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Away from a unisex psychology: individual differences in visual sensory and perceptual processes

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Abstract. Four tests of visual perception were given to twenty-five men and twenty-five women. These were a test of acuity, threshold for four field positions, visual persistence, and a measure of comfortable brightness. Subjects also completed five personality questionnaires. In most measures, differences were found to be related to sex rather than to personality factors. In fact, the analyses performed suggest that personality tests do not measure equivalent processes in men and women. Correlational analysis showed all visual functions to be independent of one another with the exception of photopic acuity and scotopic threshold, which were highly correlated. Two new findings on the visual system emerged which have not been reported elsewhere: (i) Four distinct dark adaptation curves were produced, and have been labeled as exponential, flat-exponential, linear, and plateau. All subjects fell into one of these categories and showed a consistent trend to exhibit these curves for *all* field positions. (ii) Highly significant differences were found in sensitivity for the four visual fields, the upper field was superior, followed by the right, then left, with the lower visual field considerably poorer.

1 Introduction

In a recent study (McGuinness 1972) a large effect of sex was found in three out of four parameters of hearing. This finding considerably extends the range of previous studies on sex differences in hearing (Corso 1959; Eagles et al 1963; Elliott 1971; Hull et al 1971). Although the data on sex differences in hearing are sparse, they are nonetheless consistent and convincing, and show women to be more sensitive. Comparable studies on individual differences in the visual modality are lacking. It is known only that visual acuity both for static and for moving targets is greater in males (Burg and Hulbert 1961; Burg 1966; Roberts 1964).

The experiment reported here has been designed to remedy this deficiency and to determine whether performance on one visual task is related to performance on another. Four tests of primary visual capacity were employed: a test of binocular scotopic threshold, a test of photopic acuity, a test of persistence in the visual system of a revolving line of light produced by a stroboscope, a phenomenon originally noted by Charpentier (1891; cited in Rubin and Walls 1969) and reexamined recently by Allport (1970) and Dixon and Hammond (1972). A final test was of subjective judgement of light intensity.

In the case of audition, it has been shown that correlations between hearing abilities (McGuinness 1972) produce no reliable relationships between performances on the various tests. While a lack of correspondence between various aspects of visual performance might be expected, it is possible that a relationship exists between the visual and auditory modes where these are comparable. Therefore the visual experiment was designed to complement the experiment on audition. It was possible to procure many of the subjects originally tested to assess this possibility.

Studies investigating the relationship of personality factors to individual differences in perception have largely ignored sex differences. The reader is referred to a collection of findings (Nebylitsyn and Gray 1972) which illustrates a lack of consistency in

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personality effects. This raises the question of whether certain contradictions in results are due to the inadequacies of the tests themselves, or are due in part to the lack of control over the effect of sex. In the experiment on hearing, personality was found to relate to those measures for which judgement was less constrained by peripheral factors, but only when the sexes were considered separately. The battery of tests was enlarged in this study to include the EPI (Eysenck and Eysenck 1964) as well as the IPAT tests used previously (Cattell et al 1954; Scheier and Cattell 1961; Cattell and Scheier 1963). These particular tests were chosen because they provide a reliable measure of robust second-order factors, such as extraversion and neurotism, and also because there is a large body of behavioural data related to them.

Finally, it must be stressed that in experiments on the visual system the combination of the problems encompassed by the physics of light and visual optics present many difficulties in measurement (Pirenne 1962). The results reported here do not claim to advance any precise data on such problems as the differing properties of rods and cones with respect to sex, or to variations in pupil diameter, etc. While the strictest possible control and standardization were maintained, the central task of this experiment was to determine phenomenological representation, e.g. *the experience of the subject under natural conditions of viewing.* To keep the record of subjective experience consistent, all responses were limited either to manual operations by the subject or to single word replies.

2 Method

2.1 *Subjects*

The subjects were fifty undergraduate students (twenty-five men and twenty-five women) with an age range of eighteen to twenty-five years. The mean age was 19·8 years. Thirty subjects had participated in the previous experiment on hearing. These subjects performed in each experiment at the same time of day. The subjects were all volunteers and were paid for their participation. They were recruited from highly selective departments, medicine and psychology, and it was assumed that intelligence was uniformly high.

2.2 *Apparatus*

(i) The experiment was carried out in an acoustically tiled windowless room of $\sim 4 \times 5$ m^2. Light levels were therefore constant (27·4 cd m^{-2}) over each day of testing.
(ii) *Acuity* was measured by means of two Snellen eye-charts (viewing distance 3 m), the letter and E charts familiar to most people as the traditional optician's eye chart. Both charts are devised so that the subscaled visual angle visible at 20 ft (American version) or 6 ft (English version) is the criterion for normal vision. This is derived from the scale based on the topmost letter, which subtends 10 min of arc. These were constantly illuminated by an incandescent flood light of 150 W. This produced a photometric reading at source of 34·5 cd m^{-2}.
(iii) *Threshold.* A tungsten filament lamp attached to a variable-control lamp driver illuminated a 25 cm diameter circular disc of pot opal glass. The glass was screened from the subject by a 30 cm diameter black metal shield into which was cut a 1 cm^2 slot. The slot, which appeared at 20 deg of visual angle from the fixation point at all positions, was covered by a number 3 neutral density filter (1 : 1000). The metal disc revolved in a clockwise direction and was driven by a small Mullhard motor operating at 10 rev min^{-1}. A panel with four push buttons allowed the presentation of the stimulus in one of four positions: centre top, centre bottom, left, and right.

From the subject's viewing position at 30 cm, he saw a dim red fixation light placed at the centre of the shield. The subject viewed the fixation light and stimulus through a binocular visor which supported his forehead and upper face.

The apparatus was encased in a rectangular box with a tightly fitting lid which was painted black inside.

Linearity was assessed with the aid of an SEI photometer. The range of illumination at source was measured in foot-lamberts. These readings were converted to millilamberts x $-1:1000$, which produced a range of approximately 10^{-5}–10^{-1} millilamberts. The variable control was linear to the first setting. All readings for this setting were subsequently corrected for nonlinearity and all data were transformed into a numerical log scale for ease of computation. The total variable control range was 0–50, with larger units of 1–10. A refocusing lens was omitted from this apparatus, as all subjects were photopically dark-adapted before the start of the experiment.

