Mikaelian, H. H.

An investigation of the effects of video display units on fundamental visual processes : temporal resolution and contrast sensitivity function.

Contractual report to the Department of Communications

An investigation of the effects of video display units on fundamental visual processes: Temporal resolution and contrast sensitivity function

by

H. H. Mikaelian

Department of Psychology

University of New Brunswick

Fredericton, N. B.

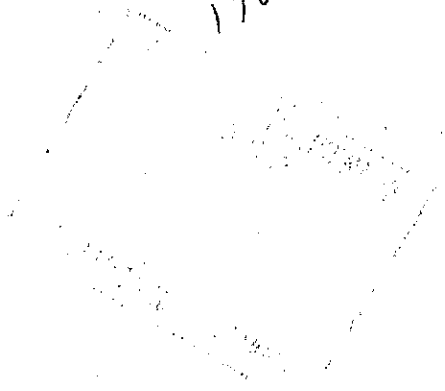
Department of Supply & Services Contract # OSU82-00196/OST83-00059
Department of Communications Requisition # RN:36100-2-4224/36100-3-0019

DOC Scientific Authority: William C. Treurniet
Behavioural Research & Evaluation

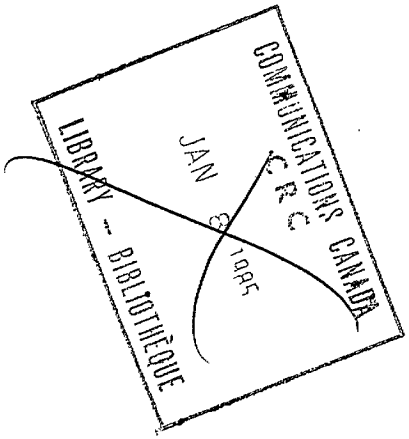
Classification: Unclassified

DISCLAIMER: THIS REPORT REPRESENTS THE VIEWS OF THE AUTHOR.
PUBLICATION OF THIS REPORT DOES NOT CONSTITUTE
DOC APPROVAL OF THE REPORT'S FINDINGS OR CONCLUSIONS

April 1984



Rec'd from W. Thurrell DBRE Jan 8'85. There are no restrictions in this report



This is a report on a series of experiments undertaken on behalf of the Department of Communications to develop visual performance measures of videotext viewing conditions. The purpose of the present studies was to develop stable measures of the effects of video viewing on visual performance, using psychophysical techniques. The two performance measures selected were a) two pulse resolution and b) contrast sensitivity. Part I of this report deals with the effects of video viewing on two pulse resolution. Part II of the report concerns measurement of contrast sensitivity following video viewing.

Part I

Two pulse temporal resolution, hereafter referred to as 2PR, is a measure of the ability of the visual system to resolve two brief pulses of light presented in succession and to the same retinal locus (Boynton, 1972). This particular response was selected because it is sensitive to the visual system's handling of stimuli that vary in time, and should reflect changes in this function brought about by prolonged viewing of videotext (whose major parameter is luminance variation across time). Since temporal resolution is of fundamental importance in the processing of visually presented information (Brown, 1965), it was thought that changes in visuo-temporal mediation produced by videotext would have appreciable effects on subsequent visual performance.

Theoretical considerations

It is generally accepted that the duration of a perceptual response to a brief visual stimulus is not necessarily equally brief. Most of the evidence suggests that the critical duration seems to be in the order of about 60 to 100 ms, meaning that the duration of the perceptual response even to the briefest stimulus is about 60 to 100 ms (Pieron, 1923; Lichtenstein, 1961; Efron, 1970; for an

interesting discussion of this issue see Uttal, 1981). Presumably this elongation of the perceptual response is due to the prolongation of the underlying neural response of the visual system (Sperling, 1965).

It is also very well established that when two brief stimuli are presented in succession with particular temporal and/or spatial relationships, they interact with each other (either additively or subtractively) (Breitmeyer, 1983; Weisstein, 1972). The most common form of this phenomenon is known as masking (backward or forward masking, metacontrast, etc.). Breitmeyer and Ganz (1976) have attempted to understand masking in terms of interactions between spatial frequency channels in the visual system; they have suggested that the temporal parameters of masking reflect the spatiotemporal response properties of these channels. They speculate that masking (at least of the backward type) is produced by interchannel inhibition; that is, the activity of the 'transient' channels (short latency and short duration neural responses) initiated by the presentation of the second stimulus (the mask), interacts with and inhibits the activity in the 'sustained' channels (longer latency sustained neural responses) that were initiated by the first stimulus (the target) but which lag behind due to their longer latency.

The Breitmeyer and Ganz (1976) model for masking provides a useful theoretical framework within which to understand 2PR studies. In such studies two pulses of light are presented in succession with the psychophysical task being the determination of the minimal interstimulus interval (ISI) for the detection of two pulses (Boynton, 1972). Of the several hypothesized mechanisms that determine the length of the ISI, perhaps the most important is the 'sustained'–'transient' interaction. Each pulse of light generates a transient and

a sustained response from the appropriate visual channels; since there are appreciable latency differences between them, as the temporal separation of the two pulses gets shorter the transient responses of the second pulse begin to interact with the sustained responses of the first pulse (much as the transient responses of a mask stimulus interact with the sustained responses of a target stimulus in a masking paradigm). Presumably when the visual system is responding optimally in discriminating two pulses (that is, when the visual system response to flashes of light is within the critical duration as discussed in the first paragraph of this section) the temporal separation for sustained-transient interaction will play a dominant role in determining the ISI in 2PR.

It is hypothesized that reading videotext modifies the transient mechanisms of the visual system (although the sustained mechanisms may also be influenced somewhat). This speculation is based on the nature of the videotext stimulus generation and presentation, whose relevant features in this context include: a) scan lines generated by the raster, b) dot matrix character generation, c) scan lines and therefore characters plotted in time with concomitant jitter, c) frame rate flicker, d) interaction between eye movements entailed in reading and the dynamic nature of the display, e) temporal characteristic of field construction, etc. This line of reasoning would lead to the prediction that one of the effects of reading videotext would be a change in 2PR threshold. The following experiments were conducted to explore this possibility.

General design considerations

At the beginning of the contract period significant effort was devoted to the development and design of the 2PR test apparatus and control procedures. An Apple II microcomputer was used to:

a) Present the 2PR stimuli in appropriate sequence;

b) Collect subject's responses and vary the ISI in the sequence accordingly (modified staircase procedure)

c) Present videotext;

d) Control timing of experimental procedures.

Software development for the above processes was done at the Vision Labs at U.N.B. Details of the actual test stimulus display and the VDT are presented in the Method section.

In the following exeriments 2PR was measured on different parts of the retina following periods of reading videotext as well as reading print. The basic design consisted of initial familiarization with the apparatus and test procedures, followed by a set of 2PR measurements. Upon completion of the first set of measurements subjects read videotext or print, for a period of 15 minutes, following which another set of 2PR measurements were taken. This design was carried out for two different studies: in the first study (Exp. 1) duration of the pulse of light for the 2PR was 250 ms, in the second study (Exp. 2) pulse duration was reduced to 25 ms. An additional study (Exp. 3) was conducted with a somewhat modified design and with pulse durations of 300 ms.

Method

Subjects

Ten subjects were used in Experiment 1 (250 ms flash), another group of 8 subjects were used in Experiment 2 (25 ms flash), and a third group of 5 subjects were used in Experiment 3 (300 ms flash). All subjects were volunteers and between the ages of 20-32, with normal or corrected to normal vision.

