast matching data to that obtained using a computer-video system and continuous contrast test increments. The final chart will be used for large population, clinical and performance testing.

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Suprathreshold Contrast Sensitivity Vision Test Chart:

Annual Progress Report

15Jun89

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A. Objectives

1. Optimization of the suprathreshold chart design.
2. Determine relationship between suprathreshold contrast sensitivity and visual performance and for the detection and treatment of eye disease.
3. Determine large population suprathreshold contrast sensitivity norms.
4. Compare suprathreshold contrast sensitivity chart results to results obtained with computer video systems.
5. Present and publish results.

B. Status of Research

1. Optimization of the suprathreshold chart design.

Phase I research showed that a family of suprathreshold contrast sensitivity curves using sine-wave grating patches having discrete contrast levels are similar to those obtained using more complex computer-video systems. Using the contrast matching technique, the test and standard contrast levels were chosen from the same contrast samples. Although the same contrast samples were at one time during the test also a test contrast, the results showed there were significant individual differences in contrast matches. The next series of experiments were designed to investigate the sensitivity of contrast matches by having different discrete contrast levels between the test and standard gratings, different test frequencies, test patch placement, and test reliability and stability.

Suprathreshold Chart Development

This research period concentrated on finalizing the development of the suprathreshold contrast sensitivity chart system. Three different chart designs were developed and tested to determine their psychophysical and production capabilities. Phase I research showed that linear grating patch arrangements provided contrast matching data similar to that obtained by previous researchers using computer controlled video systems.(1) However, those data could be biased by the spatial arrangement of the grating patches in two ways. First, the standard gratings were always positioned to the left of the test gratings. Second, the contrast of the test gratings always went from high to low from left to right. In order to determine if the position of the standard grating patch biased the contrast match, different spatial arrangement of the standard and test grating patches were created. The standard grating patches were placed in the middle of a circular arrangement of test grating patches. The contrast values of the test grating

patches were randomized. An example of the spatial arrangement of the grating patches are shown in Fig. 1. The spatial frequencies of the test grating patches were 1.5, 3, 6, 12, and 18 cycles per degree (cpd). The contrast of the test and standard grating patches ranged from approximately 0.003 to 0.019. In general, the subject's task was to match each test grating patch frequency to the corresponding standard grating patch for each contrast level. The subjects' ages ranged from 22 to 47 and they were volunteers. They viewed the test charts at a distance of 18 in. with best correction. The subjects were given written instructions on how to make the contrast matches (see Appendix 1a, b).

Experiment 1: Circular, ramdomized test chart with global contrast match instructions.

The suprathreshold test chart had standard and test gratings as described above: standard grating patch surrounded by a circle of test grating patches having random contrast. The spatial frequency of the standard grating patch was 6 cpd having contrast levels of 0.019, 0.014, 0.011, 0.008, 0.005, 0.004, and 0.003. The five circles of test grating patches had spatial frequencies of 1.5, 3, 6, 12, and 18 cpd. The experimenter inserted the seven standard contrast grating patches into the center of each of the five test grating patch circles one at a time. The subjects were instructed to find the grating patch in the outer circle that matched the contrast of the center grating patch using a global contrast match (Appendix 1a). Specifically, the subjects were old to "tell which patch has a contrast level most like the reference patch".

Results and Discussion

The median contrast matching curves for 8 subjects is shown in Figure 2. In general, the family of contrast matching curves are similar to those obtained from computer-controlled video systems and the row-and-column contrast matching chart used in Phase I.

Experiment 2: Circular, randomized test chart with local contrast match instructions.

This experiment was designed to begin an investigation of the effect of the subject instructions on the contrast matching task. Previous researchers have shown that subjects can perform a contrast match in one of two general ways that can create different results (2). Contrast matching judgments based on the overall appearance of the gratings can be different than contrast matching judgments based on local contrast of the grating bars. This

experiment had 6 of the subjects of Experiment 1 perform the contrast match using the same chart as in Experiment 1 but with instructions to "compare the patches by comparing the dark and light bars from the surrounding patches with the dark and light bars from the standard patch". (Appendix 1b).

Results and Discussion

The median matching contrast levels for 6 subjects is shown in Figure 3. In general, the family of contrast matching curves are similar to those obtained using the more global contrast judgments as instructed to the subjects in Experiment 1. The medians of these data were compared to the median data of Experiment 1 using the paired t test. The statistical results were -0.423, not significant at the 95% confidence level (Table 1). These results suggest that the subject instructions requiring either a global or local contrast match produce similar contrast matching data using these kinds of suprathreshold test charts.

Here, as was also found in the Phase I research, significant individual differences were found. For example, the family of contrast matching functions of two subjects shown in Figures 4a and b and 5a and b are visibly different. The retest of subject GK (Figures 4a and b) was not significant at the 95% confidence level using a paired t test (Table 2). However, similar statistics on the data of subject PH (Figures 5a and b) reveals non-significant test-retest (Table 2). Further test-retest studies will be carried out when the final suprathreshold chart is chosen.

Experiment 3: Circular, randomized test chart (8 standard contrast levels).

The previous results showed that the subject instructions appear not important to the contrast matching results using these test charts. It was decided to use the global comparison instructions for future experiments because of its relative ease of subject understanding and compliance. These next experiments started an investigation as to how the number of standard contrast levels might effect the contrast match. The new test chart configurations were developed that used the previous circular, randomized test chart design but now included 8 instead of 7 standard contrast levels (Figure 1). The 8th contrast level was a blank of uniform luminance. The only difference between the two charts was the different random order to the test grating patches.

Results and Discussion

The median contrast matching curves for 10 subjects is shown in Figure 6a and 6b for the two different test charts. Figure 6c shows the median contrast matching curves for both test charts. In general, these family of contrast matching curves are similar to those previously obtained by computer-controlled video systems and the photographic charts. Examination by eye suggests that the curves are more smooth than those obtained from the previous test charts, evidently due to the addition of the blank test patch. Presumably, the blank test patch allows a more "stable" reference for the low contrast matches.

The medians of the family of contrast matching curves obtained from test charts B1 and B2 were compared to each other using an analysis of variance. The results in Table 3 show spatial frequency and test grating patch value as highly significant, as expected. The difference between charts B1 and B2 was highly significant. In addition, the between subject differences also accounted for a significant variation in this test. Why the results between the two charts differ from each other is an interesting question. Presumably the different random ordering of the test grating patches is creating an "adjacency effect" that is effecting the contrast match perhaps operating similarly to simultaneous brightness contrast phenomenon. This result needs further investigation before a final grating test patch configuration can be used for the remainder of these experiments.

Experiment 4: Circular, randomized test chart (8 contrast levels). New subjects.

In order to help rule out the effect of subjects as being the cause of the different contrast matching results between two different randomized contrast level charts of Experiment 3, 6 new subjects were tested whose ages ranged from 6 to 47 years.

Results and Discussion

The median contrast matching curves for the 6 new subjects for charts B1 and B2 are shown in Figure 7. In general, the family of contrast matching curves are similar to those obtained previously. The median data of each chart configuration were compared to the median data of Experiment 4 using an analysis of variance using the same model as in Experiment 3 (Table 4). Again, spatial frequency, test grating patch value and the difference between charts B1 and B2 were highly significant. The between subject difference was not significant. These statistics suggest that each

chart produced similar results with both subject populations.