(iv) *Visual persistence.* The details of this apparatus are available in Allport (1970) and Dixon and Hammond (1972), and so only a brief description will be given here. An opaque disc surfaced in stiff black paper, into which a radial slot was cut (10 cm x 0·5 cm), was rotated at 1 rev s^{-1}. A stroboscope set behind the disc illuminated the slot and a small central fixation point. To produce a phenomenological difference in the number of lines seen by the subject, the stroboscopic flash rate was altered in the range 600–2700 flashes min^{-1}.

Luminance levels were approximately 34·5 cd m^{-2} at source (strobe lamp), but light levels at subject were difficult to estimate in the dark condition. In the light condition (room at 27·4 cd m^{-2}) no change in luminance was produced when the apparatus was switched on owing to the small area illuminated.

(v) *Brightness.* A sealed beam 12 V headlamp of 375 W maximum was inset at the rear of a tubular sleeve 15 cm in diameter and 32 cm long. The sleeve was painted white inside. The headlamp was wired into a Lyons Variac control which produced a reading of 0–250 W. The Variac control was entirely linear over the range employed, 3·45–3460 cd m^{-2}.

2.3 *Procedure*

The order in which men and women participated in the experiment was random, with the exception that the thirty subjects in the previous experiment came at the same time of day. All subjects performed the tests in the same order.

(i) *Acuity.* After 3 min of adaptation to the room illumination the subject took a test of visual acuity, using both the Snellen letter and E charts. Subjects were instructed first to read two lines above normal criterion (6/6), and were then tested in an ascending or descending fashion depending upon performance. Each eye was tested separately without spectacles or contact lenses, then both eyes together, and the subject was tested with spectacles as a check on their accuracy for the subject's use and for further information if needed. The subject's score was determined by the reading for a line having a maximum of one error.

(ii) *Personality tests.* Next the subject was asked to fill out the five personality scales. During this period the eye-chart lamp was switched off, and the subjects spent approximately 15 min on this task in normal room illumination.

(iii) *Threshold.* When the tests were completed, the subject was dark adapted for 7 min and the threshold test began. This was carried out with unaided vision in all cases, and with no artificial pupil. The subject pressed his forehead and upper face against the viewing visor and was told to fixate the dim red spot. It was emphasized that owing to the properties and distribution of rods and cones, the subject's best strategy would be to maintain central fixation, and that detectability would diminish if he directed his gaze to the periphery. He was told that the stimulus, a patch of white light, would appear in one of four positions in a random sequence, and that his task was to respond by saying 'up', 'down', 'right', 'left'. If he could see nothing he was asked to guess. Each trial was signaled by a faint motor click. The stimulus presentation was constant, and the subject had 15 s to make his decision before the stimulus position was changed. In this sense, the experiment was self-paced, each stimulus following the preceeding one as soon as a reply was forthcoming.

At the start of the experiment the subject was given fully visible presentation of the light in each of the four positions. The illumination was increased until a definite response was made. The initial trials were used to establish the subject's threshold for the four positions. This took 3 min, and these readings were not assessed as data. Following this the light intensity was continually diminished over trials to ensure a detection rate of approximately 75%. Catch trials were also employed throughout. As the rate of dark adaptation was different for each of the four positions (as determined by a pilot study), alterations in intensity were commensurate with this. All new intensity settings were derived from the response given to the previous setting in that position only. The subject continued to respond until a total of 25 min had elapsed, which produced a reasonable, though not total, approximation to rod dark adaptation. Time was carefully noted throughout.

(iv) *Visual persistence.* Immediately after the threshold test the subject was seated on a chair 60 cm from the visual persistence apparatus. The apparatus was set in motion with the display operating at the lowest flash rate. The subject was asked to tell the experimenter how many lines he saw. He was told that the number of lines was going to increase and that he was to report immediately each point at which he *distinctly* saw an additional line. The flash rate was altered in ascending and descending directions. As each change in the number of lines seen was reported, the flash rate was recorded. When the subject had completed two ascending and two descending trials, the room lights were switched on and the subject was light adapted for 3 min. The test was then repeated in a light adapted state. Subjects who wore spectacles were allowed to wear them during this part of the experiment at their own discretion. There were no detectable differences in the number of lines reported between trials with and without aided vision.

(v) *Brightness.* Next the subject was seated in a chair 60 cm from the headlamp display tube. He was asked to adjust the Variac control, which was below his left hand and out of sight, to a level of light which he felt he could look at indefinitely. The word 'indefinitely' was stressed and repeated. The subject turned the control to the level which matched his criterion. The control was then reset to a random level preceeding light emittance, and the subject had two more trials at the same criterion. This criterion was finally adopted after trying a number of approaches, because it produced nearly uniform responses over trials. The brightness test concluded the experiment.

Details of any history of abnormal vision, the subject's degree of myopia or hyperopia, astigmatism, and information on whether the subject wore spectacles or contact lenses were noted. Female subjects were questioned as to the day of their menstrual cycle, and whether or not they were taking the contraceptive pill.

3 Results

3.1 *Acuity*

Each subject's score was computed as the median of two scores of both eyes during unaided vision, one taken from the letter chart and one from the E chart. A subject who scored 6/6 on the letter test, but 6/12 on the E test, would receive a score of 6/9, or 9. Although the E chart is considered the more reliable (Rubin and Walls 1969), this combined method was adopted to reduce excessive ties. Subjects' scores could range from 6/4 to 6/60. The data are not ordinal and thus could not be assessed by a parametric analysis. A Mann–Whitney *U* test was employed to measure sex differences. This resulted in a $z = 1\cdot79$, which is significant at $p < 0\cdot05$ (one-tailed test), with males having better acuity than females. The difference in acuity resulted from the males being underrepresented at the high end of the scale (scores of 6/18 or worse: M = 4; F = 11) and overrepresented at the low end (scores of 6/5 or better: M = 10; F = 6). The mean score for males was 6/9, and for females 6/18. Best-eye performance, on the basis of individual scores for each eye, showed little difference between the eyes in both men and women. Where differences were noted, neither left- nor right-eyed superiority was evident.