Apparatus

The test apparatus consisted of an enclosure (1.5 m wide x 1.7 m high x 0.7 m deep) in which all interior surfaces that might be visible during testing were either draped with black cloth, or painted flat black. The test enclosure was located in a room that was made light tight during testing.

The observer was seated on a fixed position stool that was centered in front of the enclosure. During all active segments of the test procedures the observer sat with his or her chin supported on an adjustable height chin-rest.

Two response buttons were mounted below and in front of the chin-rest. The position of the response panel could be adjusted to a more or less comfortable position for each individual. Dim red marker lights bearing the legends "yes" and "no" were located directly above and below the respective response buttons.

Test targets consisted of an array of five light emitting diodes mounted in an arc on a hinged assembly. During testing the array could be raised so that the targets were located in the transverse plane at the observers eye level. The radius of the arc on which the targets were mounted was such that each target was 64 cm from the observers eyes. The center target of the array was located

on the median line. The remaining targets were spaced 7.5 degrees apart, on either side of the median line. Each target consisted of a light emitting diode (Peak spectral emission at 665 nm; Luminance 4.19 cd/m^2) mounted in a brass sleeve with a 17 minute viewing aperture. During exposure to the video display the test array could be lowered out of the visual field.

For experiments 1 and 2 the video display was an APPLE/// raster scan monitor with P39 phosphor. For experiment 3 the monitor was an Electrohome RGB display. The monitor was mounted behind the test target array 65 cm from the observers' eyes. A black mask covered the monitor screen during all experimental phases except those that required exposure to the video display. The area of screen used represented a rectangle approximately 15 degrees high and 19 degrees wide. The viewing area was centered in the observer's field of view. The background luminance of the screen was 1.29 cd/m^2. The luminance of character strokes was 4.14 cd/m^2. Character contrast was 0.52.

In experiments 1 and 2, the 5 x 7 dot matrix characters were presented with 40 characters on each row and 24 rows per page with one raster line spacing between rows. The cursor was a solid 5x7 block.

For experiment 3, text characters were generated by a Norpak Mark IVA Videotex decoder. The characters were displayed as 5 x 7 dot matrix with 40 characters on each row and 19 rows per page. Successive rows were separated by three raster lines. The cursor was not visible.

During video exposure phases text was written to the display at a rate of 30 characters per second. All alphabetic characters were written in upper case. Characters were written by cursor replacement. After each page of text was

written, and after a nine second waiting period the screen was blanked and the next page presented.

The video monitor, and test target array were controlled by an Apple microcomputer that was located in a room nearby the test apparatus. Signals to the light emitting diode array, and from the observer response switches were arbitrated through a custom interface. Control programs were coded in Pascal. Time critical events in the control process, and interface to the response switches and light emitting diode array were coded in Assembly language.

The video text presentation program controlled the sequential selection of characters from an array in memory for presentation on the observer monitor. At the beginning of a text presentation session, the monitor screen was held blank until receipt of a session start signal from the experimenter. After receiving a session start signal, the control program cycled through the text array by pages until receipt of a signal from the experimenter to terminate the session. When text presentation was terminated, the monitor screen was held blank while the experimenter prepared the apparatus for the next experimental condition.

The 2PR test program controlled the presentation of a series of trials. In general a trial consisted of a) the presentation of a fixation target for 1000 ms; b) the presentation of a double pulse test target consisting of a 250 ms (25 ms in Exp. 2, 300 ms in Exp. 3) pulse, a variable ISI, followed by a second 250 ms (25 ms, 300 ms) pulse; and, c) an open-ended wait for an observer response. Schematic diagrams of the pulse sequence for two trials are shown in Figure 1. The first sequence is of a trial on which the fixation target is also the 2PR test target. The second sequence shows separate fixation and 2PR test targets. Each trial required:

- Selection of a fixation point target
- Selection of a 2PR evaluation target
- Determination if trial is to be "catch"
- Presentation of 2PR trial
- Collection of observer's response
- Response criterion evaluation
- Intertrial interval timeout

The fixation and 2PR target choices could each be any of the five targets shown in Figure 1. Selection of target pairs from the set of 25 possible combinations (1-1, 1-2, .. , 5-4, 5-5) was constrained in the interest of shortening the length of time required to complete a test session. Target pairs chosen from the set are checked against the response criterion.

After selecting a usable target pair, a random decision was made whether to present a 2PR trial or a catch trial (one trial in ten). If the decision called for a catch trial, the ISI for the test target was set to zero. Thus, on a catch trial the 2PR stimulus was just a single 500 ms (50 ms in Exp. 2, 600 ms in Exp. 3) pulse.

If the trial was not a catch trial, the fixation and 2PR targets were lit as described. The ISI had some duration greater than 0.64 ms depending on previous observer reponses to the specific target combinations.

Immediately after the termination of the last flash of the 2PR target, the observer push buttons were polled for a valid "yes"/"no" response. A valid response was taken to be a single "yes" or "no" button press. If an invalid response was detected (both "yes" and "no" buttons pressed), the response input buffer was cleared and then repolled for a new response.

If a "yes" response was detected subsequent to a "yes" response the ISI was decremented by an amount not greater than 25%, and not less than 20% of the previous ISI. If two successive "no" responses were detected the ISI was incremented according to the same criterion. If a "yes" response was followed by a "no" response, the ISI for the last trial was taken to be an estimate of the oberver's upper limit of detection for the ISI, and was recorded as such. If a "no" response was followed by a "yes" response, the ISI was recorded as an estimate of the lower limit of detection. Once three estimates each of the upper and lower limits of detection were recorded, the test sequence for that fixation-test target pair was considered complete and no further trials were presented in the session. This method of estimating detection threshold represents a condensation of the staircase procedure. Changes to the procedure were made in the interest of shortening the amount of time needed to complete a test session.

After each response, a delay of one second was inserted before presenting the next test trial.

Procedure

The experiment was conducted in two sessions, separated by at least 24 hours. Each session consisted of four stages: 1) Instruction, 2) Pretest1, and Pretest2, 3) Exposure and 4) Posttest.

1. Instruction. Subjects were seated in front of the test apparatus, with chin on a chin-rest, and the target lights were pointed out. They were informed that these targets, when turned on, could serve two purposes; as fixation points, or as test targets for a single or double pulse discrimination, which they were to detect as one or two flashes of light. They were instructed to press the "Yes"

response button if a double flash was perceived or the "No" button for a single flash. It was indicated that in some cases the fixation and test targets would be different lights and in other cases they would be the same; that is, in some cases a fixation light would come on (which they were to fixate immediately) and one of the other targets lights would be turned on as either a single pulse or a double pulse, while in other cases the same light would serve as fixation point and then as the 2PR discrimination target.

Subjects were then given practice trials until they felt comfortable with the task. After completion of the practice trials a three minute rest period was allowed.

2. Pretest. The 2PR testing was conducted in a dark room with no visible illumination except that emitted by the targets. In all cases Pretest1 and Pretest2 were identical. Testing began by the presentation of the fixation light, which stayed on for one second prior to the presentation of the 2PR target. The target light remained on for the flash time, went off for a pre-determined ISI and came back on again for the flash time, after which both the fixation and target lights went off. A modified staircase method was used in the presentation of trials. Single pulse presentations were interspersed wih double pulse presentations at a ratio of 1:10 in a random order. If the subject responded "Yes" to a double pulse presentation the ISI was decreased by a pre-determined amount, if the subject responded "No" the ISI was increased. Once the threshold was established for all nine presentation combinations, the test was complete. Each pretest was followed by a three-minute rest period wih partial illumination (door was ajar).