Summary

See Abstract on DD Form 1473 cover sheet.

2. Determine the relationship between suprathreshold contrast sensitivity and visual performance and for the detection and treatment of eye disease.

   Awaiting final suprathreshold chart configuration of 1.

3. Determine large population suprathreshold contrast sensitivity norms.

   Awaiting final suprathreshold chart configuration of 1.

4. Compare suprathreshold contrast sensitivity chart results to results obtained with computer video systems.

   A computer-video system (VR1000 Grating Generator by Millipede Electronics Graphics) was purchased and installed in an IBM-XT computer to create sine-wave gratings on a split screen video monitor for contrast matching experiments and grating patch stimulus charts. This sytem is ready for calibration and psychophysical test programming.

5. Present and publish results.

   The first scientific presentation of this research was at the Aerospace Medical Association Annual Meeting on 8 May 89 in Washington, DC. The Abstract is in Appendix 2.

C. Publications.

No publications at this time.

D. List of professional personnel associated with the research effort.

Arthur P. Ginsburg, PhD, biophysics, 1980, thesis title: Visual Information Processing Based on Spatial Filters Constrained by Biological Data

Greg F. Keep, BS, Psychology, 1986

E. Interactions

Paper presented as ASMA (see 5 above).

F. New discoveries, inventions or patent disclosures.

The effect of spatial position of grating test patches contrast matching of sine-wave gratings found in these initial studies does not appear to be described earlier and warrants further investigation.

G. The reasons for the slow progress of this research was listed in a 2 May 89 letter to Dr. Tangney requesting a six-month no-cost extension: relocation of the principle investigator and lab, non-transfer of a key researcher, unanticipated research results and slow SBIR contract transfer. These problems are now under control with the final problem, contrast transfer, nearing completion. There must be a better way to expedite contract transfers... five months is unacceptable. The search for a post-doc and others to assist this research effort had already begun and accelerated progress from this time forward is anticipated. The six-month extension is anticipated to be sufficient to successfully perform the research goals of this project.

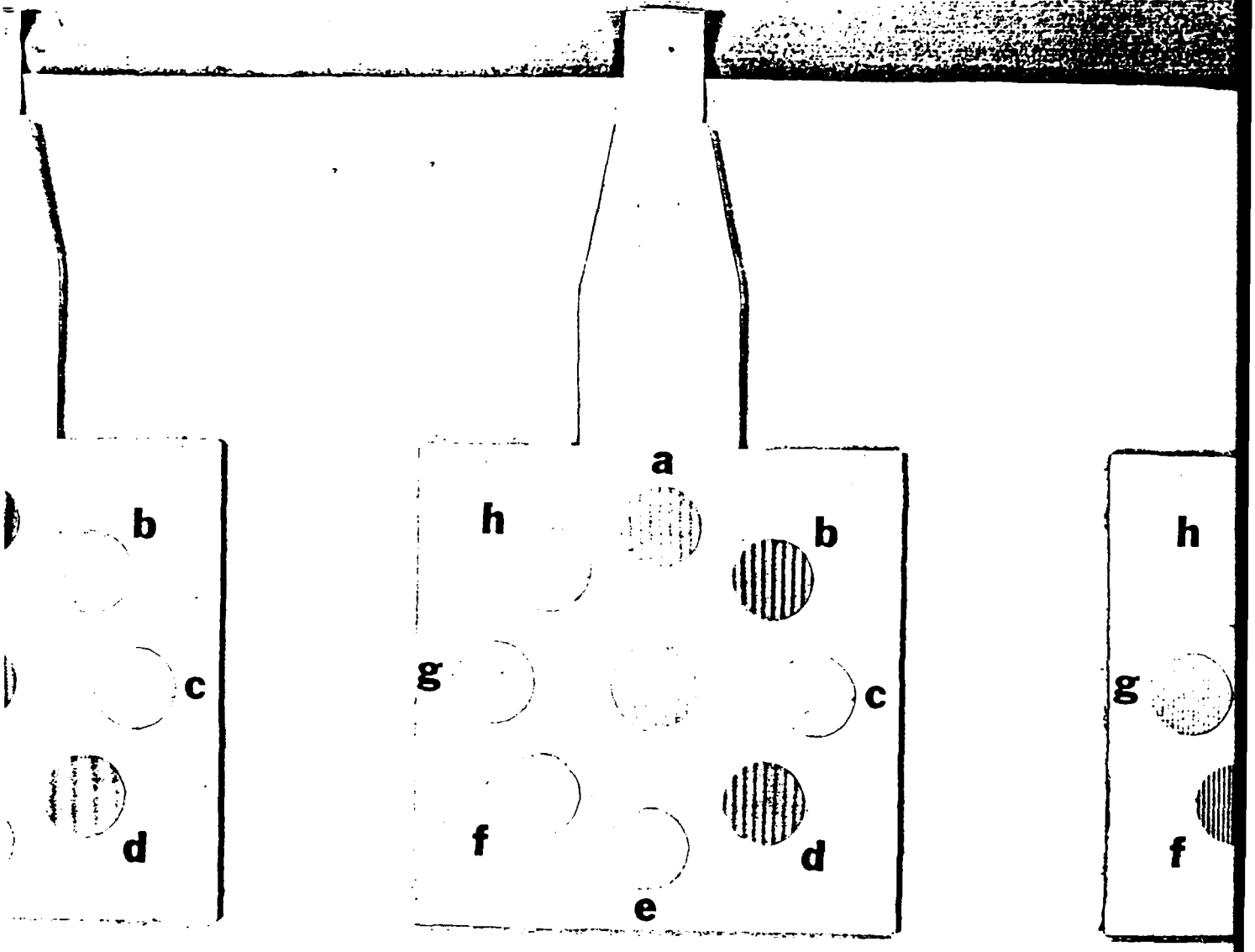

FIGURE 1

Sample Grating Patches from the Suprathreshold Contrast Chart. The best contrast match is made between the outer test grating patches (a - h) and center standard grating patch.

