MONITORING AGENCY DOCUMENT No:
ASTIA DOCUMENT No: AD
GRANT AF EOAR 61-34

AD637027

TECHNICAL REPORT

# BASIC RESEARCH ON RETINAL MECHANISMS AND RESPONSES

**M. Bittini, A. M. Ercoles, A. Fiorentini and L. Ronchi**
*Istituto Nazionale di Ottica - Arcetri-Firenze. Italy*

31 October 1962 **Best Available Copy**

CLEARINGHOUSE
FOR FEDERAL SCIENTIFIC AND
TECHNICAL INFORMATION
Hardcopy Microfiche
$ 4.00 $ 0.50 65 pp
ARCHIVE COPY

DDC
RECEIVED
AUG 18 1966
C

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

20050218156

*This research was supported in part by AIR FORCE OFFICE OF SCIENTIFIC RESEARCH, OAR through the European Office, Aerospace Research, United States Air Force.*

## ABSTRACT

In the first part of the present research the perception of contour has been studied both from a theoretical and a practical stand point.

Some experiments have been carried out by the stabilized-image technique to investigate the dependence of the visibility of contrast-borders on various factors, in the absence of movement of the retinal images. It has been found that the time during which a subject is able to see a stabilized contrast-border depends on the same factors which affect the threshold of visibility under normal (unstabilized) conditions. Evidence is also presented for the existence of interactions between a stabilized contrast-border and an unstabilized border, and also for the possibility of conditioning the subjective disappearance or reappearance of a stabilized object upon the intermittent presentation of a second stabilized object.

In addition, using normal viewing conditions, subjects were requested to report whether a given transition between two uniform fields of different luminances appears sharp or blurred. In the case of a steep edge, the sensation of sharpness arises when the percent contrast exceeds 17%, in photopic vision. At mesopic and scotopic levels a higher contrast is needed for reporting the sensation of sharpness. If the distribution of luminance is rendered graded the sensation of sharpness is reported if the slope of the graded zone does not exceed a limiting value which is found to be the greater, the greater the difference between the luminances of the two uniform fields. Thus, one cannot speak of "limiting" slope in an absolute sense.

In the second part the perception of brightness has been investigated. By fixating a uniform field of a few degrees diameter, in monocular vision, a cyclical variation of brightness has been tested, involving a periodic blackout. Such an effect is reported after a suitable training period, and in addition some differences are tested between the two eyes. This suggests a possible connection with eye dominance. In binocular vision only a faint fluctuation of brightness is tested, possibly because of a phase shift between the fluctuations of the two eyes.

In the empty field the monocular fluctuations persist for a few minuts only. In binocular vision the narrowing of the visual field is tested, presumably because of the partial overlapping of the two monocular fields.

Last, in the attempt of building up a structured situation starting from a "shapeless" element, the induction effects observed when presenting a number of thin black lines of variable thickness on a uniform bright field have been investigated.

The third part is concerned with the effect of blue light on retinal sensitivity. By taking as an index the critical flicker frequency, an unexpected increase in flicker sensitivity is tested at about 15° - 20° of excentricity when using high frequency - high intensity blue stimulation. Thus, if the narrowing of the visual field is tested when driving high speed vehicles is due to the fact that the fusion of intermittent stimuli occurs earlier in the periphery than in the fovea, on the basis of our results the possibility of reporting an annular visual field, for blue stimuli, is emphasized.

In addition, an electroretinographic experiment seems to show that, when adding some red light to a blue stimulus, the size of the scotopic b-wave is depressed.

The fourth part deals with some training and long-term adaptation effects concerning the electroretinographic response. Such effects are quite new and exciting, in that the electroretinogram is usually regarded as an "objective" response, while now its behaviour seems to be similar to that of many perceptual tasks. The fact that the response levels change from day to day without any subjective awareness may be highly relevant to many monitoring tasks such as Radar observations, etc.

# 1 - INVESTIGATION ON THE VISUAL PERCEPTION OF CONTOURS

## ON THE VISIBILITY OF STABILIZED CONTOURS

### 1. - Introduction.

The edges of an object or, more generally, any more or less sharp transition from a homogeneous zone in the visual field to a neighbouring zone having different luminance represent a critical region for the visual response. Mutual interactions between neighbouring units stimulated at different levels are known to occur in the retina and also in the higher synaptical regions, and to be responsible for the enhancement of contrast at both sides of a contour. However, the explanation of the visual contour effects in terms of mutual interactions is complicated by the fact that, under normal viewing conditions, most retinal receptive units are not stimulated at a constant level for more than a small fraction of a second, because of the movements of the eye which cause the images of the observed objects to move with respect to the retina. The usually observed contour contrast effects are therefore the results of interactions between responses to stimuli which vary in time as a consequence of eye movements.

The effects of eye movements can be prevented by the stabilized-image technique. We have used this technique to investigate some aspects of the visual perception of contours. The results of this kind of investigation may be considered as a first step in the more general research on the visual contours effects and provide some knowledge of the behaviour of the contour-response mechanisms in the simplified, although unrealistic, case of steady stimulation.

The technique used for the experiments reported in the following sections has been devised by Riggs an coworkers (1) and separately by Ditchburn and coworkers (2) (contact lens technique). The apparatus has been described elsewhere(3).

2. - Subjective blur of a stabilized test object.

When the image of a sharp-defined object is stabilized on the retina, subjective blur is reported after a few seconds: the image of the object appears progressively diffused and finally disappears. The object usually reappears after some time, either sharp-defined or with diffused borders, and then disappears again and so on.

The subjective blur of the stabilized image can be ascribed either to involuntary fluctuations of accommodation which would throw the retinal image of the object out of focus, or to an impairment of the retinal contour-sharpening mechanisms, due to the constraint of movement. Involuntary fluctuations of accommodation are very likely to occur, especially when no unstabilized fixation spot is provided, but they are not the only cause responsible for subjective blur. This has been proved by an experiment where accommodation was paralized in the observing eye of the subject by instillation of a cyclopegic drug.

The stabilized test object was a black vertical line (27 min arc length, 3 min arc width) on a bright circular field 1° diameter, 1 nit luminance. The observer reported subjective blur of the line during a large fraction of the time during which the stabilized line was visible.

The observation time was 60 sec. The total time during which the observer was able to perceive the line was 35 sec (average of three observations). The total time during which the line was subjectively sharp was 15 sec (average of five observations).

Subjective blur was reported during stabilization also for different test objects, namely a bright spot 13 min diameter on a dark background, and a bipartite photometric field, 1° diameter, with a different luminance in the two parts.

## 3. - Visibility of a luminance difference as a function of the sharpness of the edge.

The visibility of the luminance difference between the two parts of a bipartite field, 1° diameter, whose image was stabilized on the retina, has been investigated as a function of the objective sharpness of the edge between the two parts of the field.

The two parts of the field had the following luminances: 0.5 nits, 0.2 nits. The vertical edge between the two zones could be either sharp or defocussed by a variable amount. The degree of blur will be indicated by the size of the diffusion spot in the optical image of the target projected on the viewing screen and which was used as test object. The diffusion spot in the test object had the following sizes: 0, 5, 10, 14 min arc.

The observer pressed the key of a recording devise whenever was able to perceive a difference in brightness between the two zones of the field. Ten observations have been made for the sharp edge as well as for each of the three defocussed edge test objects. Each observation lasted 60 sec.

The total time during which the brightness difference was perceived during the ten observations has been averaged and expressed as a percentage of the total observation time. The results are reported in Fig. 1. The figures shows that the decrement in contrast sensitivity produced by an increment of objective blur of the edge is small as compared with the overall loss of contrast sensitivity due to the constraint of movement. (The brightness difference was perceived during the whole observation time, when movement was not constrained).

It has seemed of interest to compare these results with those obtained with a test object having the same size and the same brightness difference as the previous one, but where the smooth luminance transition between the two parts of the field (the out of focus edge) was absent and the two homogeneous zones were separated by a dark interval having one of the following widths:

5, 10, 14 min arc. The edges between either of the homogeneous parts of the test object and the inner dark interval were objectively sharp.

The observer reported the time during which the brightness difference was perceived. The results are reported in Fig. 1 (dotted line). These results agree with those obtained by Clowes (4) and indicate that the absence of a smooth luminance variation between two zones having different luminances greatly impairs tha maintenance of brightness-difference sensitivity, during constraint of eye movements.

4. - Visibility of a sharp-edged test object as a function of retinal excentricity.

The time during which a small, sharp-edged test object is perceived under constraint of ocular movements depends on the location of the object with respect of the fixation point. The dependence of the time of visibility of a black vertical bar (27 min arc length, 3 min arc width) on a bright circular field, 1 nit luminance, has been investigated in two conditions: 1) steady voluntary fixation, with constraint of voluntary movements, 2) complete stabilization, with constraint of voluntary movements and involuntary movements. A paper on this subject, by A.M.Ercoles and A.Fiorentini, will be published in the journal Atti Fond.G.Ronchi Vol.XVII, No6 (1962).

The retinal excentricity ranged from 6 to 150 min of arc (angular distance of the test line from the fixation point). Circular bright fields of three different sizes have been used (1°, 2°, 3° diameter). The time during which the test line was visible was recorded during the observations, which lasted 60 sec each. The durations of single intervals of visibility where available from the records.

The results are reported in Fig. 2, separately for the two subjects who carried out the experiment. Each point in the figure represents the average of at least eight data recorded on different days.