3. Exposure. The exposure period was 15 minutes in duration and consisted of a) reading a magazine of the subject's choice in a room illuminated by fluorescent lights or b) remaining seated at the test apparatus and reading videotext displayed on the monitor. Subjects were allowed a three minute rest period following exposure.

4. Post-test. The posttest procedure was identical to that of the pretest.

For Experiments 1 and 2 the two experimental sessions were identical except for the instruction and exposure stages. In Session 2 the instruction stage consisted of reminding the subjects to keep their eyes on the fixation light and to respond "Yes" to the double flash. The exposure stage was different in that those subjects who read videotext in the previous session now read a magazine, while those who read a magazine first now read videotext. In Experiment 3 2PR measures were obtained using five peripheral targets before and after reading videotext first and then, at least 24 hours later, before and after reading print (more detailed discussion of the design and rationale for Exp. 3 is presented later).

RESULTS

The results from Experiment 1 were as follows: the mean pre measures for foveal targets was 9.5 ms and for peripheral targets 42.6 ms. The post measures for foveal targets remained statistically unchanged for both exposure conditions, whereas for the peripheral targets the average post measures following reading videotext increased (56.2 ms) in comparison with those following reading print (37.4 ms). Mean differences between pre and post 2PR threshold measures for video and print sessions for Experiment 1 are shown in Table 1. In the Tables a negative number indicates a decrease in two-pulse resolution (or an increase in 2PR threshold).

Prepost differences in 2PR thresholds following reading print were compared to the corresponding prepost differences following reading videotext. The statistical comparisons were carried out separately for foveal and peripheral data for each experimental condition. A 5 x 2 x 5 (subject x session x target) analysis of variance on foveal results failed to show significant main effects or interactions for Condition A and Condition B. This suggests that a) there are no reliable differences in 2PR threshold measured by the various targets, and b) that the prepost differences in foveal 2PR following reading print and videotext are statistically equivalent. Comparison of the peripheral data in a 5 x 2 x 4 (subject x session x target) analysis of variance showed a significant main effect of session for both experimental conditions, $F(1, 4) = 8.02$, $p<.05$ for Condition A and $F(1, 4) = 7.89$, $p<.05$ for Condition B. These results indicate that, while there are no statistically reliable differences between the various fixation point-target

combinations, significant differences in 2PR threshold changes are obtained between reading videotext and reading print.

The results from Experiment 2 were as follows: the mean pre measures for foveal targets was 34.1 ms and for peripheral targets 148.6 ms. As in Experiment 1, peripheral 2PR measurements are about a factor of four larger than foveal measurements. Also in accord with the results of Experioment 1, the post measures for foveal targets remained unchanged for both exposure conditions (mean 35.3 ms). For the peripheral targets the average post measures following reading videotext increased to 156.8 ms in comparison with those following reading print (143.6 ms). Mean differences between pre and post 2PR threshold measures for video and print sessions for Experiment 2 are shown in Table 2. A 4 x 2 x 5 (subject x session x target) analysis of variance on the foveal data from Condition A showed no significant differences between sessions, $F(1, 3) = 0.02$, $p>0.10$, or amongst targets, $F(4, 12) = 0.43$, $p>.10$; for exposure Condition B the corresponding values were $F(1, 3) = 0.45$, $p>.10$, and $F(4, 13) = 1.00$, $p> .10$. As in Experiment 1 these results suggest that no reliable differences exist in threshold measures between the various targets or between pre and post foveal measures. A 4 x 2 x 4 (subject x session x target) analysis of variance on the peripheral data also failed to show any statistically significant differences between targets or in 2PR threshold change between print and videotext, $F(3, 9) = 2.03$, $p>.10$ and $F(1, 3) = 0.37$, $p>.10$ respectively for Condition A; for Condition B the corresponding values were $F(3, 9) = 1.70$, $p>.10$, and $F(1, 3) = 2.88$, $p>.10$. These statistical results are somewhat unexpected since they indicate no reliable prepost differences in peripheral 2PR threshold measurements following

reading videotext whereas the peripheral data (at least in Condition B) suggest the existence of such differences.

The results from Experiment 3 are presented in Table 3. The mean pre measures (peripheral targets only) was 58.5 ms for the video condition and 76.2 ms for the print condition. The mean post measures were 77 ms and 70.8 ms respectively. A 5 x 2 x 6 (subject x session x target) analysis of variance comparing print to videotext showed a significant session factor, $F(1, 4) = 8.94$, $p<.05$. No significant target or target x session interaction were indicated, $F(5, 20) = 1.00$, $p>.10$, and $F(5, 20) = 2.19$, $p>.05$ respectively.

DISCUSSION

The results show that, under the conditions of the present experiments, when two 250 ms pulses of light are viewed foveally, a dark interval of about 8 to 10 ms is required between the two pulses for there to be a perception of a double flash. Additionally, at least a fourfold increase in this dark interval is required if the targets are viewed peripherally. The results further indicate that foveal 2PR appears to be relatively unaffected by reading print or videotext for 15 minutes. The situation appears to be different, however, for peripherally viewed targets; fifteen minutes of reading videotext has a significant effect on 2PR, an effect that is significantly different from that following 15 minutes of reading print.

The 8-10 ms dark interval for foveal targets corresponds to a Weber ratio of 0.01, and is similar to temporal resolution data reported in the literature (Boynton, 1972). The foveal-peripheral difference observed in our experiments are somewhat more controversial. Flicker-fusion experiments, which is another method of observing visual temporal resolution, consistently report higher critical flicker frequency (CFF) on the periphery than the fovea (using large test fields); in our experiments the test targets occupied a visual angle of 17 minutes of arc, which is considerably smaller than the 5 to 8 degrees utilized more commonly in the flicker experiments. Several experimenters (Hecht & Verrijp, 1933; Creed & Ruch, 1932) have reported a decrease in flicker sensitivity with retinal eccentricity for small fields, our results are in line with these studies, and indicate that temporal resolution for small targets decreases with retinal eccentricity. Another factor that may have played a role in foveal 2PR was the

temporal profile of the foveally presented stimuli: since the fixation point also served as the pulsing target, the first pulse of the foveal 2PR stimulus was actually 1250 ms long (1000 ms fixation and 250 ms pulse duration) while the second pulse was only 250 ms; such a stimulus configuration could lead to the Broca-Sulzer effect (Broca and Sulzer, 1902; McDougall, 1904), an illusion where the shorter of two sequentially presented stimuli appears brighter. It is quite possible, therefore, that foveal 2PR measures were based more on brightness discimination than on temporal discrimination, which could have allowed these reponses to be as low as they were.

The fovea seems to be immune to changes following short periods of reading videotext (although it is possible that longer exposure to videotext may produce temporal resolution changes in the fovea as well). The periphery, on the other hand, is susceptible to the effects of reading videotext for as short a period as 15 minutes; the results suggest that when the peripheral 2PR (using the 250 ms pulse) has attained what appears to be a stable value through training (has reached its floor ?), which in our experiments is about 40 ms, reading 15 minutes of videotext produces about a 38% increase in that threshold.