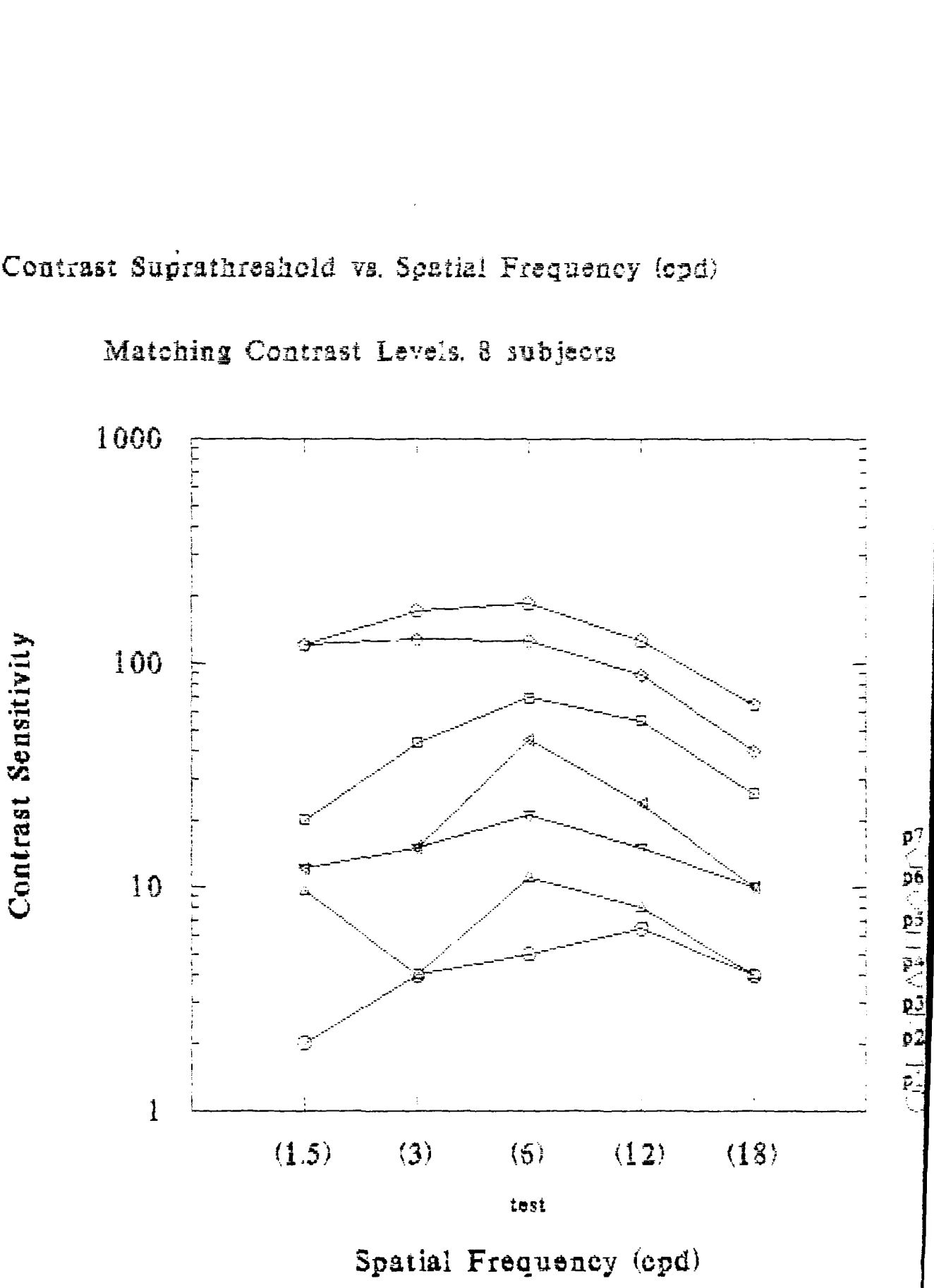
Contrast Suprathreshold vs. Spatial Frequency (cpd)
Matching Contrast Levels, 8 subjects
1000
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p7
p6
p5
p4
p3
p2
p1

FIGURE 2

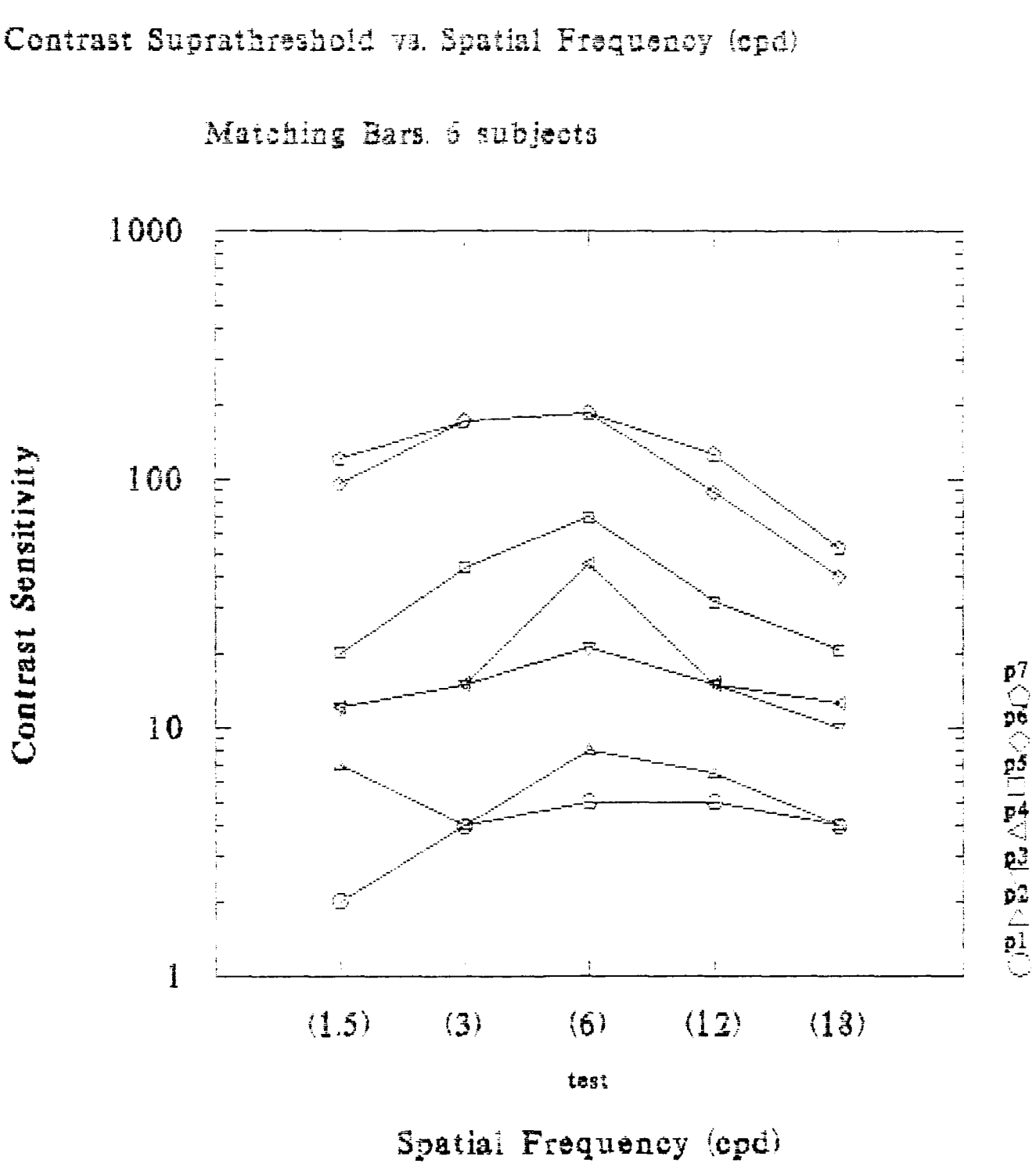
Contrast Suprathreshold vs. Spatial Frequency (cpd)
Matching Bars. 6 subjects
1000
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p7
p6
p5
p4
p2
p1