3.2 *Threshold*

A pilot study revealed that subjects dark-adapted at different rates for the four positions measured. Thus dial changes were regulated separately for each position. Analysis of catch trials showed that subjects were not able to guess the position of the slot with any degree above chance.

Data were converted to a simple numerical scale and the results were plotted separately for each subject for each of the four positions. Freehand curves were drawn in each case, for a total of two hundred curves. The data were analyzed over the final 15 min only and scores derived from the curves were tabled for each subject at 11, 13, 15, 17, 19, 21, 23, and 25 min for each position. The data were then analyzed with a three-way repeated measures analysis of variance.

Sex differences were not significant but both position and time effects were significant beyond $p < 0\cdot001$ (table 1). The position x time interaction was also significant at $p < 0\cdot001$. Because of the significant triple interaction, a further analysis was computed for left–right positions and up–down positions separately. These results are illustrated in table 2.

Table 1. Analysis of variance for dark adaptation; four visual fields combined.

Source	d.f.	Mean square	*F*
Sex	1	61·19	0·64
Position	3	350·16	75·65[a]
Time	7	808·25	287·03[a]
Sex x position	3	8·14	1·76
Sex x time	7	5·24	1·86
Position x time	21	1·13	3·0[a]
Sex x position x time	21	0·82	2·17[a]

[a] $p < 0\cdot001$.

Table 2. Analysis of variance for dark adaptation; 2 x 2 visual fields.

Source	d.f.	Left–right		Up–down	
		mean square	*F*	mean square	*F*
Sex	1	15·16	0·29	51·38	1·05
Position	1	35·07	39·43[a]	878·22	119·12[b]
Time	7	440·44	231·25[b]	369·51	273·56[b]
Sex x position	1	1·31	1·47	17·75	2·41
Sex x time	7	3·47	1·82	2·27	1·69
Position x time	7	0·15	0·93	1·54	2·89[a]
Sex x position x time	7	0·56	0·33	1·90	3·56[b]

[a] $p < 0\cdot01$; [b] $p < 0\cdot001$.

This analysis preserves the findings noted above, but the triple interaction still appears in the up–down condition, indicating that no simple generalizations can be made about these results. However, for the left–right field effects, it is possible to state that the absence of a significant second-order interaction indicates that both position and time main effects are involved, with subjects increasing in dark adaptation over time and the speed of this process varying over field position. An illustration of the data (figure 1) shows these effects clearly. This figure also illustrates the position effects, with the best performance occurring in the up condition, next right, followed by left, and worst in down.

The variance for subjects was large with the sexes exhibiting unequal variances. An F test for equal variance was found to be significant at $p < 0{\cdot}05$. As no nonparametric test can handle the number of levels and the number of conditions, a simple analysis was carried out in order to determine whether or not the final curves produced by men and by women in each field position could have occurred

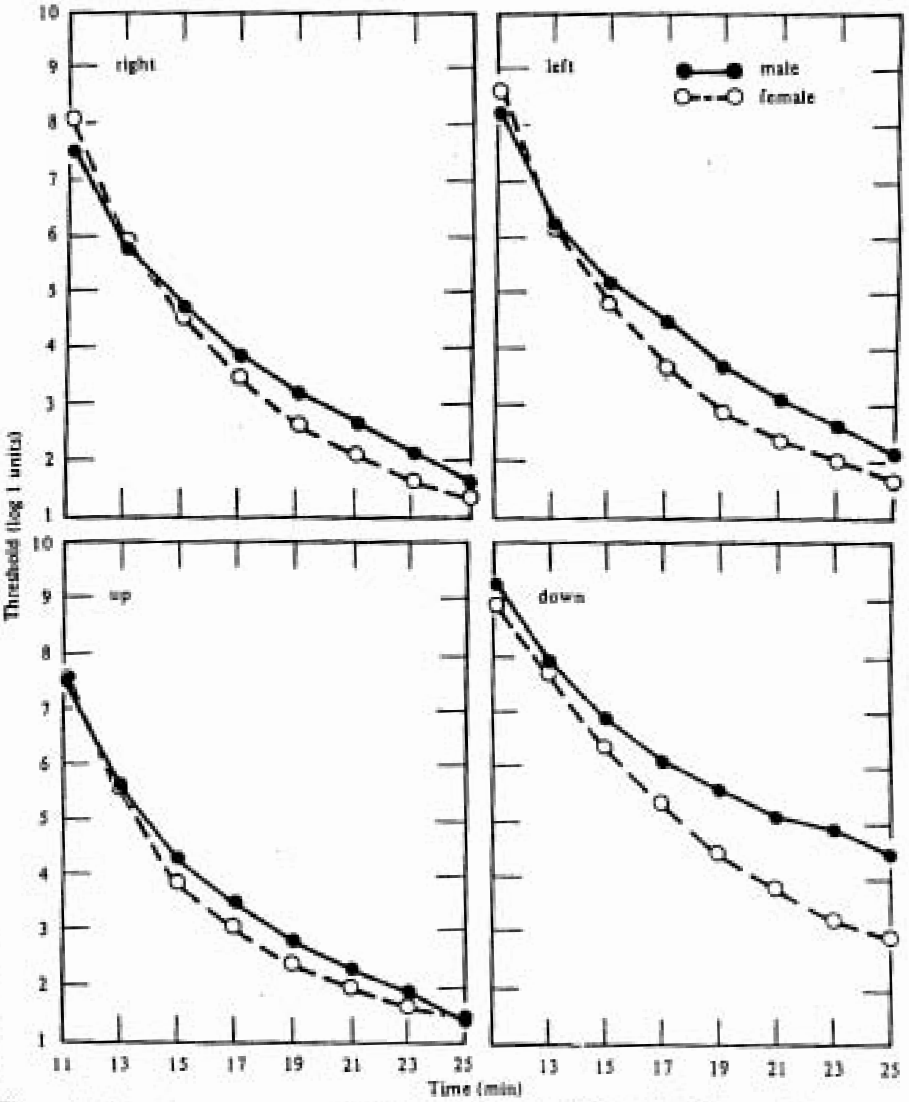

Figure 1. Scotopic dark adaptation curves for the four field positions (twenty-five males, twenty-five females).

by chance alone. The mean scores over times and positions were analyzed with a Wilcoxon matched-pairs test. This analysis showed that both the up position ($T = 3$; $p < 0{\cdot}05$) and the down position ($T = 0$; $p < 0{\cdot}01$) are significant but that there is no significant difference between the sexes in the right and left fields ($p < 0{\cdot}20$).