The data from Experiment 2 are somewhat more difficult to interpret and require additional consideration. First of all reducing flash duration from 250 ms to 25 ms created massive and unexpected problems. Data in the literature (Kietzman, 1968; Mahneke, 1958) suggest that decreasing flash duration produces an increase in the ISI for 2PR; thus we had expected that with 25 ms flash duration longer ISIs would be obtained. While several of the subjects did indeed manifest longer ISIs, the responses of others (to the peripherally presented 2PR stimuli) indicated that they were now able to discriminate dark intervals as small

as 1 ms (near the minimum allowable ISI). It was eventually realized that, since a very short duration pulse, especially when delivered to the periphery, can produce apparent flicker (Dunlop, 1915; Bartley and Wilkinson, 1953) some of the subjects in Experiment 2 were detecting not a dark interval between the two pulses but rather were responding to the apparent flicker or intensity variation of the short pulse, quite independent of there being a dark interval between the two. Substantial retraining of the subjects was then introduced until what appeared to be relatively stable peripheral 2PR responses could be obtained (it should be noted that foveal 2PR measures in Experiment 2 generated no such problems, being quite stable from the beginning of the short flash experiment). It seems that Boynton's (1972) admonitions concerning the requirement for subject training and the need for large numbers of observations to obtain meaningful 2PR results (especially when using short flash stimuli) are crucially valid!

The foveal measures from Experiment 2 indicate a temporal resolution of between 35 to 40 ms (approximately a fourfold increase from those of Experiment 1). The peripheral measures also reflect a parallel increase. While reading videotext appears to have produced about a 17% increase in peripheral 2PR threshold (at least in one set of measures), the differences in prepost measures between the video and print condition failed to reach statistical significance, due, probably, to the relatively high variance of these data.

Experiment 3 was undertaken because difficulty was experienced in obtaining meaningful 2PR data using short duration pulses. A flash duration of 300 ms was used and the design of the experiment altered to eliminate foveal targets, increase the number of peripheral targets, and use only one sequence of 2PR testing, namely, reading videotext first and then (at least 24 hours later)

reading print. Four experienced subjects but with no training on the 300 ms flash were used.

The basis for the design of Exp. 3 was the following: since, in the previous experiments, no changes in foveal 2PR were obtained these were dropped; the order of the two sessions (videotext first and then print) was selected to establish the potency of the 300 ms test condition to assess the VDT induced changes (at shorter flash durations robust VDT induced increases in threshold were detected more commonly after 2PR had reached a floor, which usually occurred at the end of the testing sequence); no pretraining at 300 ms duration was provided because subjects were experienced psychophysical observers.

The results from Experiment 3 indicate about a 32% increase in 2PR threshold following 15 minutes of reading videotext. This threshold increase is significant and is comparable to that obtained using 250 ms flash durations.

General Discussion

The results of the above experiments suggest that clearly some changes in visual functioning do occur following reading videotext for as short an interval as 15 minutes. The effects that we have measured reflect a reduction in temporal resolution, and seem to be restricted to peripheral vision. Two questions will be addressed in this section: 1) what theoretical interpretations might be made of these observations?, and 2) what is the significance of these observations to visual (and other) fatigue reported by VDT operators?.

With respect to the first question, reference was made earlier in this article to the Breitmeyer and Ganz (1976) model for masking. That model postulated an

interchannel inhibitory interaction between transient and sustained systems when the temporal delay between the mask and target stimuli were of the correct order of magnitude; within that context the present results suggest that the effect of videotext exposure is to increase the time interval within which such interactions can occur (thus reducing temporal resolution), perhaps by broadening the inhibitory action spectrum of the transient mechanisms (which now would require greater temporal separation from the sustained responses so as to avert inhibitory interactions). The fact that the VDT effects seem to be more easily obtained in the peripheral retina is likely due to the prevalence of transient channels in the periphery (Fukuda & Stone, 1974; Hoffman, Stone, & Sherman, 1972). It might be noted in this respect that, similar to the present observation, most masking is restricted to the periphery with little or no masking reported to occur at the fovea (Alpern, 1953; Kolers and Rosner, 1960). One consequence of this speculation is that, in a masking paradigm VDT exposure should produce an increase in the optimal stimulus onset asynchrony for masking. This possibility will be explored in subsequent studies.

Now to the second question: are these effects related to visual fatigue and other symptoms reported by VDT operators?. It should be noted that in the present experiment VDT exposure was extremely artificial in the sense that subjects were required to use a chin-rest (to control screen distance) and to read for only 15 minutes, hardly analogous to hours of demanding work using VDTs, nor were any efforts made to obtain the best VDT. If anything the present effects seem to be similar to the usual visual aftereffects produced by ten to fifteen minutes of exposure to stimuli that presumably induce fatigue in a particular hypothesized channel in the visual system. The relevant aspect of these findings

is that temporal resolution is affected and that the effects are anisotropic, being evident primarily in peripheral vision. The peripheral retina naturally plays an important role in generating information concerning orientation in visual space, determining gaze direction and onset of saccadic eye-movements, perception of moving stimuli and, in general, whenever a requirement exists for processing sequentially presented stimuli (alphanumeric or otherwise). Changes in temporal resolution in the periphery could well affect these functions not necessarily by making it impossible or even difficult to carry on, but perhaps by requiring more effort from the operator in the performance of these ordinary tasks. Over the course of an eight hour workday, these changes in temporal resolution could significantly stress the visual system and, in turn, add to the loading of the central nervous system. Whether these effects are cumulative, their time course and decay function, etc., still remain to be explored; whether the effects observed in the present experiment can be shown to affect tasks usually performed by VDT operators is still a question requiring further experimentation.

Part II

Contrast Sensitivity Function

Contrast sensitivity function refers to the ability of an observer to discriminate spatial frequency gratings with a sinusoidal luminance profile. The relevance of contrast sensitivity to visual functioning is based on the channel theory of vision, which postulates that the visual system contains spatial-frequency selective channels (Campbell and Robson, 1968; Graham and Nachmias, 1971). According to this view the spatial-frequency components of complex patterns are detected by these channels as seperate Fourier components, which are subsequently transmitted to the central visual system for further processing. Since the perception of the complex pattern is assumed to be a function of the response of these channels, it seemed reasonable to expect that the effects of exposure to visual tasks that effect visual functioning may be assessed by alterations induced in these hypothetical channels. Accordingly two experiments were conducted to explore possible effects of VDT viewing on contrast sensitivity. The usual parameter in determining sensitivity is contrast ratio, commonly defined as (Lmax - Lmin)/(Lmax + Lmin) where Lmax and Lmin refer to, respectively, the maximum and minimum luminance values; the measure reported is the inverse of threshold contrast, referred to as contrast sensitivity function (CSF).

The design of these experiments parallelled those of the 2PR studies; following pretraining, measures of contrast sensitivity, using seven different

spatial frequencies, were obtained before and then after reading videotext and print for specified periods of time. Differences between pre and post measures were used as an index of the effects of the exposure condition. Experiment 1 was designed to determine whether changes in contrast sensitivity would be obtained following reading videotext, thus no attempts were made to obtain comparable measures following print. In Experiment 2 CSFs were measured before and after reading print and videotext.

Method

Subjects

A total of 6 subjects were used in Experiment 1 (videotext only) and a different group of 7 subjects were used in Experiment 2 (videotext and print). All subjects were volunteers and between the ages of 20-32, with normal or corrected to normal vision.