The results obtained with steady voluntary fixation confirm that the involuntary movements alone are not effective in maintaining steady visibility of a detail even if this is imaged in the fovea, and show that the effectiveness of these movements decreases by a considerable amount when the excentricity of the detail increases from 6 to 150 min of arc. Involuntary fluctuations of accommodation are possibly responsible in part for this result.

The results obtained with the stabilized image technique are more significant if we consider the duration of the single intervals of visibility, rather than the total time of visibility of the test object. The frequency distributions of the single intervals of visibility of the line for the various retinal locations seem to be bimodal. The mode of the short-duration branch of the frequency distribution curves could indicate the most probable duration of visibility of the test object when the stabilization is maintained rigorously constant. The difference between the modes of the two branches of each curve would indicate the most probable increment of the time of visibility due to a break-down of stabilization (slippage of the contact lens brought about by a sharp movement of the eye, or convulsive change of accommodation). If this interpretation is correct, our data would show that the visibility of the test object under complete stabilization decays more rapidly at 150 min excentricity (average visibility interval 1 sec) than near the center of the fovea (average visibility interval 2.5 sec). Moreover, a break-down of stabilization is more effective in lengthening the time of visibility in the fovea than in the parafovea.

A continous recording apparatus was used to record the time during which the subject was able to perceive the disc and, separately, the time during which the ring was presented. Two subjects took part in the experiment. The stimulus luminance was 1 nit for subject A.M.E. and 0.6 nit for subject A.F.

A session consisted of two observations of the disc alone and of eight observations during which the ring was presented at various rates and with light and dark phases of equal duration, while the disc was steadily illuminated. Each observation lasted 60 sec. The periods of the ring presentations were 8, 6, 4, 2 sec for A.F. and 10, 8, 6, 4 sec for A.M.E. Two observations for each period were made in a session. Six sessions were carried out by A.M.E. and five by A.F. One further session carried out by A.F. consisted of ten observations during which the ring was not presented at a constant rate, but was delivered 0.75 sec after each subjective disappearance of the disc and was removed 0.75 sec after each subjective reappearance of the disc.

The results for subject A.F. are the following. For ring periods of 8 and 6 seconds, the fluctuations of visibility of the test stimulus are aperiodical, the occurrence of disappearances and reappearances of the disc being little correlated with the presentations and removals of the ring. For the 4 sec period, the records of the time of visibility of the disc are periodical: 74% test stimulus reappearances immediately follow the onset of the ring and 88% disappearances immediately follow the removal of the ring. Most of the remainig disappearances and reappearances occur simultaneously or immediately preced the removal and the onset of the ring, respectively.

For the period of 2 sec the situation varied during the experiment. During the first session, the first record was aperiodical, with an average duration of the visibility-invisibility cycles much greater than 2 sec, while the second record contained a train of six 2 sec cycles. All records from the following sessions were periodical, almost all appearances and disappearances of the disc being exactly synchronized with the onsets and removals of the ring.

For the other subject the same results are found for periods respectively 2 sec longer.

5. - Influence of a stabilized or non-stabilized contrast border on the visibility of another stabilized borde

The presence in the field of view of unstabilized contrast borders can affect the visibility of stabilized objects. This fact was pointed out by Mc Kay (5), who noticed that, if he introduced his finger in the field of view of the eye wearing the contact lens with the stabilizing device, the stabilized pattern immediately disappeared.

We have investigated the effects on the visibility of a stabilized test object produced either by an unstabilized object or by a second stabilized object presented intermittently.

In the first experiment the stabilized test object was a bright disc, 13 min arc diameter, 1 nit luminance. It was surrounded by a bright narrow annulus, 1° diameter somewhat brighter than the disc, whose image was not stabilized. The subject was instructed to look at the center of the annulus during the observation and the projecting system of the stabilizing apparatus was arranged to center the stabilized disc with respect to the fixation point.

Ten observations, of 60 sec each, have been made with the annulus surrounging the disc, and ten observations have been made without the annulus. The time during which the observer could perceive the stabilized disc was recorded. The total time of visibility of the disc, expressed as a fraction of the toaal observation time, was 0,55 in the observations with the unstabilized annulus and 0.71 in the observations without the annulus.

This confirms that the presence of an unstabilized object impairs the visibility of a stabilized object.

In the second experiment the test object was the same bright disc used in the first experiment. It was surrounded by a bright ring (inner diameter 26, outer diameter 32 min of arc) whose image was also stabilized. The ring could be presented intermittently at various rates of intermittence, during steady presentation of the disc.

A progressive increasing periodicity of visibility and invisibility phases was found in the records from the session where the presentations and removals of the ring were delayed by a constant amount with respect to the subjective disappearances and reappearances of the disc. In the first few records the fluctuations of visibility of the test stimulus seem to be largely independent of the ring presentations. In the intermediate records the presentations of the ring are always closely followed by a reappearance of the disc, while the removals of the ring do not always bring about a prompt disappearance of the disc. In the last records appearances and disappearances of the disc are almost completely driven by the ring.

Alltogether the results of the present experiment confirm the possibility of influencing the disappearance and reappearance of a steadily illuminated, stabilized object by intermittent presentation of a second stimulus. For this to occur, however, the second stimulus has to be removed when the steady stimulus is almost ready to disappear spontaneously, or presented when the steady stimulus is almost ready to reappear; otherwise the intermittent stimulus can scarcely interfere with the steady stimulus.(+)

## 6. - Discussion.

The results of the experiments reported in the sections 2, 3 and 4 can be summarized as follows.

The visibility of a brightness difference between two adjacent areas is maintained only for a limited time during steady stimulation. When the two areas are divided by a sharp edge, the sendation of sharpness decays more rapidly than the sensation of contrast. The time during which the brightness difference can be perceived

---

(+) This experiment has been described and discussed in the paper "On some factors influencing the disappearance of a stabilized image", by A.Fiorentini and A.M.Ercoles, presented at the 6th CIO Meeting, Munich, August 1962.

is not very sensitive to an increase in the physical blur of the edge, whereas it decreases very rapidly when the separation between the two areas increases, if no smooth luminance transition is present in between. The time of visibility of contrast decreases rapidly with increasing retinal excentricities.

All these results reflect in some way the behaviour of the contrast threshold, measure under normal (unstabilized) viewing conditions: the liminal contrast required for the sharp perception of a physically sharp edge is higher than the liminal contrast required to perceive a brightness difference (6); the liminal luminance difference between two homogenous areas required to perceive a brightness difference is smaller if a smooth luminance transition is present between the two areas, than if the interval in between is dark (7); the contrast threshold for a test object of constant size decreases when increasing retinal excentricity (8).

We could say that the same factors which affect contrast sensitivity when the eye movements are not constrained, affect the maintenance of contrast visibility in the absence of movement.

This fact would have two implications. First, the eye movements should not have a great role in enhancing the contrast or contour perception, but merely that of maintaining the contrast response in time. In other words, spatial factors, namely changes in illumination across small retinal regions, would prevail with respect to temporal factors, namely changes in illumination at a given retinal point due to eye movements, as far as the contrast sensitivity is concerned. This agrees with what is known about the role of eye movements in acuity thresholds. (9)

Second, the duration of visibility of a brightness difference or of perception of a contour does not depend merely on the objective luminance difference, but rather on the subjective brightness difference. For instance, in the experiment with the bipartite field (section 3) for the same luminance difference between the two parts of the field, the time of visibility is longer in the presence of a smooth luminance transition (which enhances the sensitivity to luminance differences) than in the presence of a dark interval. The deca

of contrast sensitivity under prolonged constant stimulation occurs probably not at the receptor level, but at a further stage in the visual path, where the response is realaborate to introduce contour enhancement.

Let us consider now the results of the experiment reported in section 5. The presence in the field of view af an unstabilized object depresses the visibility of a stabilized object. This can be accounted for in part by the more accurate fixation allowed by the presence of the unstabilized ring: in the absense of the ring the eye could perform uncontrolled movements which would possibly destroy stabilization. However the effect could also be due to an inhibition of the steady response from the stabilized object by the variable response from the unstabilized object. The interactions between the stabilized disc and the stabilized intermittent ring seem to be somewhat different, because the presentation of the ring facilitates the reappearance of the disc, and the removal of the ring anticipates the disappearance of the disc. Both experiments however agree in showing that it is possible to influence the time course of the response from a steadily stimulated area by changing the stimulation of a different area, at some distance from the first.

In some previous researches (10)(11)(3) it has been shown that a stabilized test object can be prevented from fading away by flickering it on and off, and this was considered as a prove that a variation in the stimulus is required to maintain the response in the absence of movement. Here we are faced with the evidence that the response can be controlled by changing the amount of inhibition from a laterally displaced stimulus. This points again in favour of the hypothesis that the dacay of sensitivity produced by the constraint of movement is a consequence of fatigue of the coutour enhancing mechanisms mediated by lateral inhibition, rather than the result of a depression of the response from the steadily stimulated retinal receptors.

Possibly the retina is not the only seat of interactions between the responses to a steady stimulus and to a variable stimulus. Evidence for central interactions can be found in the close analogy between the suppression of the stabilized disc by the unstabilized ring and the phenomenon of binocular rivarly, as was first pointed out by MacKay, and also in the increasing effect of the pulsating ring on the stabilized disc from the first experimental session to the followings.