FIGURE 3

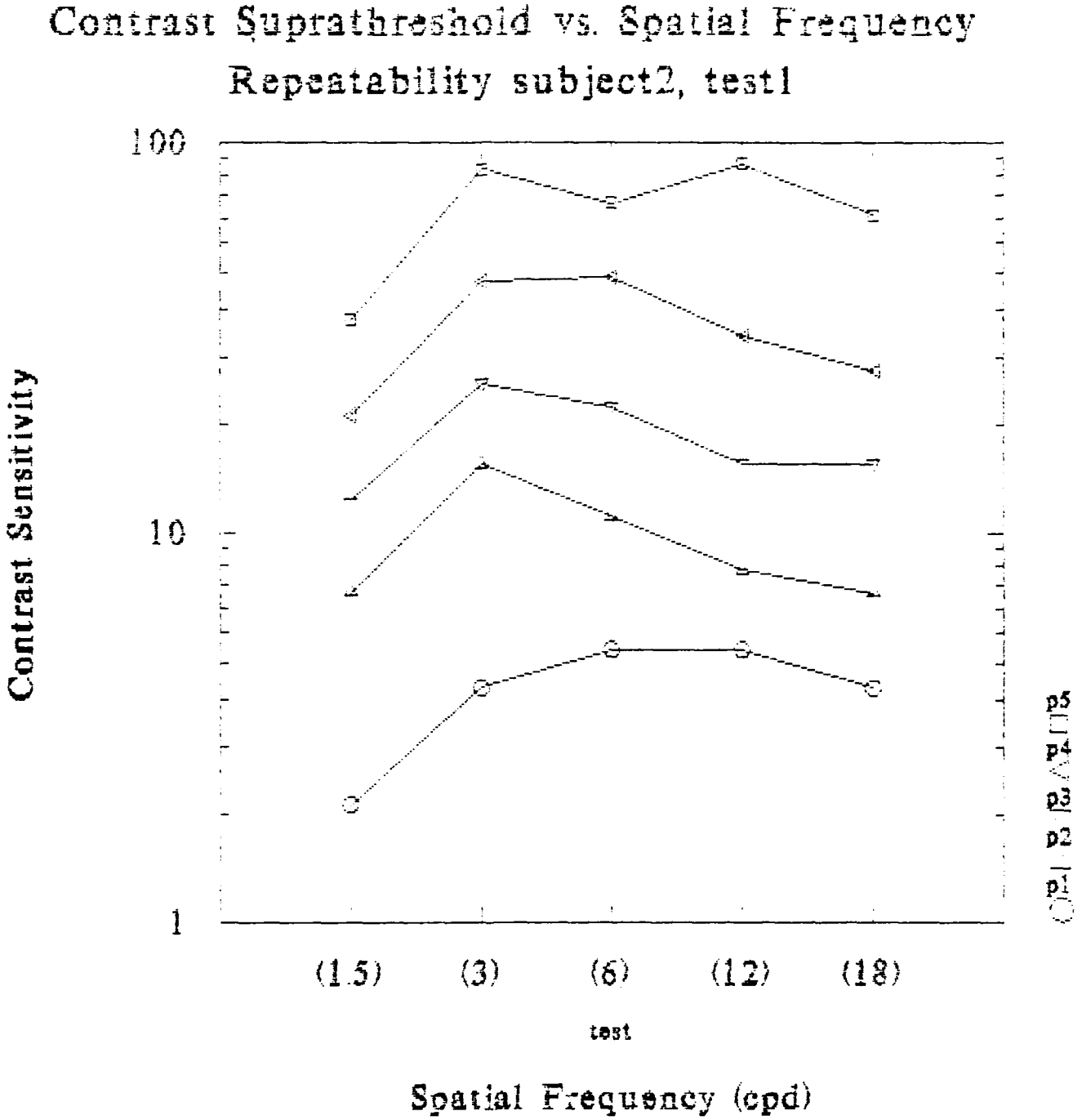
Contrast Suprathreshold vs. Spatial Frequency
Repeatability subject2, test1
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p5
p4
p3
p2
p1

FIGURE 4a

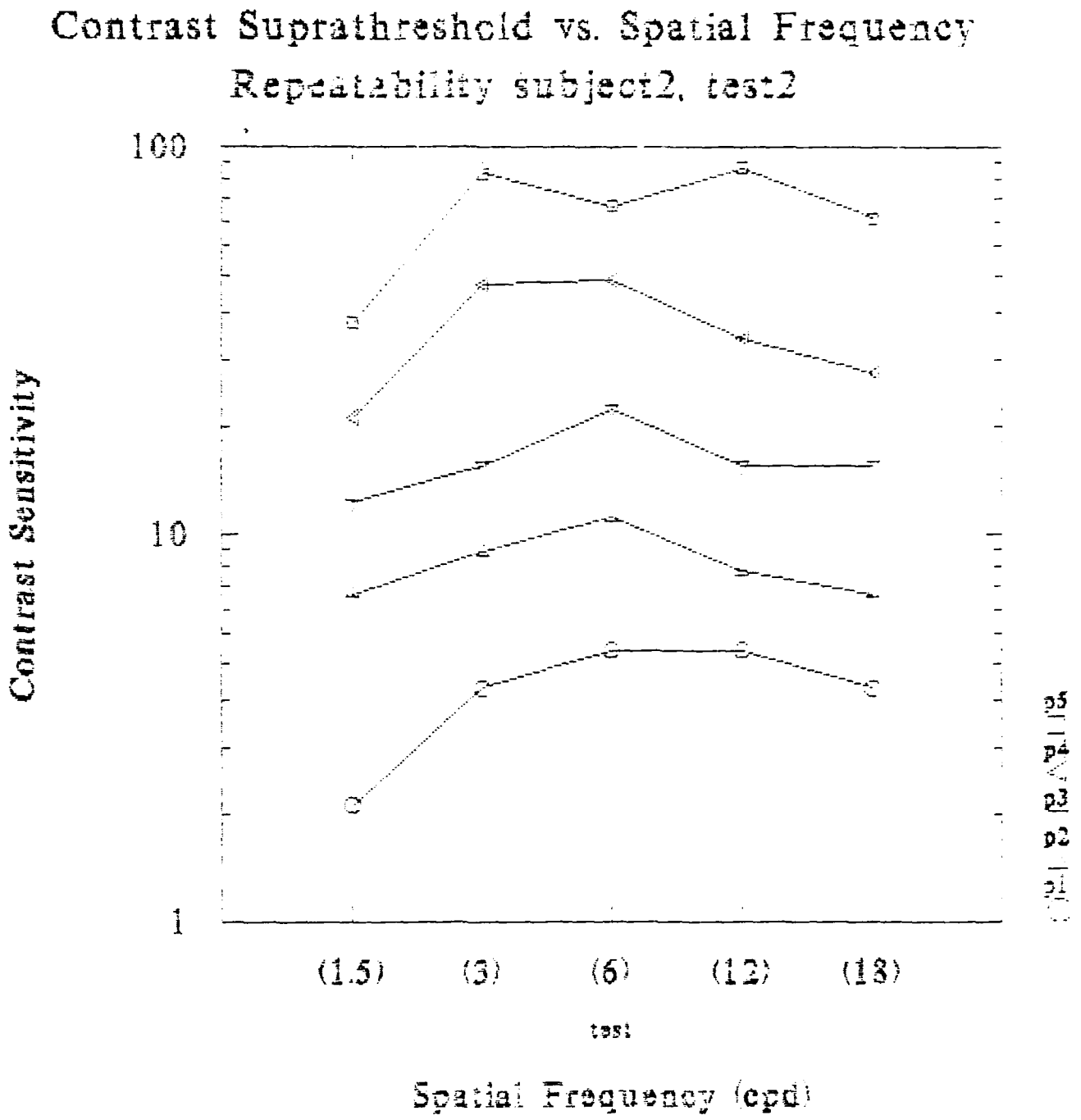
Contrast Suprathreshold vs. Spatial Frequency
Repeatability subject2, test2
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p5
p4
p3
p2
p1