Apparatus

Measurements of contrast sensitivity were obtained using a computer based system which generated sinusoidial spatial frequency gratings on a high resolution raster scan video display (P4 phosphor). The gratings occupied a test field of 3 deg by 3 deg of visual angle in the center of an equiluminant (28 cd) surround 8 deg wide by 6 deg high. Transition from surround to test field was a discrete unmasked boundary. Gratings were inserted into the test field such that the left edge of the field was equi-luminant with the surround; the right edge transition luminance was determined by the spatial frequency of the grating. On each trial the contrast of each grating was ramped from 0 to a value above threshold. The start of each trial was signaled by a short tone burst. The subject was instructed to indicate when the grating became visible by pressing a push button switch. Total ramp time, if the subject made no response was 21 seconds. The relative contrast of the grating at the time the subject responded was recorded by the computer which then immediately reset the test field contrast to 0 and, following a fixed delay of two seconds, started the next trial. The following spatial frequencies were used: 0 (blank test field), .5, 1, 2, 4, 8, 12,

and 16 cycles/degree ; each frequency was presented three times for a total of 24 trials. The order of grating presentations was randomized such that each grating was presented once every eight trials and that the last grating presented in a block of eight was not the first grating in the next block.

Procedure

Except for pretraining Experiment 1 was conducted in one session, while Experiment 2 required two sessions separated by at least 24 hours. Each experimental session consisted of five stages: 1) Instruction, 2)pretraining, 3) Pretest1, and Pretest2 (Experiment 2 had an additional Pretest3), 4) Exposure and 5) Posttest.

1. Instruction. Subjects were taken into the experimental room and seated facing the test monitor on which a low frequency sine wave grating of relatively high contrast was displayed. The concepts of contrast and frequency were explained to the subject. The experimenter then manipulated the contrast of the grating so as to indicate to the subject the difference in appearance of a high and low contrast grating. A high frequency grating was then displayed on the screen and the contrast gradually increased until the subject reported that they could see the grating. The subject was told that during testing a tone would preceed the start of each grating presentation and that his/her task was to press the response button as soon as they were able to determine that a grating was present.

2. Pretraining. Subjects were given two pretraining sessions on consecutive days with each session consisting of two testing sequences of 24 trials each. Each

test sequence consisted of three presentations of seven different frequencies presented randomly along with three blank (0 c/d) trials (the blank trials were used in Experiment 2 only).

3. Pretest. Testing was conducted in a dark room with no visible illumination except that emitted by the monitor. Subjects were required to sit in the room for three minutes prior to the beginning of testing and were given a 30 second rest period between pretests. Subjects in Experiment 1 were given two pretests while those in Experiment 2 were given three pretests.

4. Exposure. Following the completion of the last pretest subjects were asked to face the text video monitor and place their chin in the chin-rest. Text presentation began 1 minute after the last pretest and continued for a total of 30 minutes. For the print exposure condition subjects were handed the text to be read with the general illumination provided by fluorescent lighting.

5. Posttest. Testing began 1 minute after the end of the exposure period and consisted of one test sequence.

The design in Experiment 2 was different from Experiment 1. In Experiment 1 contrast sensitivity was measured before and after reading videotext only, a condition that was equivalent, from a design standpoint, to reading videotext first. Experiment 2 called for CSF measures before and after reading print first (in the first session) and then videotext (in the second session). In session 2 of the second experiment the 'Instruction' stage consisted of reminding the subjects to keep their eyes on the grating display and to respond when a grating became visible after the signalling tone.

Results

The results of Experiment 1 are shown in Fgure 2 The numbers are values recorded by the computor (related linearly to the threshold contrast ratios of the gratings) and transformed into sensitivity measures (inverse of threshold). The zero contrast (blank field) was correctly detected by all subjects, and thus is not included in the results. The curve marked 'pre' in Figure 2 (mean of the two pre exposure measures) is a typical contrast sensitivity function comparable to similar curves published in the literature (Ginsburg, 1978). The curve marked 'post' represents CSF obtained following the half hour of reading videotext. The data were categorized into the customary Low (0.5 and 1 c/d), Medium (2, 4, and 8 c/d) and High (12 and 16c/d) frequency ranges for purposes of statistical analysis. With a square root transform of the data (to equalize population variances) a 6 x 2 x 3 (subject x prepost x frequency) analysis of variance showed a significant frequency effect $F(2, 10) = 18.23$, $p<.05$ and a significant prepost x frequency interaction $F(2, 10) = 4.51$, $p<.05$. A test of the simple main effects of the interaction showed a significant prepost main effect for the high frequency $F(1, 5) = 7.59$, $p<.05$.

The results of Experiment 2 are shown in figures 3, and 4. As before the numbers are values recorded by the computor and transformed into sensitivity measures. Pre and post exposure data for the video condition are graphed in figure 3 (the data points for the 'pre' curve represent the mean of the three pre exposure measures). Figure 4 shows differences between pre and post measures for print and for video exposure conditions for comparison. Since the data from Experiment 1 had indicated differential effects as a function of frequency, that

is, that exposure induced changes were likely to occur only at some spatial frequencies and not at others, the data from Experiment 2 were analyzed a) without grouping them into frequency ranges, and b) separately for the two exposure conditions. With a square root transformation (as above) a 7 x 2 x 7 (subject x prepost x frequency) analysis of variance of the video exposure condition showed a significant main effect of prepost, $\underline{F}(1, 6) = 9.85$, $\underline{p}<.05$, a significant main effect of frequency, $\underline{F}(6, 36) = 12.55$, $\underline{p}<.01$, and a significant prepost x frequency interaction $\underline{F}(6, 36) = 3.58$, $\underline{p}<.05$. A test of the simple main effects of the interaction showed a significant subject x prepost effect at 0.5 cpd $\underline{F}(1, 6) = 12.78$, $\underline{p}<.05$, and also at 16 cpd $\underline{F}(1, 6) = 6.47$, $\underline{p}<.05$. A similar analysis on the data from the print condition yielded only a significant main effect of frequency $\underline{F}(6, 36) = 14.11$, $\underline{p}<.01$; neither the prepost or the prepost x frequency interaction were significant $\underline{F}(1, 6) = 0.44$, $\underline{p}>.10$ and $\underline{F}(6, 36) = 1.77$, $\underline{p}>.10$ respectively.

Discussion

The results of the contrast sensitivity measures indicate, first, that the procedure used to obtain CSF in the present experiment yields data that are very comparable to those published in the literature, thus the measurement procedures in these experiments produce reliable indices of subjects' contrast sensitivity functions. The data shown in Figure 2 indicate that changes in contrast sensitivity are induced following 30 minutes of VDT work, although it is clear that these changes are restricted to the high frequency range; the low and medium frequency ranges appear to be not affected. The average changes in sensitivity at the high frequency range are about 10%. In simplest form these effects may be said to represent visual fatigue of the high frequency channels, perhaps induced by working with pixelized alphanumeric characters (whose spectrum contains substantial energy at the high frequency) as well as the accompanying degradation of the accommodative mechanisms (Campbell and Durden, 1983).

The results of Experiment 2, where contrast sensitivity was measured before and after reading videotext and print, show that while reading videotext for 30 minutes produces reliable changes in CSF, no such effects on CSF are observed following reading print. As before high spatial frequency sensitivity is reduced following VDT work, although reliable changes in the very low frequency are also evident. In addition to the high frequency roll-off following reading videotext, the somewhat unexpected increase in threshold for the low frequency gratings might reflect possible changes in the 'transient' mechanisms of the visual system

(which mediate low frequency gratings) as speculated previously in interpreting the two-pulse resoluton data.