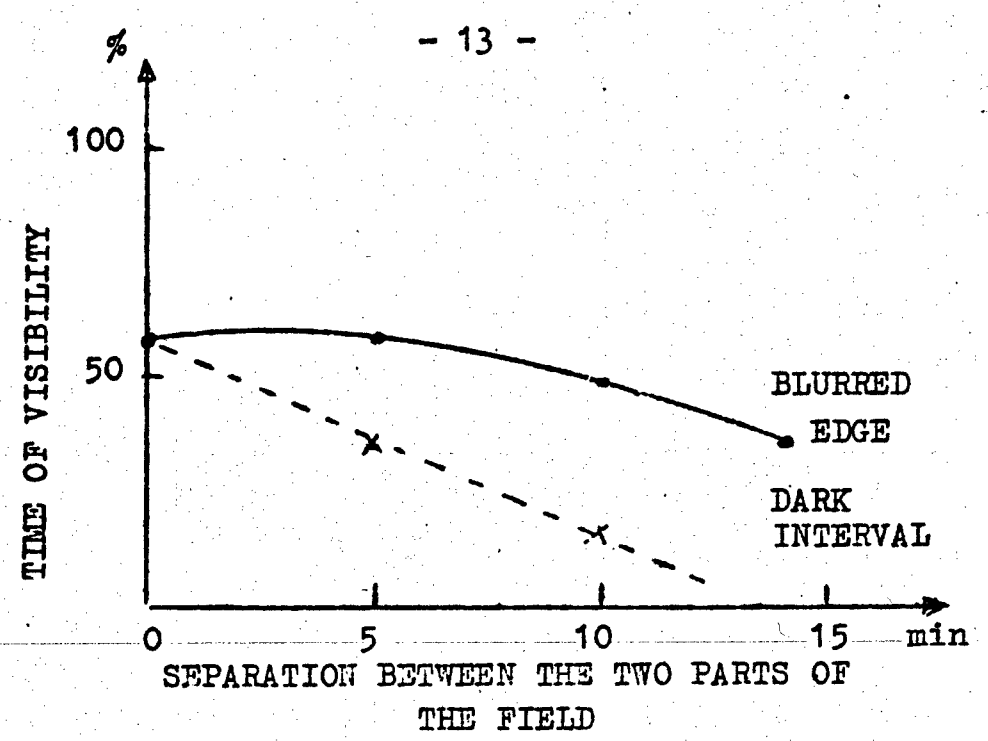

%
100
50
TIME OF VISIBILITY
BLURRED
EDGE
DARK
INTERVAL
0
5
10
15
min
SEPARATION BETWEEN THE TWO PARTS OF
THE FIELD

Fig. 1

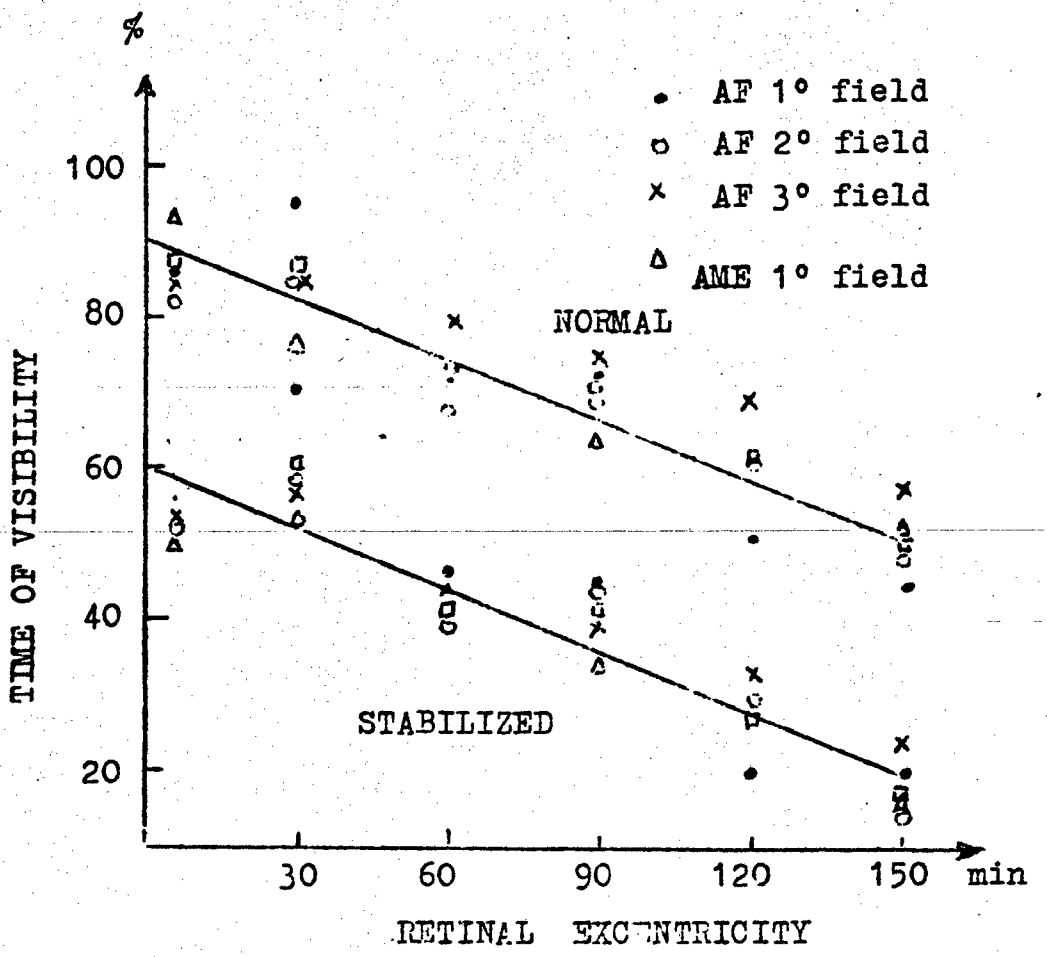

%
AF 1° field
AF 2° field
AF 3° field
AME 1° field
100
80
60
40
20
TIME OF VISIBILITY
NORMAL
STABILIZED
30
60
90
120
150
min
RETINAL EXCENTRICITY

Fig. 2

## REFERENCES

(1) - L.A.Riggs et al., The disappearance of steadily fixated visual test objects, J.opt.Soc.Am. 43, 495 (1953)

(2) - R.W.Ditchburn and B.L.Ginsborg, Vision with a stabilized retinal image, Nature, 170, 36 (1952)

(3) - A.Fiorentini and A.M.Ercoles, Vision with stabilized images and intermittent illumination, Atti Fond.G.Ronchi, 15, 618 (1960)

(4) - M.B.Clowes, Some factors in brightness discrimination with constraint of retinal image movement, Optica Acta, 8, 81 (1961)

(5) - D.M.MacKay, Monocular rivarly between stabilized and unstabilized retinal images, Nature, 185, 834 (1960)

(6) - M.Bittini, Subjective sharpness and contrast threshold, Atti Fond.G.Ronchi, 17, 387 (1962)

(7) - H.W.Hake and E.Auerbach, Spatial effects in foveal brightness discrimination, J.opt.Soc.Am. 46, 274 (1956)

(8) - W.S.Stiles and B.H.Crawford, The liminal brightness increment for white light for different conditions of the foveal and parafoveal retina, Proc.Roy.Soc. B 116, 55 (1934)

(9) - U.Tulunay Keesey, Effect of involuntary eye movements on visual acuity, J.opt.Soc.Am.50,769 (1960)

(10) - R.W.Ditchburn, The stabilized retinal image, Optica Acta 2, 128 (1955)

(11) - T.N.Cornsweet, Determination of the stimuli for involuntary drifts and saccadic eye movements J.opt.Soc.Am. 46, 987 (1956)

## ON THE SENSATION OF SHARPNESS

Our contribution in this area is reported in detail in five papers(1)(2)(3)(4)(5).These works aim at determining:(a),under what conditions a physically steep border appears either sharp or blurred,(b),under what conditions a graded distribution of luminance appears sharp or not,and (c),which is the physiological mechanism subserving the perception of sharpness.Both the threshold of visibility at the threshold and the threshold of sharpness of physically contoured test-objects have been determined at various luminance levels.The ratio of the luminance at threshold of perception,to the luminance at threshold of sharpness is found to vary as a function of the adapting luminance as shown in fig.3.In addition,the threshold of sharpness has been found to vary as a function of the exposure time as shown in fig.4.

Now,if a steep edge is rendered graded,the eye feels a change in the aspect of the figure as soon as the size of the penumbra attains 2 or 3 min. of arc of visual angle,according to Campbell's criterion(see: Optica Acta,4,157,(1957)).Such a value is found to depend on contrast,in the sense that the lower the contrast,the more tolerant the eye is.

If the graded zone is further decreased,sharp Mach bands are seen to delimitate it,up to values of the penumbra of about 20-24';such a value is again depending on the contrast value,interpreted as the percent difference of the luminances of the two uniform fields enclosing the graded zone;however,the dependence on contrast is now tested to be opposite with respect to that reported by Campbell.

If the size of the graded zone is increased from 24' on,according to Fiorentini's results(see years 1955 through 1959 of the "Atti della Fondazione G. Ronchi), Mach bands are seen up to extents of the penumbra of 4-5°.The bands ,now,have lost their sharpness and vividness,which,on the other hand,is tested for penum-

---

NOTE-For bibliographical references see the "List of Technical Notes".

brac smaller than 24'.The dependence on contrast of the se bands is found to be complex.