FIGURE 4b

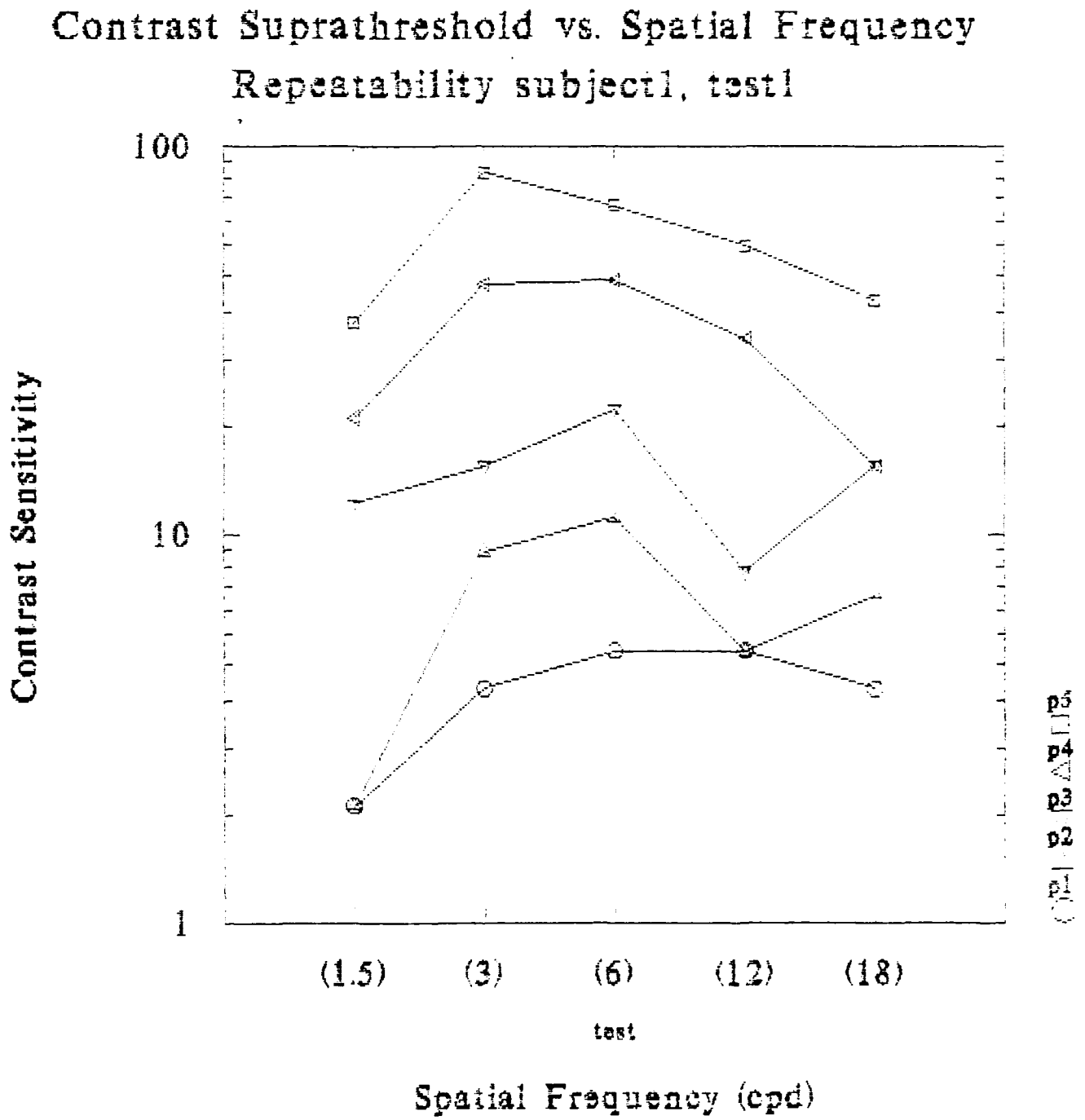
Contrast Suprathreshold vs. Spatial Frequency
Repeatability subject1, test1
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p5
p4
p3
p2
p1

FIGURE 5a

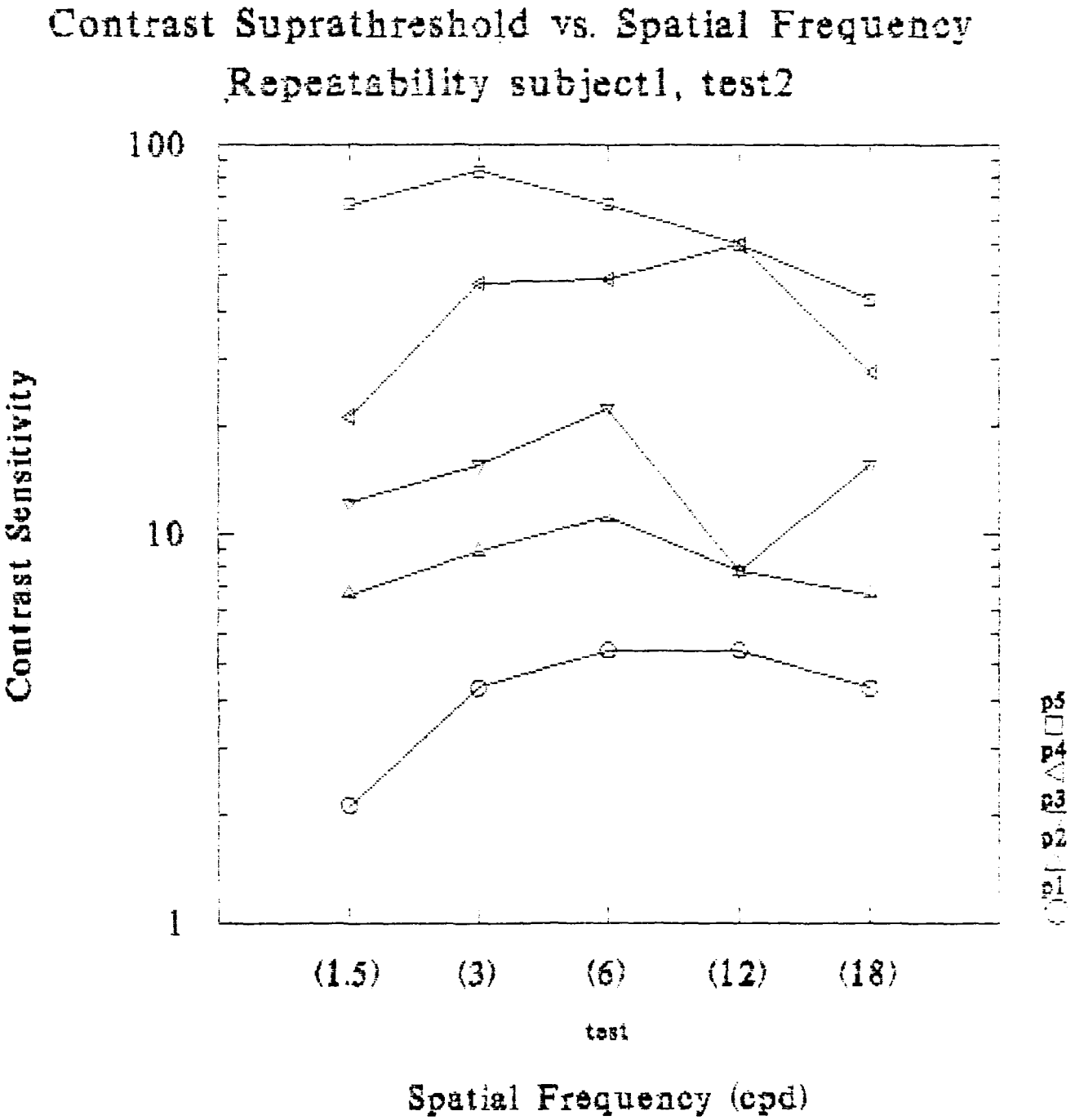
Contrast Suprathreshold vs. Spatial Frequency
Repeatability subject1, test2
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p5
p4
p3
p2
p1