In summary, it is clear that changes in contrast sensitivity do occur following reading videotext for 30 minutes. These changes, however, are small and limited primarily to the high frequency range (although there is some evidence that low frequency response may also be somewhat attenuated), and probably reflect the combined effects of overdriving these channels and fatigue of the accommodative mechanisms. The mid-frequency channels appear to be robust and not readily subject to VDT influence; since these are the channels most commonly thought to be used in extracting useful visual form information, it would seem reasonable to conclude that reported VDT induced fatigue and other visual symptoms cannot be ascribed directly to alterations in contrast sensitivity. It remains to be determined whether, as the visual system becomes increasingly stressed with continuous VDT work, the alteration in sensitivity of the high frequency channels may play a role in augmenting symptoms of visual discomfort.

The above assertions refer to contrast sensitivity measured at threshold; it may well be that psychophysical responses to supra-threshold spatial frequency gratings, such as in spatial frequency discrimination (as opposed to contrast detection) are more adversely effected by VDT use. These remain to be examined.

REFERENCES

Alpern, M. (1953). Metacontrast. Journal of The Optical Society of America, 43, 648-657.

Bartley, S. H. & Wilkinson, F. W. (1953). Certain factors in producing complexity of responses to a single pulse of light. Journal of Psychology, 9, 299-306.

Boynton, R. M. (1972). Discrimination of homogenous double pulses of light. In D. Jameson & L. M. Hurvich (Eds.), Handbook of Sensory Physiology (pp. 202-232). New York: Springer-Verlag.

Breitmeyer, B. G. (1983). Visual masking: An integrated approach. London: Oxford University Press.

Breitmeyer, B. G. & Ganz, L. (1976). Implications of sustained and transient channels for theories of visual pattern masking, saccadic suppression, and information processing. Psychological Review, 83, 1-36.

Broca, A. & Sulzer, D. (1902). La sensation lumineuse fonction du temps. Journal de Physiologie at de Pathologie general, 4, 632-640.

Brown, J. L. (1965). Flicker and intermittent stimulation. In C. H. Graham (Ed.), Vision and visual perception (pp. 251-320). New York: John Wiley.

Campbell, F. W. & Durden, K. (1983). The visual display issue: A consideration of its physiological and clinical background. Ophthalmic and Physiological Optics, 3, 175-192.

Campbell, F. W. & Robson, J. G. (1968). Application of Fourier analysis to the visibility of gratings. Journal of Physiology, 197, 551-566.

Creed, R. S. & Ruch, T. C. (1932). Regional variation in sensitivity to flicker. Journal of Physiology, 74, 407-423.

Dunlop, K. (1915). The shortest perceptible time interval between two flashes of light. Psychological Review, 22, 226-250.

Efron, R. (1970). The relationship between the duration of a stimulus and the duration of a perception. Neuropsychologia, 8, 37-55.

Fukuda, Y. & Stone, J. (1974). Retinal distribution and central projections of Y-, X-, and W-cells of the cat's retina. Journal of Neurophysiology, 37, 749-772.

Ginsburg, A. (1978). Visual information processing based on spatial filters constrained by biological data. AFAMRL Technical report, AFAMRL-TR-78-129.

Graham, N. & Nachmias, J. (1971). Detection of grating patterns containing two spatial frequencies: A comparison of single channel and multiple channel models. Vision Research, 11, 251-259.

Hecht, S. & Verrijp, C. D. (1933). Intermittent stimulation by light. III. The relation between intensity and critical fusion frequency for different retinal locations. Journal of General Physiology, 17, 251-265.

Hoffman. K. P., Stone, J., & Sherman, S. M. (1972). Relay of receptive field properties in dorsal lateral geniculate nucleus of the cat. Journal of Physiology, 35, 518-531.

Kietzman, M. C. (1967). Two pulse measures of temporal resolution as a function of stimulus energy. Journal of Optical Society of America, 57, 809-813.

Kolers, P. A., & Regner, B. S. (1960). On visual masking (Metacontrast): Dichoptic observations. American Journal of Psychology, 73, 2-21.

Lichtenstein, M. (1961). Phenomenal simultaneity with irregular timing of components of the visual stimulus. Perceptual and Motor Skills, 12, 47-60.

Mahnecke, A. (1958). Foveal discrimination measured with two successive light flashes: A psychophysical study. Acta Ophthalmologica, 36, 3-11.

McDougall, W. (1904). The variation of the intensity of visual sensation with the duration of the stimulus. British Journal of Psychology, 1, 151-189.

Pieron, H. (1923). Les Problemes psychophysiologiques de la perception du temps. Annee Psychologique, 24, 1-25.

Sperling, G. (1965). Temporal and spatial visual masking. I. Masking by impulse flashes. Journal of the Optical Society of America, 5, 541-559.

Uttal, W. R. (1981). A Taxonomy of visual processes. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Weisstein, N. (1972). Metacontrast. In D. Jameson & L. M. Hurvitch (Eds.), Handbook of Sensory Physiology (pp. 233-272). New York: Springer-Verlag.

Table 1

Mean Differences Between Pre and Post 2PR Threshold Measures for Print and Video Sessions in Experiment 1.

		Condition A (Print - Video)		Condition B (Video - Print)	
		Fovea	Periphery	Fovea	Periphery
Print	M	0.85	9.58	1.31	8.30
	SD	2.57	14.73	2.17	8.30
Video	M	1.82	-16.18	2.37	-14.61
	SD	7.01	16.58	2.81	17.75

Table 2

Mean Differences Between Pre and Post 2PR Threshold Measures for Print and Video Sessions in Experiment 2.

		Condition A (Print - Video)		Condition B (Video - Print)	
		Fovea	Periphery	Fovea	Periphery
Print	M	-1.11	4.47	0.23	24.58
	SD	10.92	52.00	5.86	36.41
Video	M	-1.76	-6.79	-1.94	-25.77
	SD	3.60	42.90	6.78	30.33

Table 3

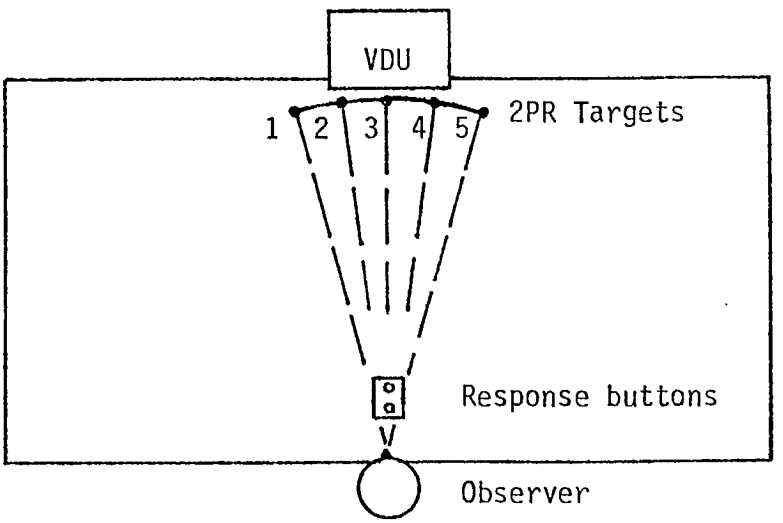
Mean Differences Between Pre and Post 2PR Threshold Measures for Print and Video Sessions in Experiment 3.