In the graded zone of any size,multiple Mach bands are seen,often transitory and fluctuating.

An analysis of the results obtained by various authors brings to the conclusion that the discrepancies as tD the above reported dependence on contrast,in the various cases,is only apparent and illuosry,in that,if we evaluate the slope H of the graded zone,at the threshold of visibility of Mach bands,we find that such a quantity increases linearly when the luminance difference between the two uniform fields is increased.If we regard H as the first derivative of the luminance function f(x),representing the photometric profile with respect to the spatial coordinate x,it follows that,if also the luminance L of one of the two uniform fields is taken as a variable,Mach bands are seen for a given constant value of the second derivative of the said function with respect to both the variables,x and L.

Thus,one cannot speak of "limiting slope" in an absolute sense.

The physiological explanation of the above described effect is reported in detail in ref.(4).Here it will be briefly summarized as follows.

By regarding as inexistent the old distinction between "border contrast" and "surface contrast",we will speak in terms of simultaneous contrast in the general sense of the word.In addition, we will asume that Mach phenomenon arises also in the se case of a physically steep edge.There is a controversy on this point,however microphysiological evidence plays in favour of our assumption.Last,according to our point of view,sensation of sharpness(in the case of a physically steep edge) and Mach phenomenon are subserved by the same mechanism which is activated when the difference between the luminances of two nerby fields is sufficiently high.

We think that such an activation occurs when the stimulus is so intense that a change in the state of adaptation of the eye is produced at the "locus" of stimulation.Such a change would imply a transitory effect, so that we may speak of "rapid local adaptation".This is in agreement with the view that the vividness of Mach phenomenon is greater just at the beginning of stimu-

lation that after a few sec of steady fixation(Riggs-Ratliff-Keesey-JOSA,51,702,(1961)).

In the case of a physically steep edge,the said explanation seems to be confirmed by the following experiment,reported in detail in ref.(5).The eye is first presented with a bipartite field,consisting of two adjacent fields of different luminances,the relative contrast being c;after a given "adaptation " time T,the eye is abruptly presented with a field of uniform luminance, upon which,if steady fixation is maintained,a difference in brightness is seen to persist for a given time t.For given values of both T and c,the behavior of t as a function of log luminance has been recorded;t is found to vary from a few sec to,say,150 sec.For low values of c the difference in brightness appears after a latency time of a few sec.Last,the transition between the two zones of different brightness appears as delimitated by a dark band.In addition, to such a "slow" effect,a rapid bright band is seen to appear for a brief time after the onset of the gradient of brightness.The likelihhod of perceiving such a band is found to be in good, at photopic levels,if contrast exceeds,say,50%.For lower contrast,the perception of the band is couteracted by the above said slow effect,which,in turn,is characterized by the presence of a dark band,running parallel to the bright one,but with different time characteristics. If the time T is suitably reduced,the probability of perceiving the bright band may be increased even in the case of a low contrast,in that the effect due to the slower process may be minimized.

All it shows how difficult it is to interprete the influence of "time" as a factor;the interpretation based on lateral inhibition in a "steady" state requires that the simultaneous contrast effect is reduced when the exposure time is decreases.However,recent microphysiological experiments(Hartline-Ratliff-"Nervous inhibition" Pergamon Press,New York,(1961)) put into evidence some transitory effect occurring when the state of the retina is other than "steady".These effects affect in a complicate way the mutual balance between excitation and inhibition within the receptor field.

In the case of a graded distribution of luminance,the important factor seems to be the drop of luminance through

a receptor field. According to Pirenne and Denton's view (Nature, 170, 1039, (1952)), when luminance is increased, smaller units, contained within each receptor field, are likely to reach their absolute threshold. Their existence might explain both the presence of multiple bands in a graded distribution of luminance, and the increase in liminal slope tested when the difference between the luminances of the two uniform fields is increased.

In conclusion, the greater vividness of Mach bands, for penumbrae smaller than 24', might be ascribed to the fact that both lateral inhibition (in the steady sense) and rapid (transient) effects are at work, so that the bands are a compromise between simultaneous and successive contrast effects. For penumbrae larger than 24', on the other hand, the former factor only plays a role.

In the case of a thin stripe, black on a bright background, at the threshold of sharpness, rapid effect are likely to be again at work. When the angular size is lesser than, say, 1 min. of arc, at the luminance level considered, (0.35 nit), the stripe appears blurred; but, if such a stripe is placed at a small distance with respect to another equal stripe, both them are seen sharp. Analogously, a grating, at the resolution limit, apperas to consist of a series of parallel sharp lines. In this connection, we would suggest that such a situation is analogous to that of a graded distribution of luminance which produces sharp Mach bands, in that, in both the cases, a rapid local adaptation would occur within the receptor field. It follows that the determination of the resolving power implies a quite different process with respect to the determination of contrast threshold in the Techneriàn sense, which, in turn, imples such a small increment of luminance that the state of adaptation of the eye is not troubled at all. Last, if the slope of the response function of the eye (measured by the aid of a grating) is determined, we find that, whatever the frequency, the drop of contrast through the unit of visual angle is of the same order of magnitude as that required for having sharp Mach bands.

////////////////

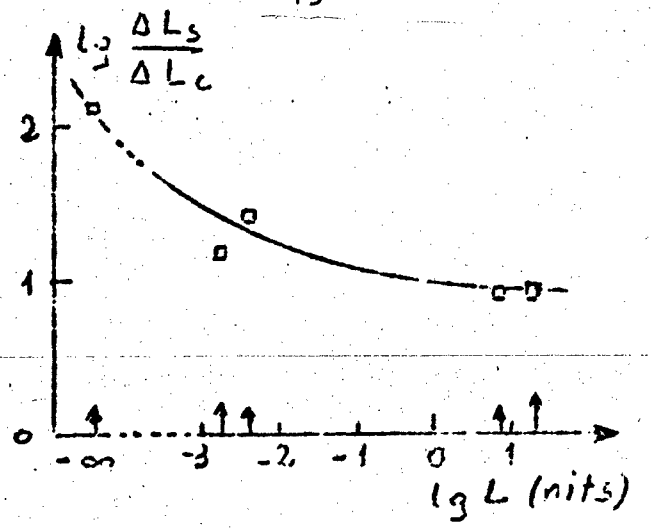



Fig.3-Subjective sharpness threshold relative to the corresponding contrast threshold(or absolute threshold) plotted against log luminance of the adapting field

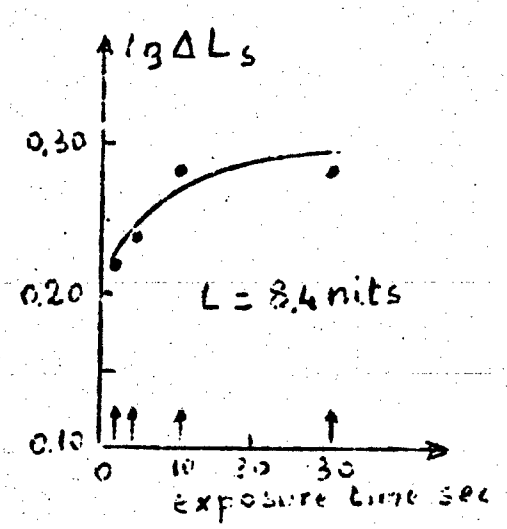



Fig.4- Behavior of the subjective sharpness threshold during adaptation to light,in the time interval 1-30 sec.

## 2-INVESTIGATION ON THE SENSATION OF BRIGHTNESS

It is known that the sensation of brightness does not depend on the intensity(or luminance) of the stimulus,only,but other factors play a role.The fundamental factor is the state of adaptation of the retina:the apparent brightness of a stimulus seems to increase when passing from the light adaptation to the dark adaptation state.In this sense,the sensation of brightness is relative to the adapting luminance.Another factor is represented by the induction effects exterted by the stimuli (if any) present in the visual field.These stimuli also cooperate in determining the state of adaptation of the retina.Distinction is made between the "general state of adaptation",which is referred to a mean luminance level,evaluated by averaging the intensitites of all the sources present in a not homogeneous visual field,and the local adaptation which occurs at a limited portion of the retina and produces a transitory variation in the general adaptation level.

The so-said brightness constancy law may be regarded as a consequence of the fact that the retina provides a relative (and not absolute) information for brightness: the apsect of (familiar) objects does not seem to vary appreciably,for instance during the course of the day, in spite of the changes in luminance occurring from time to time,and in spite of the complex and variable induction effects.The law of brightness constancy is generally regarded as a defense of individuals against a too variable situation,which,otherwise,would be extremely confusing and rich of unimportant information.

In spite of the fact that recent microphysiological research tends to ascribe to retinal organization the major responsability as ~~af~~ far as constancy is concerned,obviously central factors cannot be excluded.Sophysticated subjects tend to couteract the consequences of constancy law,and they note many changes in the aspect of test-ojects(in particular,in their brightness),which appear quite irrilevant to navy subjects.

By now,for the sake of simplicity,let us make ~~di-~~ ~~minution~~ abstraction from induction effects.Let a test object be superimposed upon a background of uniform lu-

NOTE:for bibliographical references see the"List of Technical Notes".

minance;in addition,let us assume that when the luminance od the test-object is varied,the luminance of the background is correspondingly varied,so that the object contrast relatively to the background does not depend on the actual illuminance level.Let us consider now the following example:at photopic levels,the threshold contrast is known to be constant;however,if one wants to know whether the sensation of brightness,for a given suprathreshold value,at a given level,is the same as that evoked by the same contrast value,at a different level,he must perform a "successive " comparison,relatively to sensations far apart in time.In fact,when the luminance of the background is changed,some time must elapse before adapting the retina to the new level.Thus, the "memory for brightness" is involved.At mesopic and scotopic levels,the problem is more complicated,because of the change in sensitivity as a function of the adaptation level.