In a post hoc analysis mean scores were also computed for all subjects with near normal or better visual acuity. This group included thirteen men and ten women, and these data are plotted in figure 2. A Wilcoxon test applied to these data showed that, when acuity was held constant, females were superior at each field position ($T = 0$; $p < 0{\cdot}01$, in all cases). These results indicate that there may be some relationship between acuity and dark adaptation, findings which will be discussed under correlations.

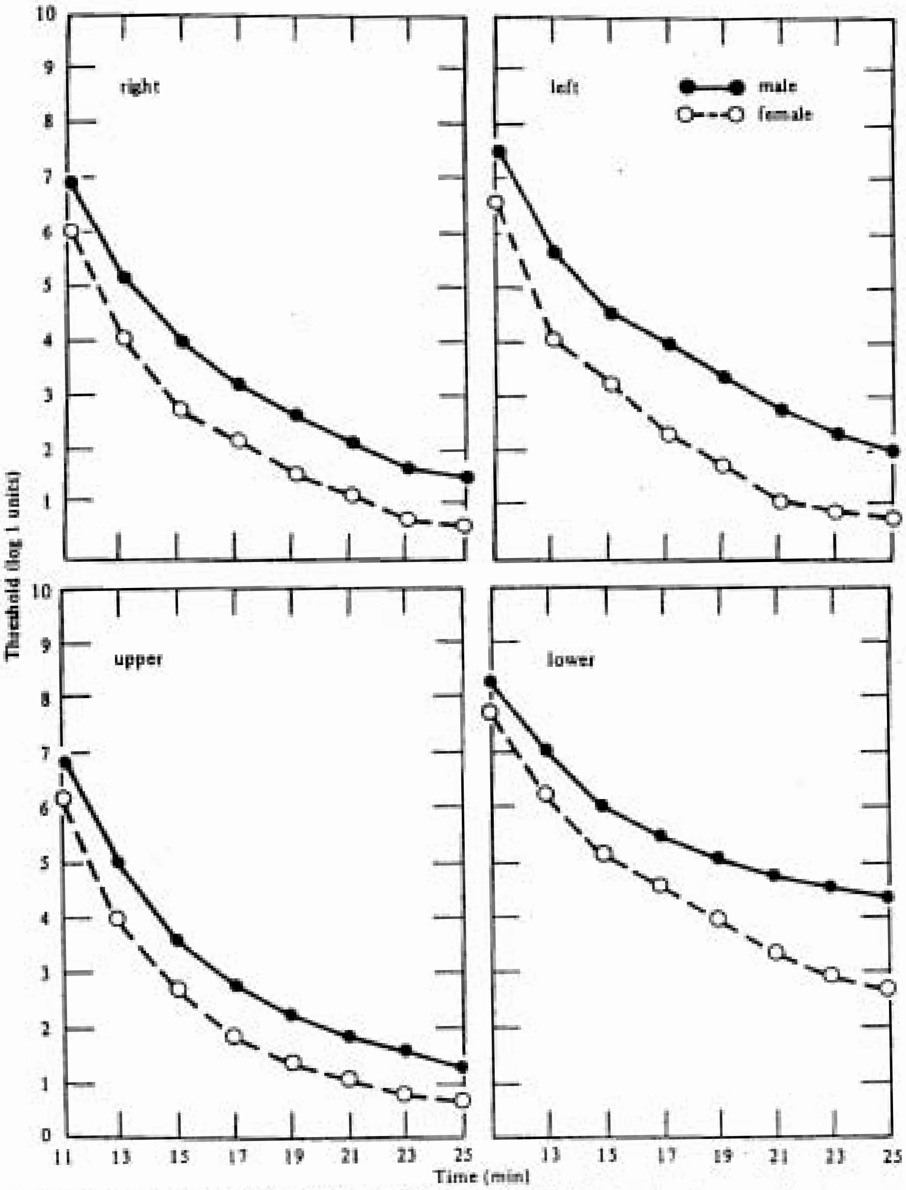

Figure 2. Scotopic dark adaptation curve for subjects with superior to normal acuity only (thirteen males, ten females).

An additional finding emerged from this investigation. When plotting individual curves, it was noted that they were remarkably free of noise. However, while the majority of curves looked identical to the exponential curves illustrated in figures 1 and 2, three further types of curve appeared with a certain amount of regularity. These have been labeled by the author as flat-exponential, linear, and plateau, and their significance will also be discussed in the section on correlations. Just under half of the total subject group exhibited these three types of curve.

3.3 *Visual persistence*

Data from this test were analyzed using the formula:

visual persistence = $(n-1)$ interstimulus interval

where
n is the number of lines reported, and
the interstimulus interval is calculated as the reading of the number of flashes ms^{-1},

each time there was a reported change in the number of lines seen by the subject. (For a more comprehensive discussion, see Dixon and Hammond 1972.) Mean scores were derived from the data recorded when two, three, and four lines only were reported, as this was the range that included all subjects. Dark and light conditions were computed separately and the data analyzed with a two-way repeated measures

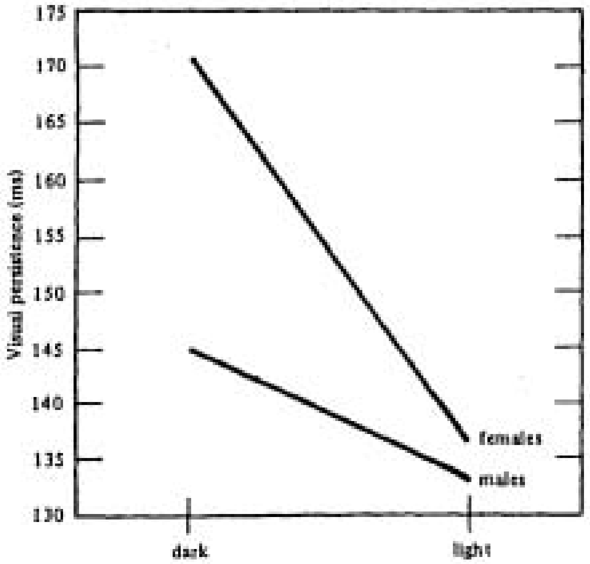

Figure 3. Visual persistence in two conditions of light.