FIGURE 5b

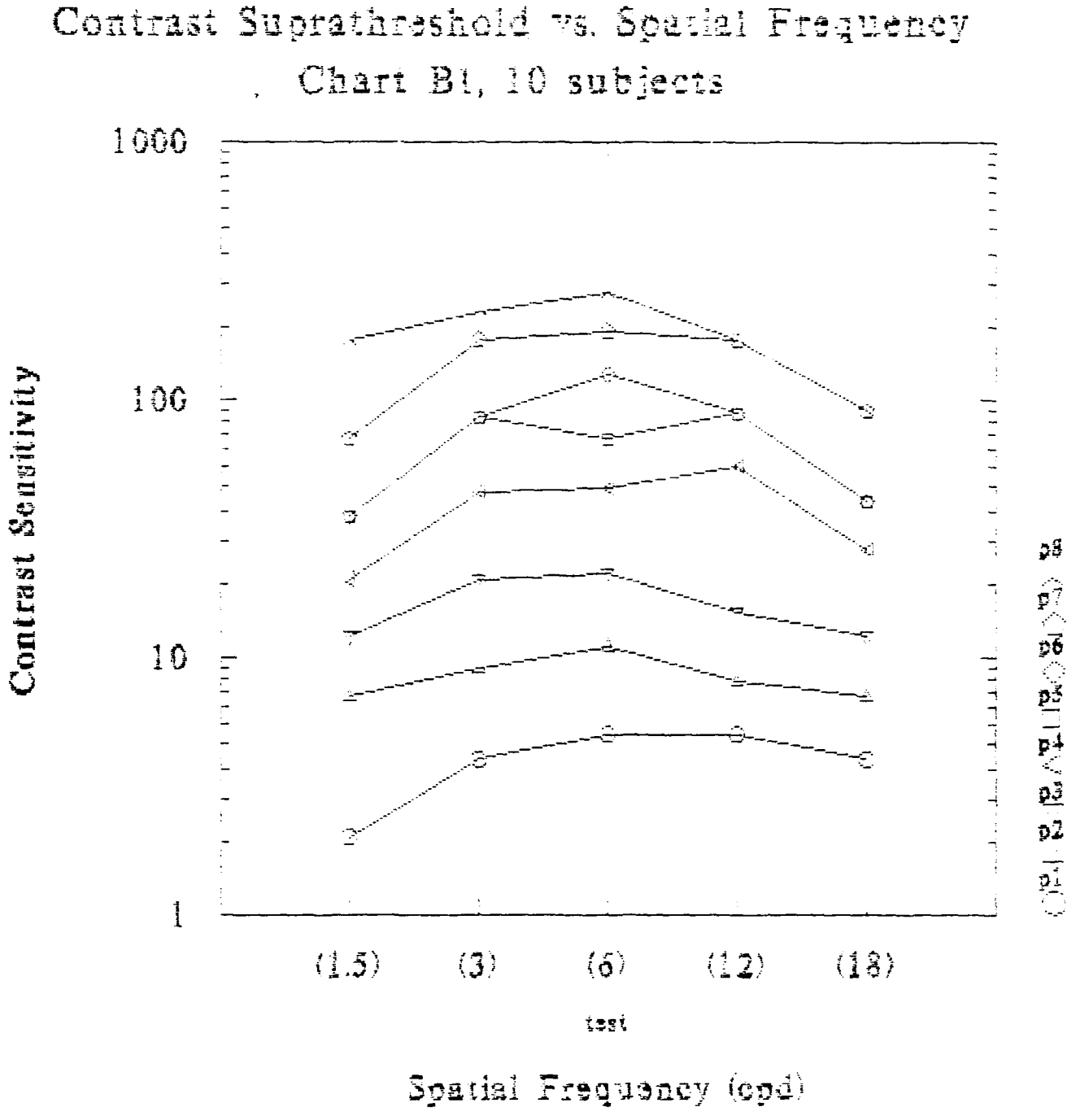
Contrast Suprathreshold vs. Spatial Frequency
Chart B1, 10 subjects
1000
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p8
p7
p6
p5
p4
p3
p2
p1

FIGURE 6a

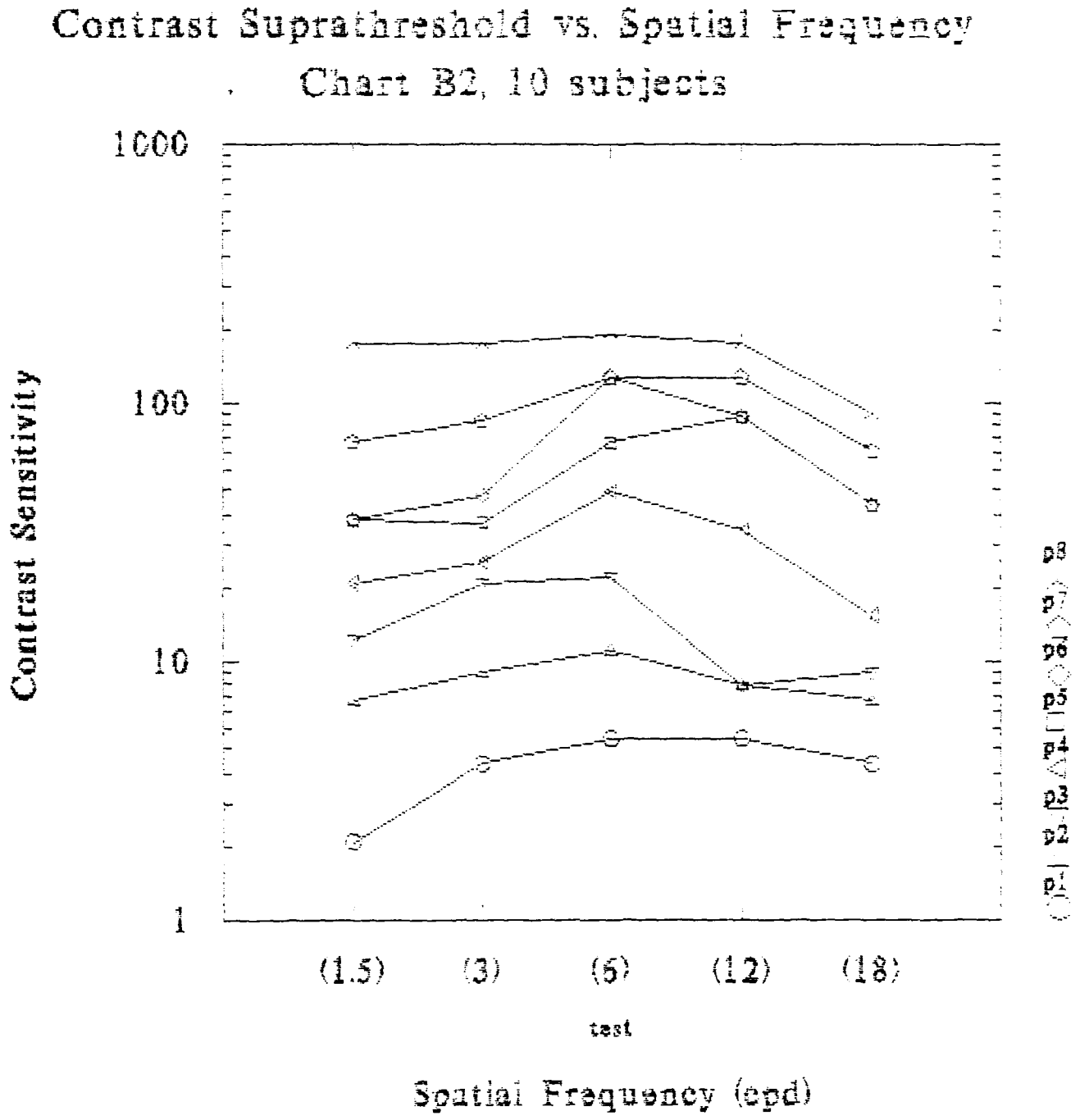
Contrast Suprathreshold vs. Spatial Frequency
Chart B2, 10 subjects
1000
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p8
p7
p6
p5
p4
p3
p2
p1