If we assume that after the off-set of the stimulus a trace of it remains,not only in the retina(in the form of after-image),but also in the higher centers,which deteriorates with time,the question arises as to the characteristics of such a deterioration.

From a practical stand point the couterpart of this problem may be found in some peculiar tasks required to Radar operators,and,in addition,in some peculiar situations,where the subject is requetsed to spend some time in ambients containing no visual reference cue at all, except for a uniform illumination(empty field).

Many factors are involved in the problem,and,in addition,we are faced with long-lasting experiments,in order to avoid the interaction between successive presentations of some blocks of test-stimuli.

The experiment on memory for brightness performed by us during the past year(6) refers to the following conditions:two stimuli of different luminances(both mesopic,each lasting 60 msec),in a dark room,are delivered to the central retina,either contemporaneously,or in succession.Subjects are instructed to express their judgement about the relative difference on brightness.In the first part of the experiment,the luminance of the former stimulus differed with respect to that of the latter by 0.1 log units.In the second part,of 0.2 log units.

In the former case,where the percent contrast between

the two stimuli to be compared was 20%) the effects of memory are difficult to be separated from the effects arising from unexpected changes in sensitivity occurring as a function of luminance.

In the latter case, the number of wrong responses is found to increase rapidly when passing from the simultaneous match to the memory match, corresponding to a time interval of 8 sec. If such an interval is increased, from 8 through 60 sec, a slow increase in the number of wrong responses is tested. Once accepted that an adaptational process affecting the trace left by the former stimulus (of the pair presented in succession), is at work, the "time constant" of such a process is shown in fig.5.

Four subjects took part in this experiment.

Before investigating the effects on memory of prolonged exposure to an empty field (a work along such a line is now in progress), a study of the behavior of our subjects as that reported in references (7) through (10) has been performed.

In a preliminary experiment (7), a 10 deg. diam. uniform field, surrounded by dark, is steadily gazed in monocular vision, and a cyclical variation of apparent brightness is reported. As indexes of such an effect we assumed both the frequency of the fluctuation and the ratio of the time through which the field is seen as bright to the time through which it is seen as "dark". Such a quantity has been indicated by the aid of symbol LDR. During the "training" period for an unexperienced subject, the frequency of the fluctuation is found to increase (starting from zero value on), while the LDR tends to decrease. No significant differences are tested between the LDR for the right eye, and that for the left eye, if the fixation point lies at the center of the 10° field. But, if the fixation is brought at one extreme of the horizontal diameter, different LDR are recorded, within one of the eyes, according to the halfth (either right or left) of retina stimulated.

When the 10 deg. diam field is fixated in binocular vision, the apparent brightness is seen to fluctuate faintly, and the total blackout is never reported. A small contrast difference, superimposed upon the fixated test-field is perceived only for a fraction of the time of presentation. The amount of the variation in brightness occurring during the course of fluctuation has been tentatively eva

luated,by assuming that a decrease in apparent brightness involves a decrease in liminal contrast(by analogy with Fechner's law concerning the variation of contrast threshold as a function of adapting luminance).

The mutual influence of the two eyes represents a rather complex problme.One might suggest that a slight phase shift between the periods of the fluctuations of the right and of the left eye,respectively,avoids the periodical black-out in binocular vision.However,we had the opportunity of noticing that the fluctuation reported by one of the eyes is influenced by the state of adaptation of the other eye.In some cases we are led to infer that one eye is periodically suppressed by the other,and viceversa.For instance,if one eye is presented for a given time with a test-field of given shape(say,a diamond),and soon after having switched off such a stimulus,the other eye is presented with a stimulus of different shape(say, a circle),the fading effect,in this latter eye,occurs according to a diamond shaped pattern, at least during the first few minutes.Such an effect has been quantitatively investigated(8) by viewing the test field in Maxwellian view.Under such conditions,perhaps as a consequence of the Stiles and Crawford effect,the fading is strogly reduced,so that the inter-ocular influences may appear independently of the monocual effects. The relation between the fluctuation of the after image and the [illegible] fluctuation of the interocularly induced image has been sought for,but so many fators are playing a role in this problm,that no definite conclusion has been reached up to date.

In the above reported work(7) it has been tested that the ratio of the time through which the centrally fixated field appears bright to the time through which it appears dark,as determined for the right eye,is approximately the same as that determined for the left eye.

A difference between the two eyes is tested if,instead of LDR,the period of the time fluctuation is taken into account.It has been suggested that such a difference might be put in relation with eye dominance(9).A number of subjects(twenty-one) have been tested by the aid of all the current methods,that is,binocular test,Jasper's test, vision through a monocular microscope,evaluation of after images,and the determination of the period of fluctuation of a centrally fixated 10 deg.Diam.field(in monocular visi

The result is that, in some cases, all the tests are in favour of the same response (either right or left dominance), but in some cases a discrepancy between the various tests is reported. The discrepancy is partly due to the fact that we are faced with qualitative responses, and consequently, no limitations for the tolerances are at our disposal. As a provisional conclusion, we might infer that the period of fluctuation is greater for the dominant that for the not-dominant eye.

Let us increase now the size of the centrally fixated stimulus, so as to cover all the visual filed (empty filed). In monocular vision (10), the field is seen to fluctuate centrally, while the peripehral parts appear steady. Again, the rhythm of the fluctuation of the right eye may differ with respect to that of the left eye. However, the fluctuation ceases after a number of minutes of exposure to the empty field (ranging from 1 to 20, according to the subject), and the "final situation" for the right eye is found to be different with respect to that for the left eye.

It seems (9) that, after cessation of fluctuation, the dominant eye sees a light gray field, while the not dominant eye sees a dark field. The situation is rather complicated, in that the field does not appear uniform, and, in addition, some observers perceive colored patches often in motion.

Binocular vision, in an empty field (10) is characterized by the narrowing of the visual field. A faint fluctuation of brightness appears in the central portion, which appears delimitated either by a dark ring, or by a fluctuating (often not homogeneous) oval border. In view of the fact that the periodical black-out of the fixated test-field occurs in monocular but not in binocular vision it might be argued that the narrowing of the visual field, in the empty field, occurs because of the partial overlapping of the two monocular fields.

Other effects occurring in the empty field are described in details in the above mentioned papers.

A theoretibal discussion on the periodic fluctuation is reported in Fiorentini's paper, relative to the vision with stopped images (see section 1).

An experiment concerning the memory for brightness in the empty field is now in progress.

It has been previously emphasized that the perception

of brightness depends also on the induction arising from neighbouring objects. Most of experiments up to date performed in this field (and covering subjects like simultaneous contrast, metancotrast, inhibition, disinhibition) refer to the influence exerted by bright test-objects upon the btightness of nearby located bright test-objects. Quantitative data have been produces by various authors as to the influence of factors such as luminance, shape, mutual distance, and so on.

In our experiment (11) the effects occurring when presenting a series of black demarcation lines on a wide (25 by 25 deg.) bright field are investigated. Such lines produce brightness enhancements and depressions which have been "measured" by determining the fusion conditions relatively to a small exploring spot. Such a method, however, is not wholly satisfactory, in that the luminance of the spot, at fusion, is necessarily so high that it appears unavoidably surrounded by an halo (due to diffusion and diffraction effects on the part of transparent eye media); this fact represents a limitation as to the apparent size of the exploring spot, and, consequently, the possibility of examining the details of a pattern is reduced.

Many parameters are involved, when building up any pattern. For the sake of simplicity we considered at first a black (well contrasted) line. Such a test-object, under some respects, may be regarded as "shapeless". Apparently, it does not produce any peculiar visual effect unless its thickness does not exceed, say, 10 min. of arc. Beyond such a limit, a simultaneous contrast effect is tested (at the luminance level considered, 0.35 nit), consisting of an enhancement in the brightness of the neighbouring zones; we regarded such a line as "broad". If two "thin" parallel lines (thickness 1.5 min. of arc) are present in the visual field, a brightness enhancement is tested, provided the mutual distance does not exceed, say, 30 min. of arc. By drawing other lines, all parallel and lying in the frontoparallel plane), the brightness of the stripe delimitated by the two lines is altered; if many parallel lines are presented at a small mutual distance, the situation is extremely complicated, even from the descriptive stand point.

If a thin line segment is bent, so as to form a ring, the brightness inside is found to the greater that out-

side. If a narrow break is present, such that ~~the~~ its size equal the thickness of the line, the luminance inside is found to be lesser than that outside. For greater sizes of the break, no difference in brightness is tested, when comparing inner and outer portions, respectively. On the basis of these findings, a classification of the various letters of the alphabet has been attempted. Its practical value, however, is restricted to the case of isolated letters, in that sorrounding test-obejcets may alter the inner brightness.