Table 3. Analysis of variance for visual persistence.

Source	d.f.	Mean square	F
Between subjects			
sex	1	654·5	<1
error S/A	48	1517·8	
Within subjects			
light	1	3577·5	29·27*
sex/light	1	2767·3	22·64*
error SB/A	48	122·2	

* $p < 0{\cdot}001$.

analysis of variance. The sex difference main effect was not significant [$F(1, 48) < 1$], whereas the dark versus light condition was significant at $p < 0{\cdot}001$. A significant two-way interaction was found and has been illustrated in figure 3, where it can be seen that women had significantly greater visual persistence in the dark, but that the sex difference disappeared in the light. The results of the analysis of variance are given in table 3.

3.4 *Comfortable brightness*

As stated earlier, subjects were remarkably consistent in setting dial positions when this particular criterion was adopted. Mean scores were derived from the three trials and were analyzed with a Mann–Whitney U test, as scores were nonnormally distributed. The results produced a $z = 1{\cdot}80$, which just misses significance for a two-tailed test ($z = 1{\cdot}96$; $p < 0{\cdot}05$). Men are less tolerant of light than women are. The mean comfortable level for the men was 3·45 cd m^{-2} and for the women, 6·20 cd m^{-2}.

It was apparent that at the lowest setting the white light became faintly yellowish, and it is conceivable that the change in wave length might affect choice behaviour between the sexes, although there is no reason to suppose that a marginal change in wavelength would bias brightness judgement. Since several subjects set their criterion as the maximum setting (3460 cd m^{-2}), it was not possible to control for this effect by using a neutral density wedge.

3.5 *Correlational data*

Correlations were computed for all tasks and for personality measures, and the sexes were analyzed separately.. Tables of results were produced for forty-one variables: 8 x 4 positions for threshold, acuity, visual persistence under dark and light conditions, brightness, and five measures of personality. These results will be discussed systematically in this section, but will be illustrated only where informative.

(i) *Threshold.* For the 1024 correlations for dark-adaptation scores over time and four field positions, nearly all correlations were significant at $p < 0{\cdot}05$, and the majority at $p < 0{\cdot}01$ for both sexes. These findings illustrate that subjects not only had very individual dark-adaptation curves over the four positions, but that they were also consistent in their responses throughout the trials.

(ii) *Acuity and threshold.* Correlations for men and women are presented in table 4. Almost all correlations over all times and position were significant beyond $p < 0{\cdot}05$ for the women. For the men, nineteen correlations failed to reach the $p < 0{\cdot}05$ level, but all were positive.

Table 4. Correlation of acuity and threshold in the four stimulus positions over eight time periods.

Men				Women			
right	left	upper	lower	right	left	upper	lower
0·26	0·35^{a}	0·31	0·47^{a}	0·55^{b}	0·52^{b}	0·51^{b}	0·44^{a}
0·26	0·38^{a}	0·43^{a}	0·46^{a}	0·62^{b}	0·55^{b}	0·54^{b}	0·48^{a}
0·32	0·33	0·47^{a}	0·47^{a}	0·66^{b}	0·62^{b}	0·45^{a}	0·50^{b}
0·36^{a}	0·24	0·50^{b}	0·43^{a}	0·65^{b}	0·67^{b}	0·47^{a}	0·45^{a}
0·38^{a}	0·23	0·55^{b}	0·38^{a}	0·61^{b}	0·62^{b}	0·43^{a}	0·37^{a}
0·36^{a}	0·28	0·52^{b}	0·34	0·51^{b}	0·41^{a}	0·45^{a}	0·35^{a}
0·35^{a}	0·23	0·46^{a}	0·25	0·48^{b}	0·40^{a}	0·44^{a}	0·14
0·27	0·19	0·24	0·06	0·45^{a}	0·33	0·42^{a}	0·01

[a] $p < 0{\cdot}05$; [b] $p < 0{\cdot}01$

A further comparison was made by categorizing subjects' acuity according to the type of dark adaptation curve they exhibited. Subjects produced the same type of curve in all visual fields. These four types of curve are illustrated schematically in figure 4 along with the number of subjects who fell into each category. A Kruskal–Wallis analysis showed that when subjects' acuity scores were placed in categories of normal-exponential, flat-exponential, and a combination of linear and plateau, there was a significant difference between them ($p < 0{\cdot}01$). Mid-range acuity was found in the normal curve, better acuity in the flat-exponential group, and considerably worse in the linear and plateau groups. The mean Snellen scores for subjects were: exponential, 6/12; flat-exponential, 6/6; linear and plateau, 6/30.

(iii) The remainder of the findings are given in table 5, where it can be seen that of the main effects investigated, the only significant relationship was between the two visual persistence measures. These correlations were significant for each sex at $p < 0{\cdot}001$. illustrating that this phenomenon was consistent within individuals over varying conditions of light. Visual persistence, however, was not correlated with dark adaptation ($r < 0{\cdot}10$).

(iv) *Personality*. The relationships between personality, acuity, visual persistency and brightness are also presented in table 5. In the female sample only one correlation reached significance, and that was between extraversion and comfortable brightness level ($r = 0{\cdot}44$; $p < 0{\cdot}05$), extravert women preferring higher levels of light than introverts. This correlation was found only on the IPAT scale.