FIGURE 6b

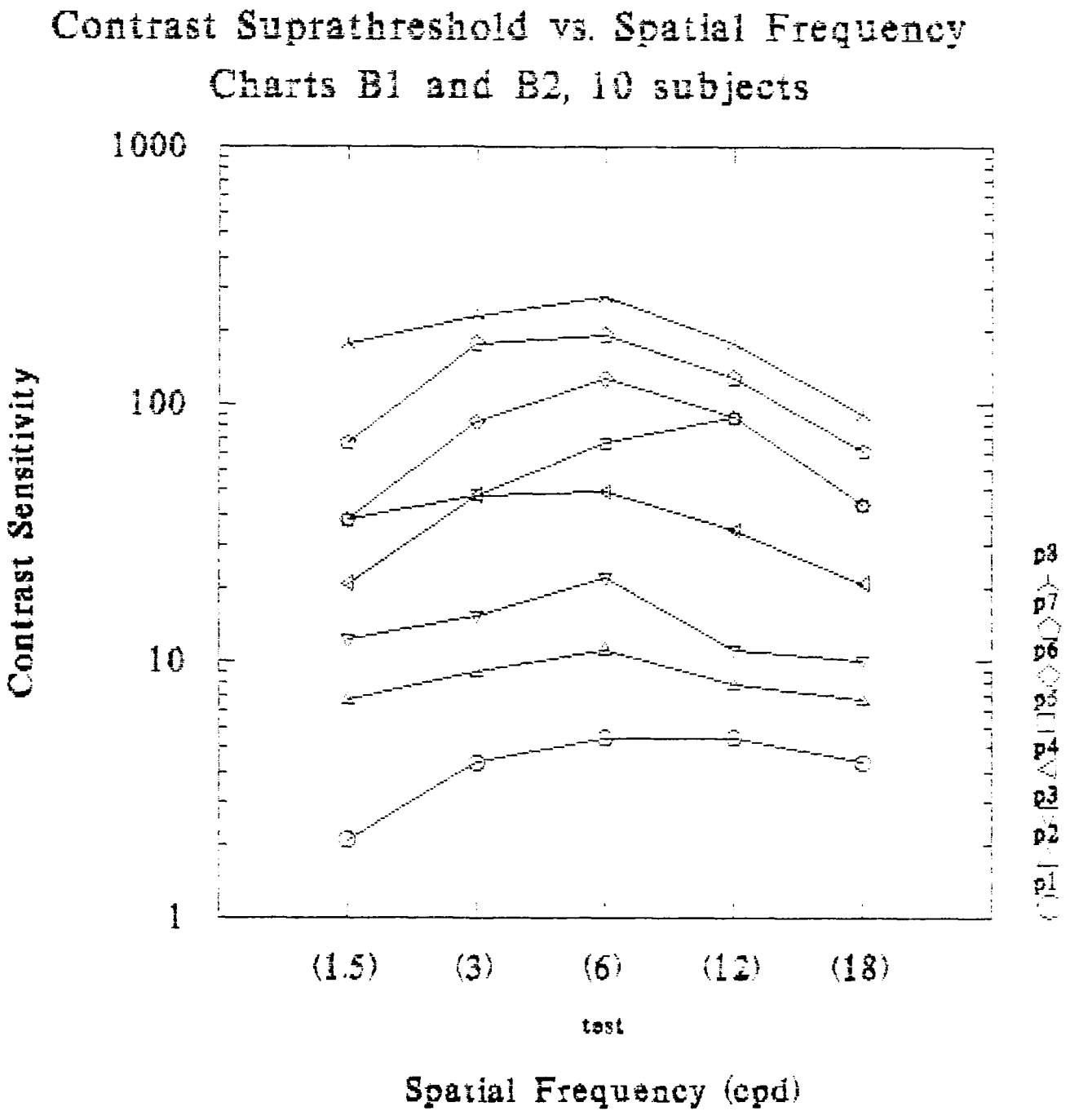
Contrast Suprathreshold vs. Spatial Frequency
Charts B1 and B2, 10 subjects
1000
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
p8
p7
p6
p5
p4
p3
p2
p1