From the theoretical point of view, it seems that the reported results might be accounted for in terms of lateral inhibition, analogously to what is usually done in the case of bright inducing test-objects. The lateral inhibition is assumed to find its counterpart in the intrinsic organization of the receptor field. Thus, it is as if the presence of the image of a thin black line through the peripheral annulus of an "on-center" receptor field would have no relevant effect when taken alone. On the other hand, two equal lines, contemporaneously present, may reduce lateral inhibition exerted by the peripheral annulus on the response of the center. Thus, the fact that the brightness enhancement in the enclosed stripe is tested up to 30' of mutual distance, might give an idea as to the size of the receptor field, at the level considered.

The research is now pursued by considering crossed lines of various ahgluar sizes.

////////////////////

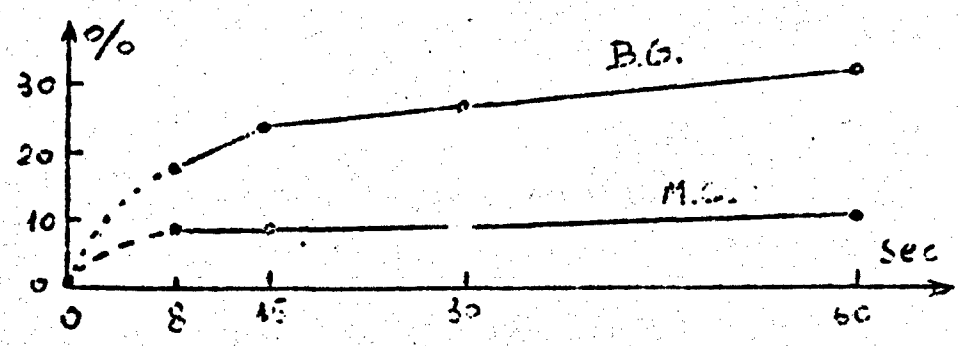



Fig.5-Percent number of wrong responses(implying a comparison between the brightnesses of two stimuli presented in succession),as a function of the time t elapsing between the two successive presentations.The log difference between the luminances of the two stimuli is 0.2.The total number of responses is 735.The responses collected at various luminances are averaged. Each curve refers to a different subject.

## INVESTIGATION ON RETINAL RESPONSE TO LIGHTS OF DIFFERENT SPECTRAL COMPOSITION, BY TAKING AS AN INDEX BOTH CRITICAL FLICKER FREQUENCY AND ELECTRORETINOGRAPHIC INTENSITY FUNCTION.

During the past few decades, the spectral composition of the radiation emitted by light sources was becoming more and more rich of blue; in addition, colored light signals and, in particular blue signals, are more and more diffusely employed. However, some points conserning the visual effects of such lights are still obscure.

In this connection, two experiments have been performed (see ref.(12) and (13)).

In the former work a peculiar effect concerning the fusion conditions relatively to a high frequency - high luminance colored signal are investigated, by taking as a variable the retinal location. The size of the stimulating spot is about 1 deg. diam. and it is seen surrounded by dark. Two trained subjects took part in this experiment. The color temperature of the lamp used as source is 2800°K. The colored stimuli are obtained by inserting in the stimulating beam one of the following filters: N.47 for blue, N.25 for red, N.61 for green.

Classical findings concerning red, white and green lights are once more confirmed by us, in the sense that at any frequency the sensitivity to flicker is greater for the fovea than for the periphery. The difference is less marked at low frequencies than at high frequencies.

On the other hand, when using blue light, peculiar effects are tested, as follows:

a) - When the frequency of interruption ranges from, say, 15 to 18 cps, the greatest sensitivity to flicker is recorded at excentricities ranging from 15 to 20 deg.

b) - When the frequency varies from, say, 20 to 30 cps, foveal sensitivity is greater than peripheral sensitivity.

c) - At highest frequencies, the maximum sensitivity is recorded at about 15°-20° of excentricity, analogously to what happened at lowest frequencies.

We did not record any response at frequencies greater than 46 cps. In fact, the threshold of flicker is reached at such an high intensity, that the light scattered by transparent eye media plays a relevant role: thus, an annulus surrounding the focal area is seen to flicker, while the center does not; being our focal area so small (1°), the determination of fusion conditions in peripheral vision becomes rather ambiguous.

NOTE: for bibliographical references see the "List of Technical Notes".

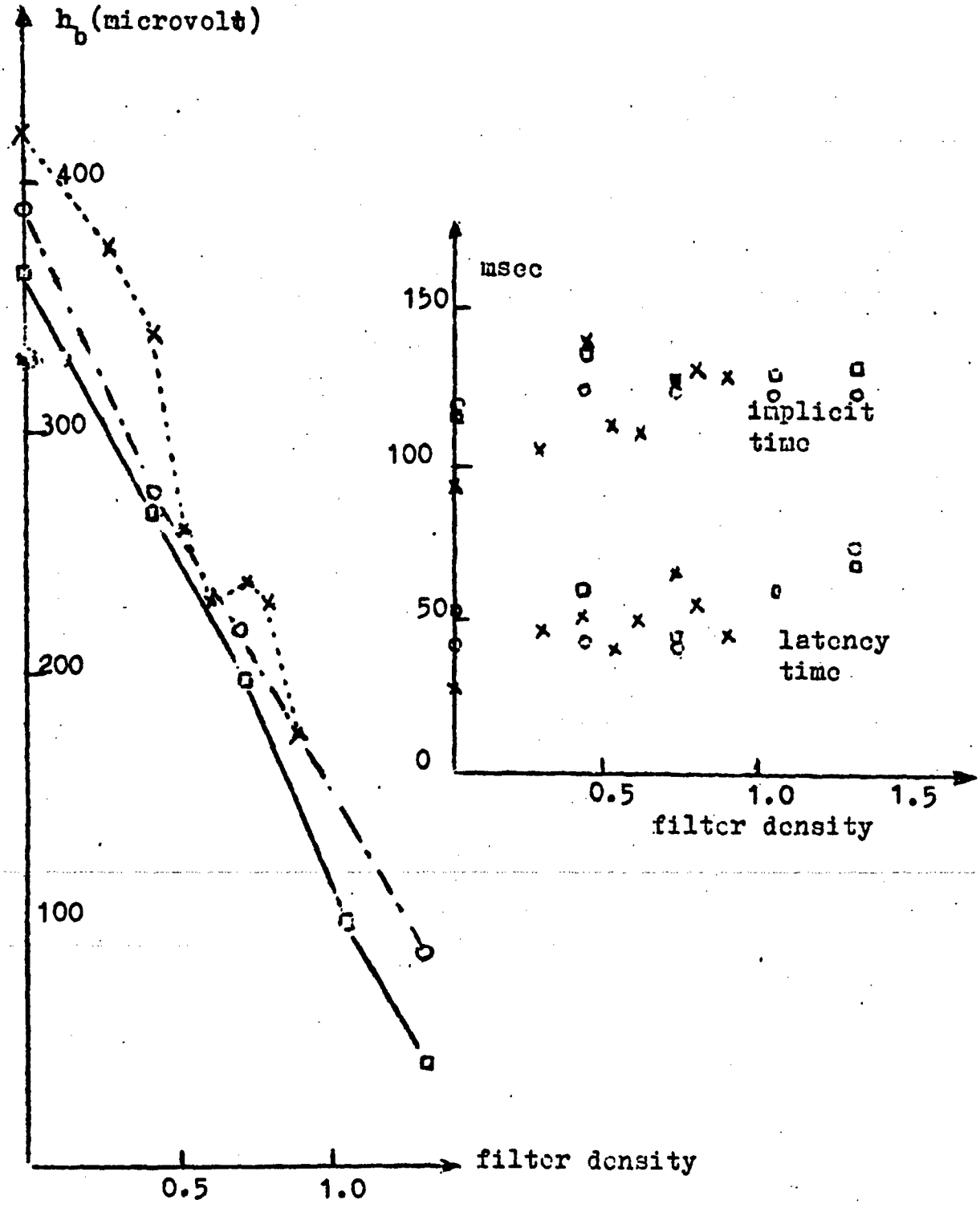
From the physiological stand point this effect might be explained in terms of the activity of blue cones.

From the pratical stand point, reference might be made to the narrowing of the visual field occurring when driving a high speed vehicle. In part at least, such an effect might be ascribed to the fact that fusion conditions in the periphery are attained at lower frequencies with respect to the fovea. On the basis of the above reported findings, it seems that, when blue light is used (say, for intense light signals, at night) there is the possibility of reporting, under suitable conditions, an annular visual field.

The addition of red light to a blue stimulus has been previously tested to produce peculiar depression effects (L.Ronchi-Atti Fond.G.Ronchi, 15, 272, (1960)-A.M.Ercoles, Atti Fond.G.Ronchi, 16, 262, (1961)) both from electroretinographic and psychophysical stand points. Such an influence has been again tested in an electroretinographic experiment(13) where the dark-adapted retina has been stimulate by the aid of variable relative amounts of blue and red lights (the radiation emitted by a 2800° K has been filtered through Wratten filters N°47 and N°25, respectively). When either blue or red light alone are used, the linear branch of the intensity function appears quite smooth. When a red plus blue stimulus is used, the smoothness is superseded by a "hump" which seems to correspond to the conditions where the red stimulus would cease to be effective when taken alone. In addition, let the intensities of the two stimuli, red and blue respectively, be such that the evoke responses of approximately the same size; now, the red plus blue stimulus is found to evoke a slightly higher response, with respect to those evoked by the components lights, taken separately. The implicit times of the b-waves elicited by red, blue and red plus blue stimuli, respectively, are of the same order of magnitude, for a given value of the density of the neutral filter controlling the intensity of the stimulating beam. In a few words, the blue and the red responses are not "additive", even far from the saturation of the electroretinographic intensity function.