		Periphery
Print	M	5.37
	SD	19.03
Video	M	-18.52
	SD	21.39

Figure 1

Apparatus schematic and luminance profile for 2PR presentations.

Apparatus Schematic



Luminance Profile for 2PR Presentations (in milliseconds)

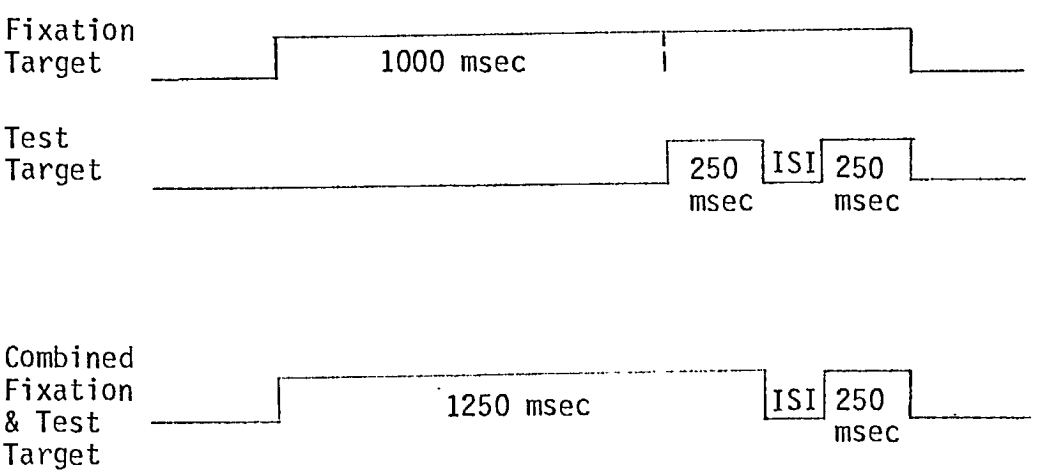


Figure 2

Contrast sensitivity for pre and post measures as a function of frequency in Experiment 1.

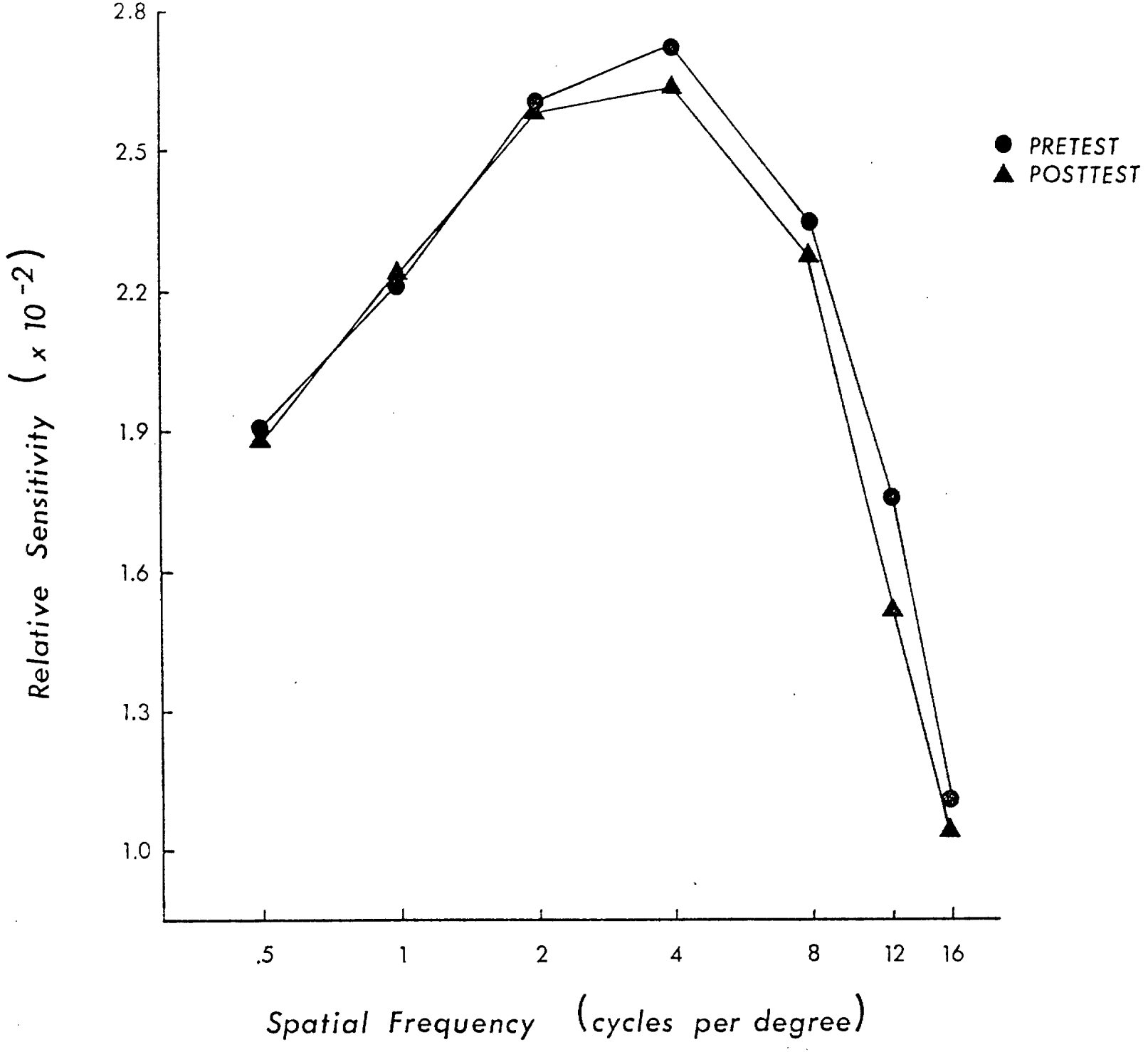

2.8
2.5
2.2
1.9
1.6
1.3
1.0
Relative Sensitivity (x 10⁻²)
.5
1
2
4
8
12
16
Spatial Frequency (cycles per degree)
PRETEST
POSTTEST

Figure 3

Contrast sensitivity for pre and post measures in the video condition as a function of frequency in Experiment 2.