FIGURE 6c

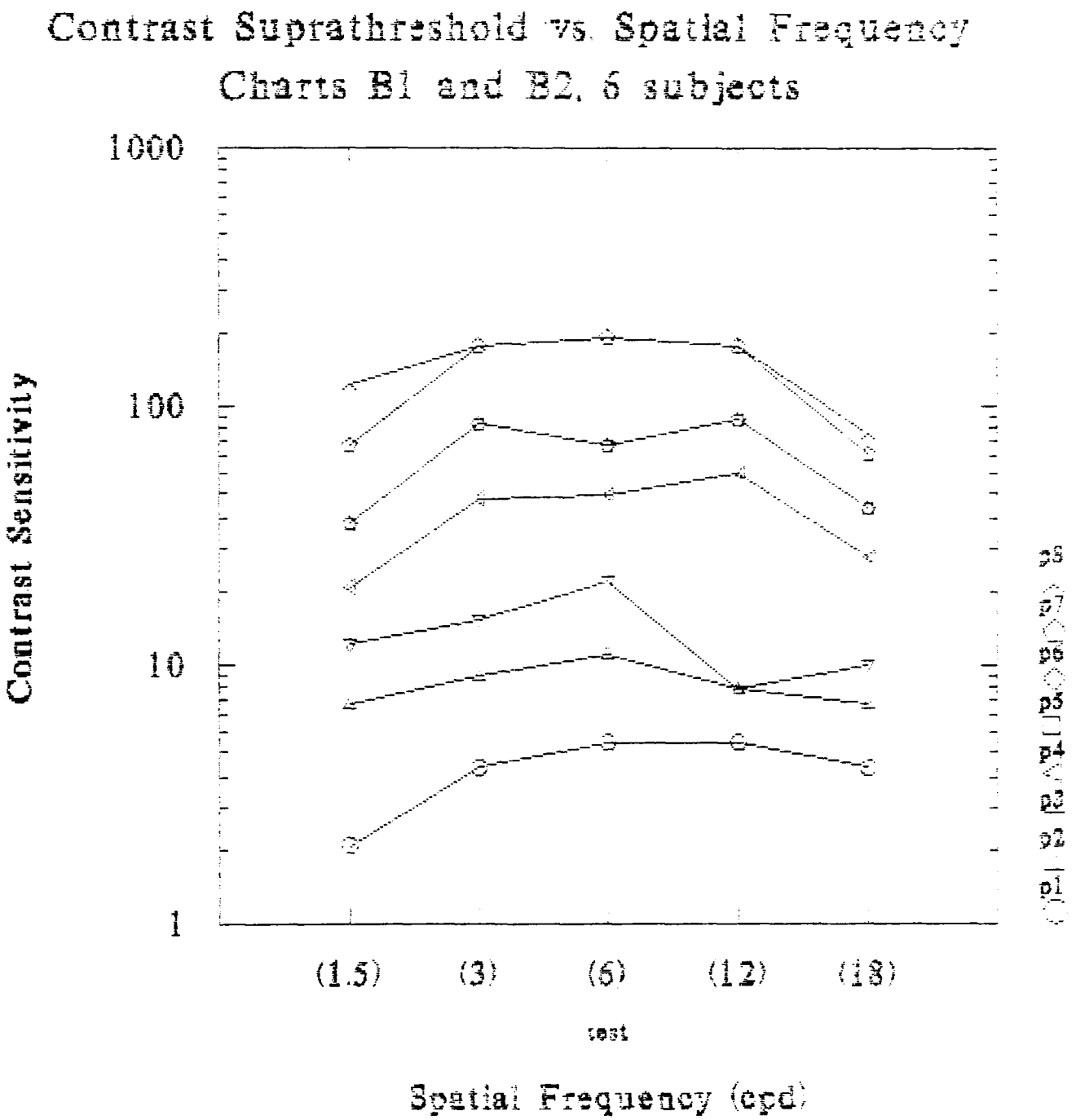
Contrast Suprathreshold vs. Spatial Frequency
Charts B1 and B2, 6 subjects
1000
100
10
1
Contrast Sensitivity
(1.5)
(3)
(6)
(12)
(18)
test
Spatial Frequency (cpd)
s8
s7
s6
s5
s4
s3
s2
s1

FIGURE 7

TABLE 1

GLOBAL VERSUS LOCAL CONTRAST MATCH

```
VARIABLES IN SYSTAT RECT FILE ARE:
       MCL                MB
>ttest mcl,mb

PAIRED SAMPLES T-TEST ON      MCL     VS       MB    WITH   175 CASES

MEAN DIFFERENCE =        -0.029
SD DIFFERENCE =          0.893
T =        -.423 DF =  174 PROB = .673
>
```

TABLE 2

INDIVIDUAL DIFFERENCES

```
VARIABLES IN SYSTAT RECT FILE ARE:
       GK1             GK2
>ttest gk1,gk2

PAIRED SAMPLES T-TEST ON      GK1     VS      GK2     WITH     25 CASES

MEAN DIFFERENCE =         0.080
SD DIFFERENCE =          0.277
T =        1.445 DF =    24 PROB = .161
>use a:ph
VARIABLES IN SYSTAT RECT FILE ARE:
       PH1             PH2
>ttest ph1,ph2

PAIRED SAMPLES T-TEST ON      PH1     VS      PH2     WITH     25 CASES

MEAN DIFFERENCE =        -0.200
SD DIFFERENCE =          0.408
T =       -2.449 DF =    24 PROB = .022
rass ENTER <-' or RETURN
```

TABLE 3

CHART COMPARISON TEST

```
>category frqnc=5, patch=8, subj=10, rep=2
>model match = constant + frqnc + patch + subj + rep
>estimate
```

DEP VAR: MATCH N: 800 MULTIPLE R: .967 SQUARED MULTIPLE R: .934

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
FRQNC	24.230	4	6.058	16.700	0.000
PATCH	3970.039	7	567.148	1563.536	0.000
SUBJ	9.411	9	1.046	2.883	0.002
REP	15.961	1	15.961	44.003	0.000
ERROR	282.208	778	0.363		

TABLE 4

NEW SUBJECTS

```
>category frqnc=5, patch=8, subj=6, rep=2
>model match = constant + frqnc + patch + subj + rep
>estimate
```

DEP VAR: MATCH N: 480 MULTIPLE R: .944 SQUARED MULTIPLE R: .891

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
FRQNC	28.015	4	7.004	11.810	0.000
PATCH	2208.261	7	315.466	531.962	0.000
SUBJ	5.045	5	1.009	1.701	0.133
REP	7.372	1	7.372	12.431	0.000
ERROR	273.977	462	0.593		

(a)

Suprathreshold Circular Chart Instructions
Matching Contrast Levels (Global Analysis)

This is a test that measures your ability to compare images of different contrast levels. The "contrast" of an image is the difference between its darkest and lightest areas. The bigger the difference, the greater the contrast level is. On the chart in front of you are five sets of patches arranged in circular orders. I will be placing patches called "reference-patches" in the center of each patch set. You will then tell me which patch has a contrast level most like the reference patch. Remember, a patch's contrast level is the difference between the lightest and darkest parts of the patch.

(b)

Suprathreshold Circular Chart Instructions
Matching Brightnesses of the Bars (Local Analysis)

This is a test that measures your ability to compare contrast levels from different images. On the chart in front of you are five sets of patches arranged in circular orders. I will be placing patches called "reference-patches" in the center of each patch set. You will then tell which one of the surrounding patches is the most similar to the reference-patch. You will compare the patches by comparing the dark and light bars from the surrounding patches with the dark and light bars from the reference patch.

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INDIVIDUAL DIFFERENCES IN SUPRATHRESHOLD CONTRAST SENSITIVITY AND VISUAL PERFORMANCE. A.P. Ginsburg. Vision Research Laboratory, Vistech Consultants, Inc., Dayton, OH 45432.

INTRODUCTION. Standard Snellen acuity has been shown not to relate well to visual performance in a wide variety of visual tasks. Contrast sensitivity has recently been shown to relate to individual differences in visual target acquisition capabilities in the laboratory, flight simulators, and in field studies. Although target detection thresholds are important in pilot visual performance, many visual tasks involve objects at suprathreshold contrast levels. This research investigates the degree to which suprathreshold contrast sensitivity contributes to visual target acquisition performance. METHODS. A new suprathreshold vision chart was developed to measure suprathreshold contrast sensitivity and obtain suprathreshold contrast sensitivity curves. Ten subjects were tested using this new suprathreshold contrast sensitivity chart. RESULTS. Individual differences between subjects were found when tested with the new chart. Analysis of the data suggested that the individual differences were due to real differences in suprathreshold contrast perception and not criterion. CONCLUSIONS. These results support the idea that suprathreshold contrast sensitivity testing may be useful in further predicting individual task performance.

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