Many sets were devoted to this experiment. In each set three intensity functions were recorded. Both size and implicit time were measured. As an example, see fig.6.

Fig. 6


$h_b$ (microvolt)
400
300
200
100
0.5
1.0
filter density
msec
150
100
50
0
implicit time
latency time
0.5
1.0
1.5
filter density

## 4)-WORK ON LONG-TERM ADAPTATION AND TRAINING, RELATIVELY TO THE ELECTRORETINOGRAPHIC RESPONSE.

The electroretinogram(ERG) is usually regarded as an objective response, and most of investigators have been concerned with its "physiological" aspect. Since 1955 on, however, we had the opportunity of noticing that some unusual factors may affect the ERG. Many records have been collected during the past few years, in order to put such effects in their proper frame. (L.Ronchi-A.Bittini-Atti Fond G.Ronchi, 13, 417, (1958)-L.Ronchi-F.Mori-Atti Fond.G.Ronchi, 15, 503, (1960)-L.Ronchi-A.M.Ercoles-Atti Fond.G.Ronchi, 16, 518, (1961)-L.Ronchi-A.M.Ercoles-Aerospace Medicine, Jan. (1962)-(see also ref.14). Nowadays we believe that one may speak of training anf long-term adaptation, and even of conditioning in the Pavlovian sense. The research is being pursued, and the statistical significance of many effects is sought for. Being originally Physicists, we appreciate the co-operation of a Psychologist in this area, and we are very indebted to Dr.S.J.Freedman(Tufts University, Mass.) for his help.

During the past year, analogous rexperiments have been performed both by Freedman and ourselves, with different apparatus and different subjects, and the results are in a good mutual agreement.

From a general point of view we are aiming at understanding the true meaning of ERG from the bio-physical-neurophysiological and psychological point of view.

Let us record the ERG in response to a given light stimulus. Although the range of variability for the response of the normal eye has not yet been standardized, we may expect a given size value, for instance on the basis of an average intensity function recorded on a number of subjects by the aid of our apparatus. Now, if the size differs with respect to that expected, there are the following possibilities:

a)-The eye is other than normal.

b)-The eye is normal, but:

- $b_1$)some instrumental artifacts occurred.
- $b_2$)the subject was not as stable as due (because of blinking, eye and head movements, lack of stability of the active electrode, etc.)
- $b_3$)The subject is suffering from some peculiar diseases of general origin

NOTE: for references see "List of Technical Notes".

$b_4$)previous retinal stimulation modified the state of retinal adaptation

$b_5$)peculiar factors of "psyhhological" nature were playing a role.

Point a) may be excluded a priori,in that we are not directly interested in clinical problems.

Let us consider now point b).The results reported below were recorded from subjects specialized in matter of psychophysical research,in the field of Physiological Optics.Two of them,L.R. and A.F.,are working since 1948. A.M.E. since 1952.Other subjects were working for 6,2,and ½ year,respectively.

Point $b_1$ may be regarded as unimportant.Our apparatus consists of a double-beam Cossor oscilloscope,of a modified Gratz pre-amplifier(overall time constant 0.7 sec),and the active electrode is fitted in the corneal bulge of a contact lens,while the indifferent electrode is applied on the fore-head.Such an apparatus is periodically revised by a technician,and anodic batteries,filament heating and current fedding the light source are rigorously stabilized.In addition,it should be noted that is unusual ERG responses are recorded in a given set,from a given subject,quite normal responses may be recorded from another subject in a just proceeding or in a just following set.It should not be forgotten,however,that when,eight years ago,we were setting up our apparatus,we modified it radically a number of times(three),in that we ascribed the unusual responses to a low performance of the apparatus itself.The third one was finally regarded as available,but now we recognize that it happened because the individuals serving as subjects were attaining,at that time ,a sufficiently high degree of training.Some complications arose,again,when another subject participated in the experiment,but now we ascribed the trouble to unusual factorsrelative to the "electroretinographic" performance of the subject,in that,when replacing the new subject with a trained one,also the degree of availability of the system as a whole was good.

Let us consider now point $b_2$.In our apparatus Maxwellian view is employed,in that the light enaters the pupil through a narrowing(2 mm diam.) of the stimulating beam. The focal area,at the retina,is about 5 deg. diam.The subject keeps his head in position by the aid of a chin-rest and fixates a dimly illuminated fixation area,also viewed in Maxwellian view.The tooth-bite is not employed,in part because a trained subject does not need it, in part because

in long-lasting experimental sets a trouble arises from the salivation.

By applying a small mirror on the contact lens, and by recording the movement of the reflected beam, we noticed that our subjects are so steady, when they are requested to keep their eye in a given position, that the amplitude of the motion of their eyes does not exceed the limits of the involuntary eye movement amplitude. In addition, our subjects are so trained to keep the eye in position, that they can easily see the fading-out (even in foveal vision) of a fixated test-object. The percent ratio of misleading responses to the total number of responses recorded in a given set, under given conditions of stimulation, for an "available" subject is found to be about 6% while the probability that an artifact, whatever its nature might occur just at the same point of the time axis where also a true response to light occurs, is about 2% (see L.Ronchi-G.Bottai-Atti Fond.G.Ronchi, 16, 532, (1961)). Note that our subjects are fitting each one his proper contact lens, and they wear it, for various purposes, even one hour per day.

Point $b_3$ includes some peculiar conditions, which, in general, were carefully avoided. Thus, for instance, we noticed a decrease in the size of ERG response, through a week or more, after blood donation (G.Abbozzo-Atti Fond. G.Ronchi, 16, 51, (1961); L.Ronchi-G.Abbozzo-T.Torrini-Minerva Medica, in press). Also the use of anaesthetic (M. Bittini-Atti Fond.G.Ronchi, 13, 44, (1958) and of analgaesic drugs (unpublished data) may alter the size of the response in a significant way.

The troubles relative to point $b_4$ were carefully avoided. In general, the eye of our subjects is adapted to darkwA stimulus, in order to evoke a sizable ERG, must be intense enough as to alter the original state of adaptation, and a local adaptation occurs concomotantly with ERG response. Now, if the time interval between two successive stimulations is suitably choosen, any response ma be regarded as independent of the residuals of previous stimulation. The above said time interval depends , obviou on the amount of stimulating energy. Let us consider a so intense stimulus, that a slight submaximal response is recorded. In general, in our ERG experiments, involving durations of a few hundreths of a sec, the interval between successive stimulations was about half-a-min. Recently we used more frequent stimulations (one stimulus in ten of in five sec). The result is that if no unusual factors are at work, soon after the initial period of training, the size of such frequent response does not change appre

bly, even if the set is prolonged for, say, half-an-hour. (In text-books we find that, in general, the time interval between successive stimulations should not be lesser than 1½sec). Thus, it is once more confirmed that the ERG provides an index of retinal adaptation which differs with respect to that obtained from psychophysical responses.

Finally, let us consider point b5. Apart from experiments on conditioning, not taken into account here, the unusual effects occurring under repeated stimulation by the aid of a given light stimulus may be subdivided as follows:

I)-Variation of both size and shape of the response during the first few preliminary sets. Such a "training" effect concerns mainly those subjects who, before, did never participate in ERG experiments. In general, the initial response appears quite negative, then, the negativity tends to decrease, and, last, it disappears. The size of the positive response increases at first, and after the first two or three days, it attains its maximum value, followed by a slow decline, until, finally, a steady level is attained.

II)-Variation of the response implying a long-term adaptation. Such an effect concerns trained subjects presented with a new condition of stimulation. Let the time interval between two successive flashes be 10 sec, and let be 100 the number of responses collected in each set. The behavior of the average size of these responses, plotted as a function of the order number of the set, is that shown in figures 7 through 9. Note the tremendous change in size while both latency and implicit time remain practically unchanged (apart from slight changes, not reproducible in all the situations).

That above reported refers to the average values of the sizes recorded trhoughout each session. However, peculiar adaptational changes are tested even during the course of a given set. In some cases, the size of the response is rigorously the same, during the various presentations. In other cases, an initial rise is followed by a drop. Last, in some cases a negatively accelerated function is reported.

One might suggest that when ERG responses are recorded over a period of months, a seasonal variation of sensitivity is likely to occur, in addition to the adaptational effects, and the question arises as to the possibility of a mutual masking.

It is our opinion that the seasonal variation is

such a slow effect compared to the abrupt changes due to long-term adaptation, that its effect plays a secondary role. Such an opinion is based on experimental evidence collected by Freedman, in our laboratory, who recorded for a period of two weeks, every day, at the same time, from the same subject, both the response to a sequence of stimuli of given intensity, and, suitably intervalled, a number (three) of intensity functions. These latters did not appear to change appreciably (in a first approximation at least), while the long-term adaptation was occurring. The conclusion is that such changes in the response level are closely related to the exposure situation, or, in other words, the gradient of generalization is extremely steep.

In addition to the above reported results, we were recording other effects. To demonstrate their statistical significance is the purpose of our future work.