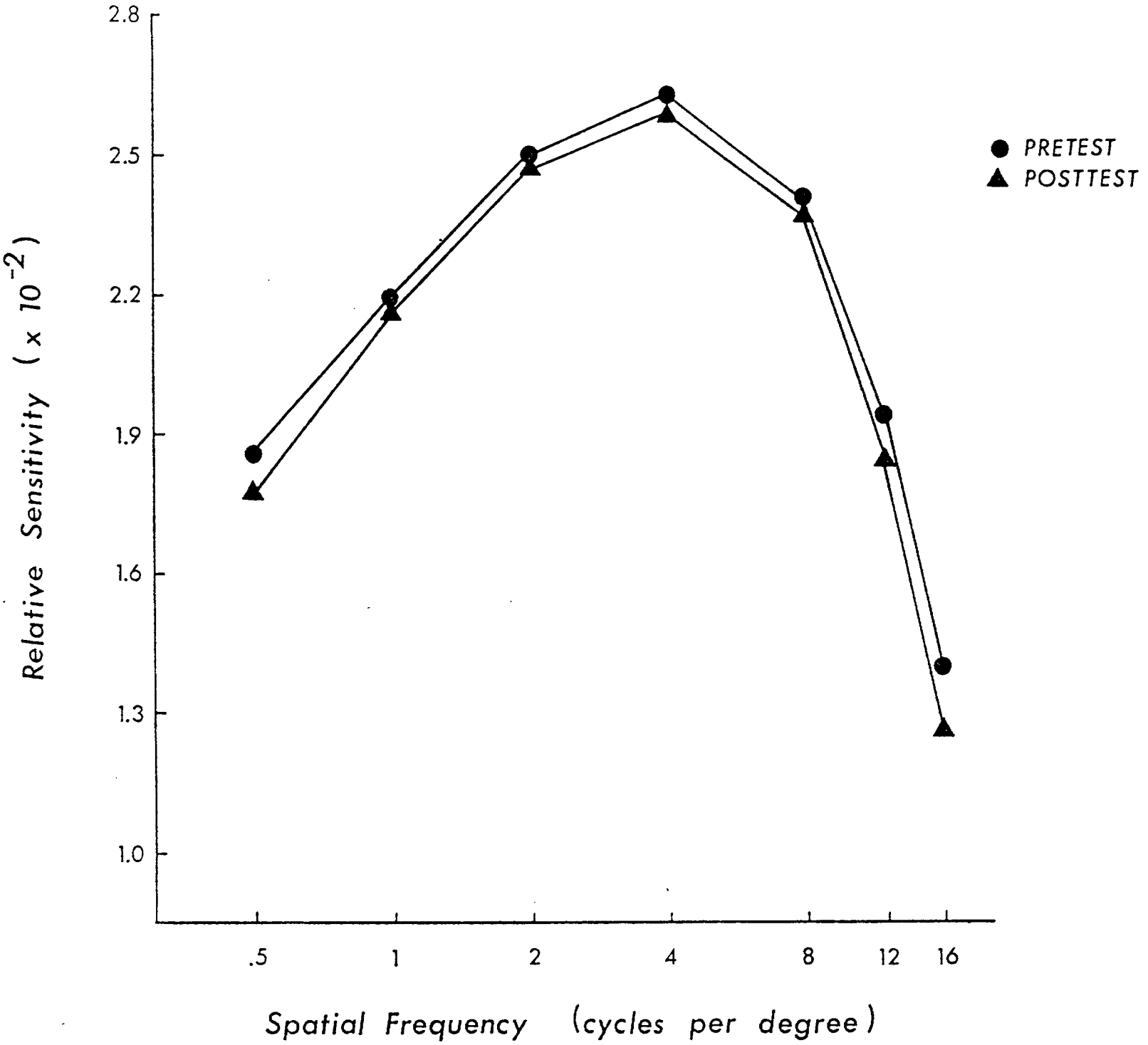
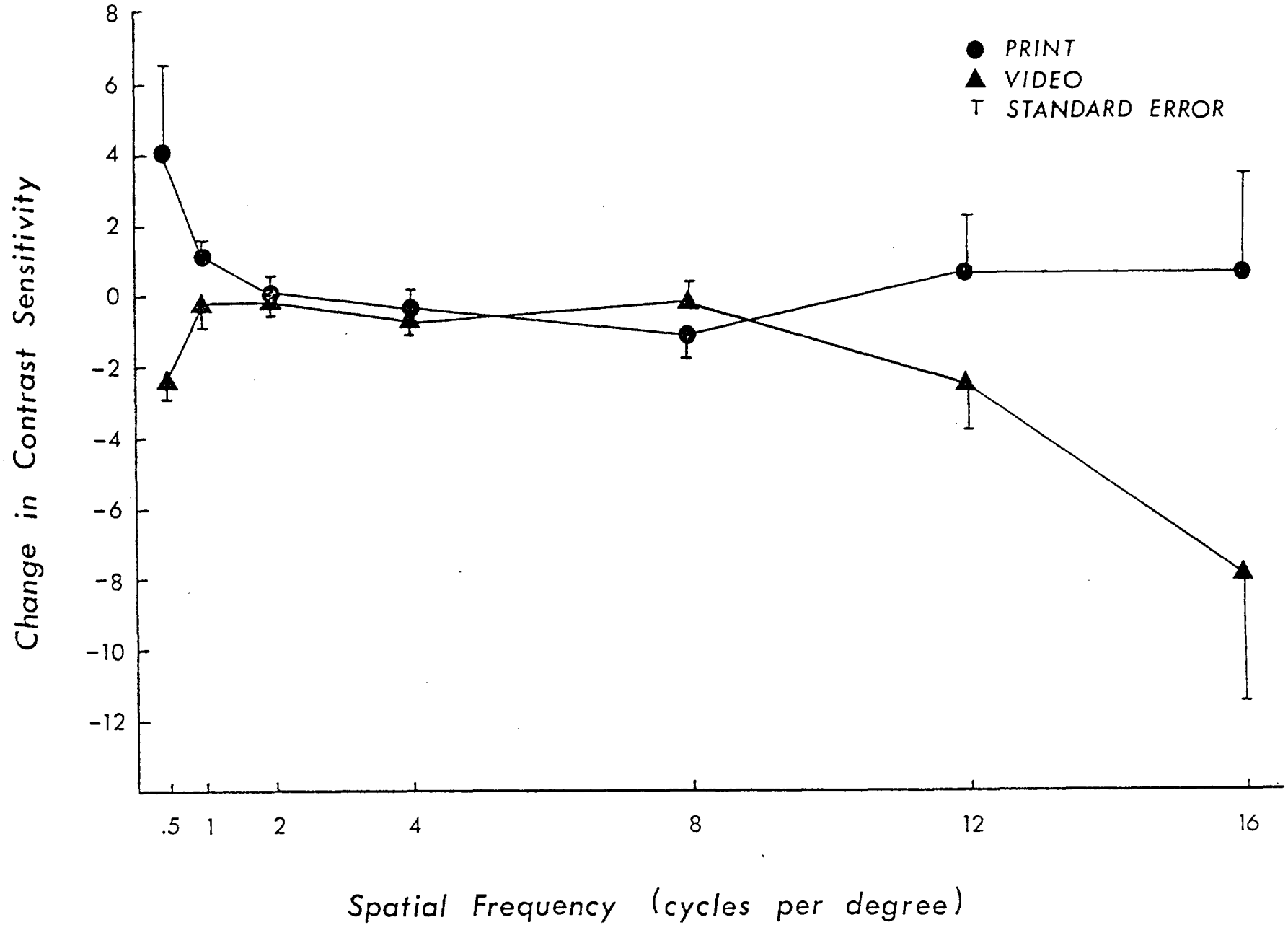

2.8
2.5
2.2
1.9
1.6
1.3
1.0
Relative Sensitivity (x 10^-2)
PRETEST
POSTTEST
.5
1
2
4
8
12
16
Spatial Frequency (cycles per degree)

Figure 4

Pre-Post threshold changes for video and print sessions as a function of frequency in Experiment 2.


PRINT
VIDEO
STANDARD ERROR
Change in Contrast Sensitivity
8
6
4
2
0
-2
-4
-6
-8
-10
-12
.5
1
2
4
8
12
16
Spatial Frequency (cycles per degree)

ACKNOWLEDGMENT

The software and instrumentation for these experiments were developed with the expert assistance of Murray Linton. Marni Turnbull assisted materially in the conduct of the experiments and in data collection. The assistance of both is acknowledged in the preparation of this report.