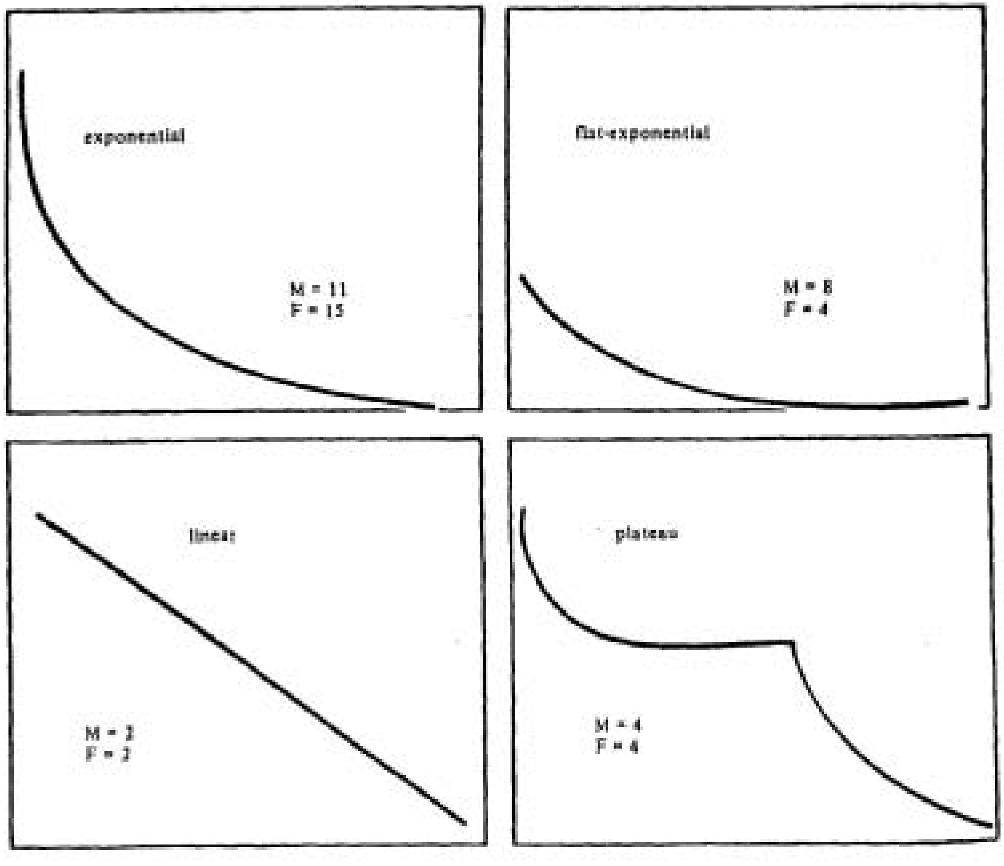

Figure 4. Four types of dark adaptation curves.

4 Discussion

Sex differences were apparent in all four parameters investigated, with the effect of sex considerably more marked in all conditions than the effect of personality variables.

The finding that males have better visual acuity than females is in accord with Roberts (1964), who found similar differences and distributions on a sample of 6672 subjects with an age range of eighteen to seventy-nine years. Roberts found that the male subjects were far less likely to be at the poorer end of the distribution and far more likely to be at the opposite end, an effect which became more noticeable with age. It is well-known that there are many 'acuities' and that the Snellen test may not be the best measure to employ. However, these results are in line with other acuity measures (Burg and Hulbert 1961; Burg 1966) in which men are superior.

At the present time there is no explanation for this difference. It is possible that there are differences in lens muscle efficiency, which is strongly suggested by the aging effects noted by Roberts. However, visual acuity is also a property of the visual cortex and of the entire cone system. The finding that males quite frequently show superior-to-normal acuity argues for a more central explanation. This is unfortunately difficult to demonstrate in man, and unless nonhuman primates share these differences it may not be possible to assess where the effect is maximal.

Before discussing the sex differences at threshold, it is important to mention one of the three phenomena that emerged during the course of this study. This is the field-position effect during dark adaptation, where targets above and to the right of the subject were perceived with greater ease than targets to the left or below. In an investigation of monocular threshold for visual fields, DeGroot et al (1952) demonstrated strong field effects in three subjects. Their results for nasal and temporal fields are not applicable here, but their findings for upper and lower fields are very similar to the current results. Taken together, these findings suggest that rod distribution is uneven across the retina, with greater rod concentration in the lower retina. An explanation concerning the right–left field differences can only be inferred from tachistoscopic presentations in which right-field superiority of nonverbal stimuli has been attributed to the more peripheral effects of sighting dominance most commonly found in the right eye (Wyke and Ettlinger 1961). Recently in our laboratories we have also noted a strong tendency for right-eyed dominant subjects to spend more time on the right-field target in a binocular rivalry situation, but only for nonmeaningful stimuli such as colours or stripes (Passmore et al unpublished data).

Sex differences at threshold were not found to be significant when data were analyzed by an analysis of variance, except for the significant sex × time × position effect in upper and lower fields. However, the sexes exhibited unequal variances, and when the data were assessed nonparametrically, a sex difference was found for the upper and lower visual fields. Females were found to be consistently more sensitive over all field positions when subjects with normal acuity were assessed separately. These findings run counter to those reported by Ippolitov (1972), though he does not analyze his results by sex. An analysis of his data by the present author disclosed lower absolute visual thresholds for men ($p < 0{\cdot}03$). Ippolitov reports no details of his experimental procedure other than time, which could range up to 75 min. This makes comparison to this experiment difficult. It is possible that, if Ippolitov controlled pupil size or used a more reduced visual angle, these could produce a variation in performance between the sexes. Further investigation is required to clarify these issues.

In the visual persistence measure, women had significantly longer visual persistence in the dark, but did not differ from men in the light. This finding has two possible consequences. The first is that greater persistence gives a higher performance at

For men comfortable brightness level was significantly related to neuroticism on the IPAT ($r = 0{\cdot}40$; $p < 0{\cdot}05$) but not the EPI, and no relationship was found for extraversion on either test. However, extraversion was found to be related to visual persistence, and was significant on both scales in the dark condition at $p < 0{\cdot}05$, and in the light at $p < 0{\cdot}01$. No score on any personality factor was related to threshold over any position or time.

The absence of consistent effects for personality factors between the sexes strongly suggests that a considerable sex effect is built into the personality questionnaires themselves. An examination of the intercorrelations between the two questionnaires shows several anomalies. For women it appears that the two extraversion scales measure different things ($r = 0{\cdot}26$), whereas for men the two scales are highly correlated ($r = 0{\cdot}66$; $p < 0{\cdot}01$). There are other inconsistencies between the relationship of neuroticism and anxiety for the two sexes.

Table 5. Correlations for male and female subjects.

	Acuity	VP (dark)	VP (light)	Brightness	IPAT-E	IPAT-N	IPAT-A	EPI-E	EPI-N
Male subjects									
Acuity	1·00								
VP (dark)	−0·14	1·00							
VP (light)	−0·18	0·90[c]	1·00						
Brightness	−0·06	−0·12	−0·09	1·00					
IPAT-E	−0·07	0·40[a]	0·53[b]	0·16	1·00				
IPAT-N	0·23	0·15	0·04	−0·40[a]	−0·50[b]	1·00			
IPAT-A	0·30	0·11	0·00	−0·12	−0·10	−0·50[b]	1·00		
EPI-E	−0·12	0·46[a]	0·48[b]	0·09	0·66[b]	−0·22	0·06	1·00	
EPI-N	0·16	0·16	−0·01	−0·25	−0·16	0·62[b]	0·58[b]	−0·09	1·00
Female subjects									
Acuity	1·00								
VP (dark)	0·21	1·00							
VP (light)	0·26	0·79[c]	1·00						
Brightness	−0·14	−0·14	0·09	1·00					
IPAT-E	−0·09	−0·11	−0·02	0·44[a]	1·00				
IPAT-N	0·03	−0·02	0·08	0·02	0·16	1·00			
IPAT-A	−0·19	−0·02	0·12	0·08	0·35	0·03	1·00		
EPI-E	−0·12	−0·10	−0·20	0·23	0·26	0·01	0·02	1·00	
EPI-N	0·01	0·07	0·25	−0·11	−0·11	0·13	0·55[b]	−0·39[a]	1·00

[a] $p < 0{\cdot}05$; [b] $p < 0{\cdot}01$; [c] $p < 0{\cdot}001$.

Key:

VP is visual persistence. N is neuroticism.
E is extraversion. A is anxiety.

3.6 *Comparison between auditory and visual measures*

Scores for the subjects who participated in both experiments were analyzed and produced the following results.

(i) Auditory and visual thresholds were unrelated for either sex.

(ii) Comfortable loudness and comfortable brightness were significantly related in both sexes. For the men $r = 0{\cdot}46$ ($p < 0{\cdot}05$) and for the women, $r = 0{\cdot}58$ ($p < 0{\cdot}02$), both using Spearman's rho.

(iii) Pitch acuity and visual acuity bore no relationship to one another.

Lastly, no sex effects could be attributed to wearing contact lenses (the sexes equally divided), nor was any correlation found between performance and phases of the menstrual cycle or between performance and the contraceptive pill, as also was found in a previous study (McGuinness 1972).

4 Discussion

Sex differences were apparent in all four parameters investigated, with the effect of sex considerably more marked in all conditions than the effect of personality variables.

The finding that males have better visual acuity than females is in accord with Roberts (1964), who found similar differences and distributions on a sample of 6672 subjects with an age range of eighteen to seventy-nine years. Roberts found that the male subjects were far less likely to be at the poorer end of the distribution and far more likely to be at the opposite end, an effect which became more noticeable with age. It is well-known that there are many 'acuities' and that the Snellen test may not be the best measure to employ. However, these results are in line with other acuity measures (Burg and Hulbert 1961; Burg 1966) in which men are superior.

At the present time there is no explanation for this difference. It is possible that there are differences in lens muscle efficiency, which is strongly suggested by the aging effects noted by Roberts. However, visual acuity is also a property of the visual cortex and of the entire cone system. The finding that males quite frequently show superior-to-normal acuity argues for a more central explanation. This is unfortunately difficult to demonstrate in man, and unless nonhuman primates share these differences it may not be possible to assess where the effect is maximal.

Before discussing the sex differences at threshold, it is important to mention one of the three phenomena that emerged during the course of this study. This is the field-position effect during dark adaptation, where targets above and to the right of the subject were perceived with greater ease than targets to the left or below. In an investigation of monocular threshold for visual fields, DeGroot et al (1952) demonstrated strong field effects in three subjects. Their results for nasal and temporal fields are not applicable here, but their findings for upper and lower fields are very similar to the current results. Taken together, these findings suggest that rod distribution is uneven across the retina, with greater rod concentration in the lower retina. An explanation concerning the right–left field differences can only be inferred from tachistoscopic presentations in which right-field superiority of nonverbal stimuli has been attributed to the more peripheral effects of sighting dominance most commonly found in the right eye (Wyke and Ettlinger 1961). Recently in our laboratories we have also noted a strong tendency for right-eyed dominant subjects to spend more time on the right-field target in a binocular rivalry situation, but only for nonmeaningful stimuli such as colours or stripes (Passmore et al unpublished data).

Sex differences at threshold were not found to be significant when data were analyzed by an analysis of variance, except for the significant sex × time × position effect in upper and lower fields. However, the sexes exhibited unequal variances, and when the data were assessed nonparametrically, a sex difference was found for the upper and lower visual fields. Females were found to be consistently more sensitive over all field positions when subjects with normal acuity were assessed separately. These findings run counter to those reported by Ippolitov (1972), though he does not analyze his results by sex. An analysis of his data by the present author disclosed lower absolute visual thresholds for men ($p < 0 \cdot 03$). Ippolitov reports no details of his experimental procedure other than time, which could range up to 75 min. This makes comparison to this experiment difficult. It is possible that, if Ippolitov controlled pupil size or used a more reduced visual angle, these could produce a variation in performance between the sexes. Further investigation is required to clarify these issues.

In the visual persistence measure, women had significantly longer visual persistence in the dark, but did not differ from men in the light. This finding has two possible consequences. The first is that greater persistence gives a higher performance at threshold, and may be a compensating factor for women. This possibility can be eliminated by the finding that no visual persistence measure correlated with any measure taken during dark adaptation. These capacities are thus unrelated. Another consequence is that longer persistence could lead to a memory advantage in a Sperling type of paradigm (Sperling 1960), however, only in the dark.

A number of explanations of the visual-persistence effect have been put forward. Dixon and Hammond (1972) suggest that visual persistence is a product of the lateral inhibition mechanism and note that, during visual masking, persistence is reduced. However, while lateral inhibition seems clearly involved in masking or metacontrast (see Robinson 1971) it is not apparent how a lateral inhibition theory applies to visual persistence. Robinson (1968) states that stimuli which deviate more than 2–3 deg during masking of a test stimulus do not succeed in masking the initial trace. Since the line stimulus used here subtended a combined total of about 7 deg of visual angle, and was in continuous motion, a lateral inhibition explanation does not seem tenable.

Allport (1970) suggests that, because of subject and task differences found in his experiment, set or attention contributes to visual persistence, and he implicates more central systems. The change in results between men and women in dark and light conditions suggests that attention or set cannot explain the sex difference.

To clarify these findings a temporal mechanism must be sought which responds differently in photopic and scotopic conditions. Such a mechanism is found extremely early in the visual system. A particular wave, the late receptor potential (LRP), has been isolated from the electroretinogram. Its significance has been thoroughly discussed by Brown (1968). The LRP is of interest because it outlasts the stimulus and appears momentarily resistent to the onset of inhibition produced by the 'off cells' and the tonic hyperpolarization of the DC component. Brown has demonstrated that the LRP behaves quite differently when rods and cones are stimulated. In scotopic vision a considerably longer duration has been noted. This result helps to clarify the significance of the differences in the length of visual persistence during dark adaptation and in the light [an effect not only demonstrated here, but consistently found by others (Haber and Standing 1969, 1970; Allport 1970; Dixon and Hammond 1972)]. This is not to say that higher centres do not contribute to this effect. Numerous reports of neural responses which outlast the stimulus have been provided. Marshall et al (1943) have found repetition effects in the cat cortex following a single flash.

The results in general suggest that women have greater rod sensitivity to contrast and also that they show a greater rod LRP, which produces an additional temporal advantage. If this proves to be the case, then it appears that rod sensitivity is a within *sex* phenomenon, but is not specific to within *individual* comparisons, because of the absence of any significant correlation between visual persistence and dark adaptation.

Men appear marginally more sensitive to high levels of light than do women. By contrast women are more affected by loud levels of sound. The implications of this latter difference have been discussed (McGuinness 1974), and the arguments presented there may also apply to light intensity. Sex differences are thus an important factor to control in experiments where input amplitude is a critical variable, for example in experiments on habituation of autonomic responses. Another important consideration relates to the power function which operates across all modes as intensity is increased (Stevens 1961). The sex difference was found in the lowest end of the intensity range. It is possible that, when levels are increased above this point, the disparity between the sexes may become more noticeable as their power slopes begin to deviate further.

Stevens and Marks (1972) found that the *slope* of brightness estimation is not altered by using an artificial pupil, though it is possible that the sex difference in light sensitivity could be due to variations in pupil diameter. This possibility was ruled out by testing a group from the original sample with pupil diameter controlled at 2 mm. No change in the ordering of subjects was observed. Further to this, an explanation based on differences in pupil size would have to predict a relationship between lower thresholds (larger pupil) and lower tolerance of light due to a larger pupil. The data show the exact reverse of this trend, with females tending to have lower thresholds, but greater light tolerance.

The correlational data generally support the earlier prediction that visual functions are not related, with the exception of acuity and threshold. This correlation was unsuspected and has not been noted elsewhere. In fact, Rubin and Walls (1969) state: "It has never been found in laboratory investigations, that central visual acuity correlates highly with anything else ...". The absence of any significant correlations with acuity is not surprising when all subjects in visual experiments are screened for acuity as a condition for participation.

It thus appears that the unaided myopic or hyperopic subject will find his vision less efficient in the dark than someone with normal vision, possibly due to the effects of lens abnormality. However, subjects with better than normal eyesight had rapid dark-adaptation rates to very low threshold levels, the flat-exponential group. An explanation for this group in terms of lens-muscle malfunction is not tenable here, which leads to the possibility that there are general neural differences.

The findings for personality point out the importance of controlling for sex when any relationship between perception and personality is sought. As was mentioned previously, in the study on hearing, personality was related to hearing only at levels beyond initial processing, especially where subjective factors were more apparent. This finding was supported here. However, the relationship found between personality and the two visual measures to which it relates tells us more about the inadequacies of the tests than about the visual processes involved. It appears that extraversion means something quite different for men and women, and until questionnaire items are standardized separately for the sexes we will not be further enlightened.

One of the most intriguing results of this study was the significant positive correlation found between loudness and brightness judgement. This suggests that the perception of intensity is a higher level phenomenon unrelated to specific modalities. A monitoring of stimulus input levels, as well as the capacity to set consistent criteria for acceptance of these levels, suggests the operation of a control mechanism finely tuned to a system which monitors intensity. Such a neural system has been outlined by Pribram and McGuinness (1975), who presented evidence for a neural circuit involving the frontal lobes, the reticular formation, and the amygdala. "Forebrain control over neurons which are quantitatively sensitized by the *amount* of input to them appears to be regulated by a reciprocal facilitatory and inhibitory mechanism centered on the amygdala." Apart from the general characteristic which appears to be specific to each individual, it must also be borne in mind that between sexes there is a further bias to reduce inhibitory tone for auditory inputs in females, while the same type of bias operates on visual inputs for males. It is important to note that when the scores from both sexes are combined the correlations disappear.

It was previously argued (McGuinness 1972) that the female advantage in the auditory mode was biologically relevant, owing to the woman's need to be sensitive to her infant's vocalizations. In an interesting way biological factors again seem relevant. When one considers that for a considerable portion of each twenty-four hour period primitive man was plunged into total darkness, a further aid to locating one's wandering infant, apart from sound localization, would be the ability to see in the dark, especially in the lower region of the field. Also, though the notion of 'man the hunter' seems an outworn phrase, until we have further insight into these perceptual differences, this experiment appears to extend its validity as an hypothesis.

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