==========

ObsL.R. FIG. 7

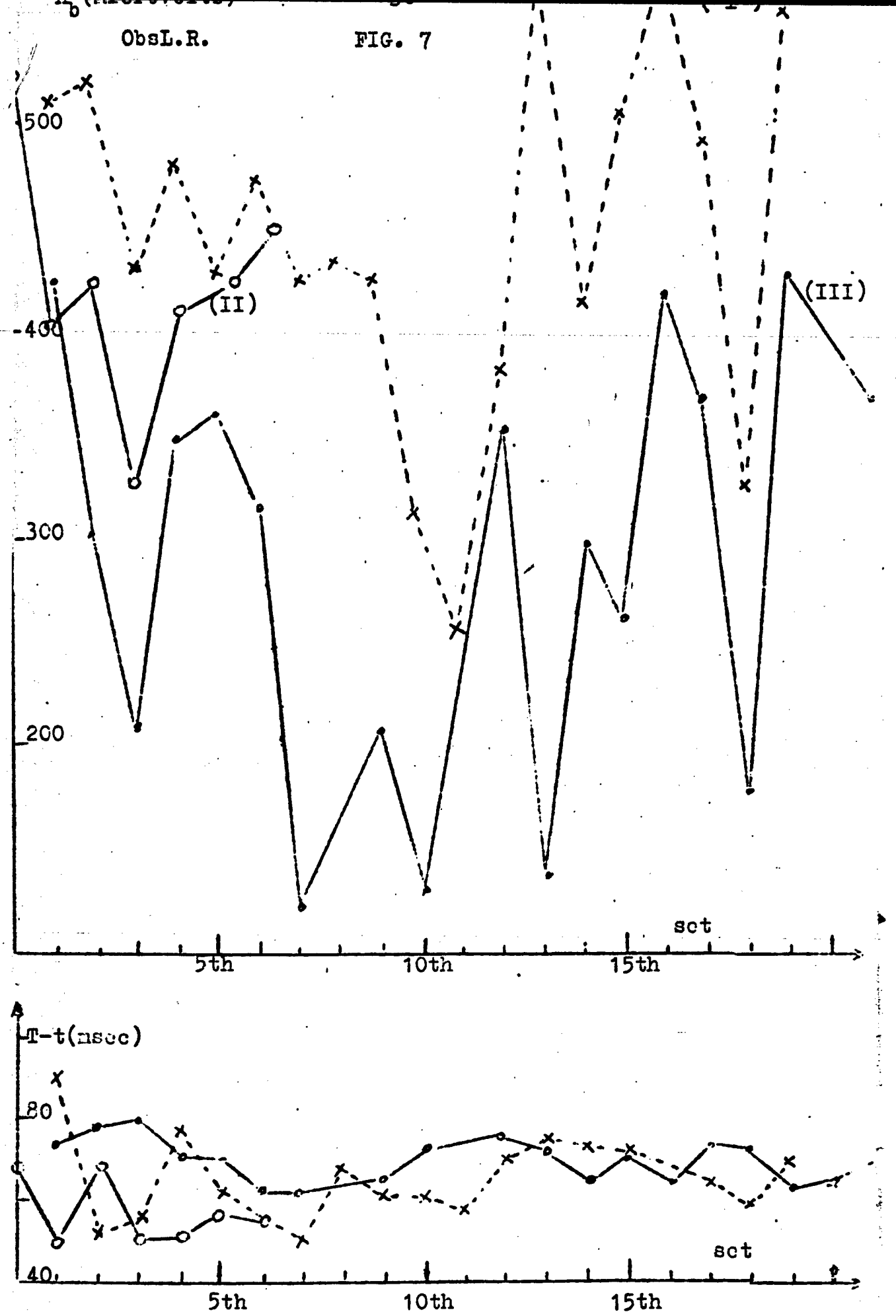
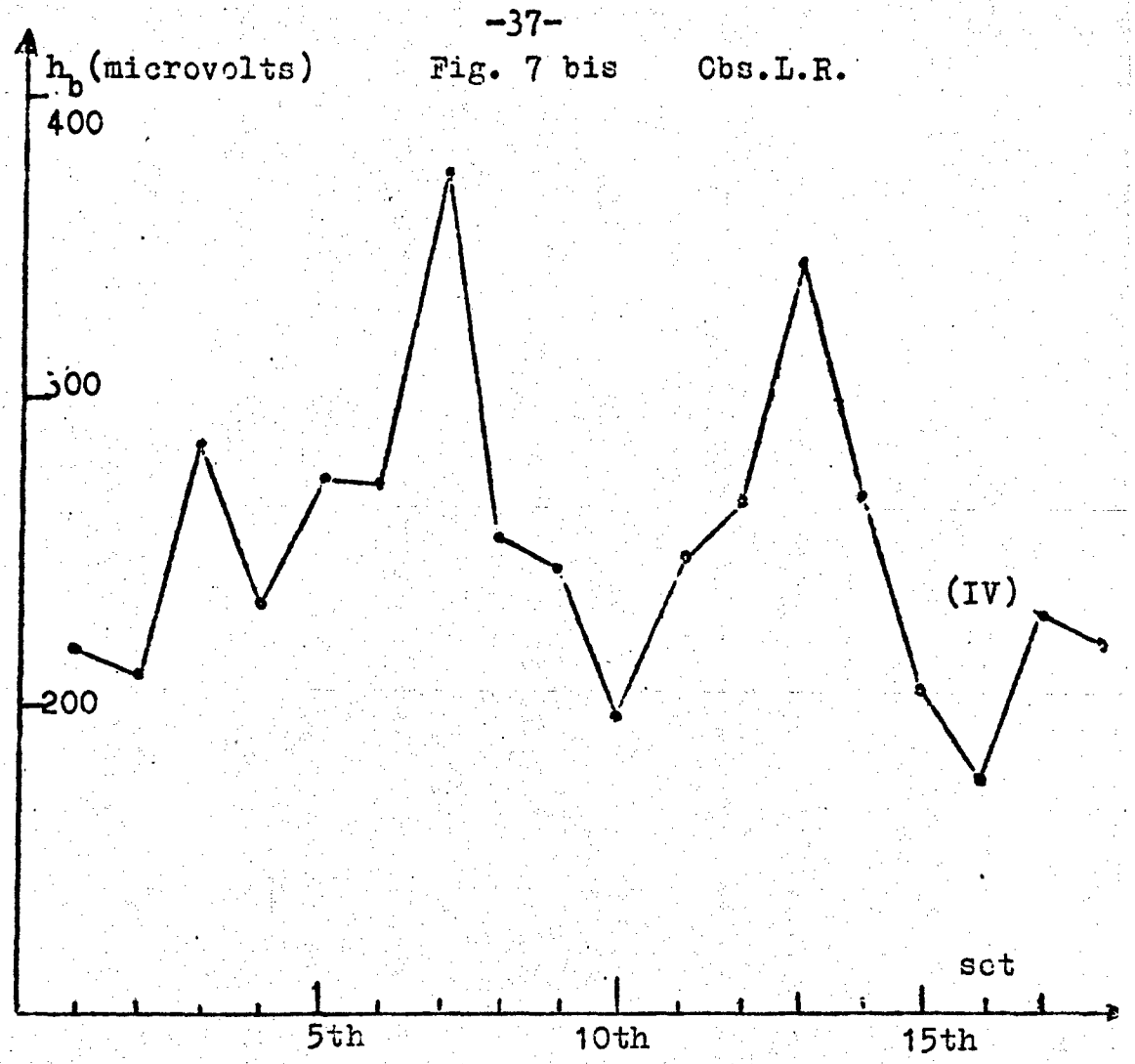

500
400
300
200
(II)
(III)
sct
5th
10th
15th
T-t(nsec)
80
40
sct
5th
10th
15th

Fig. 7 bis Obs.L.R.



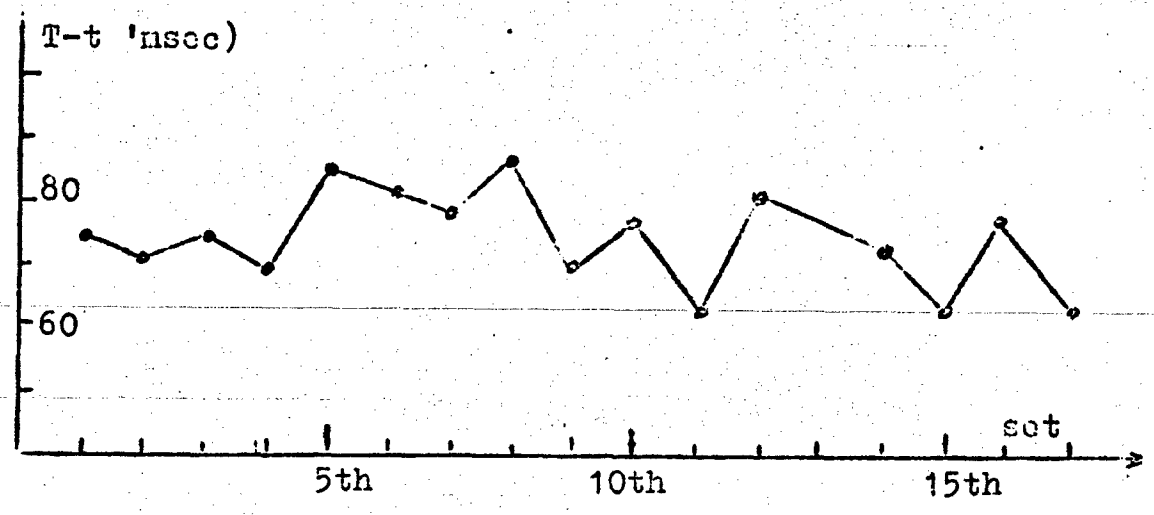



Fig. 8 Obs. A. .E.

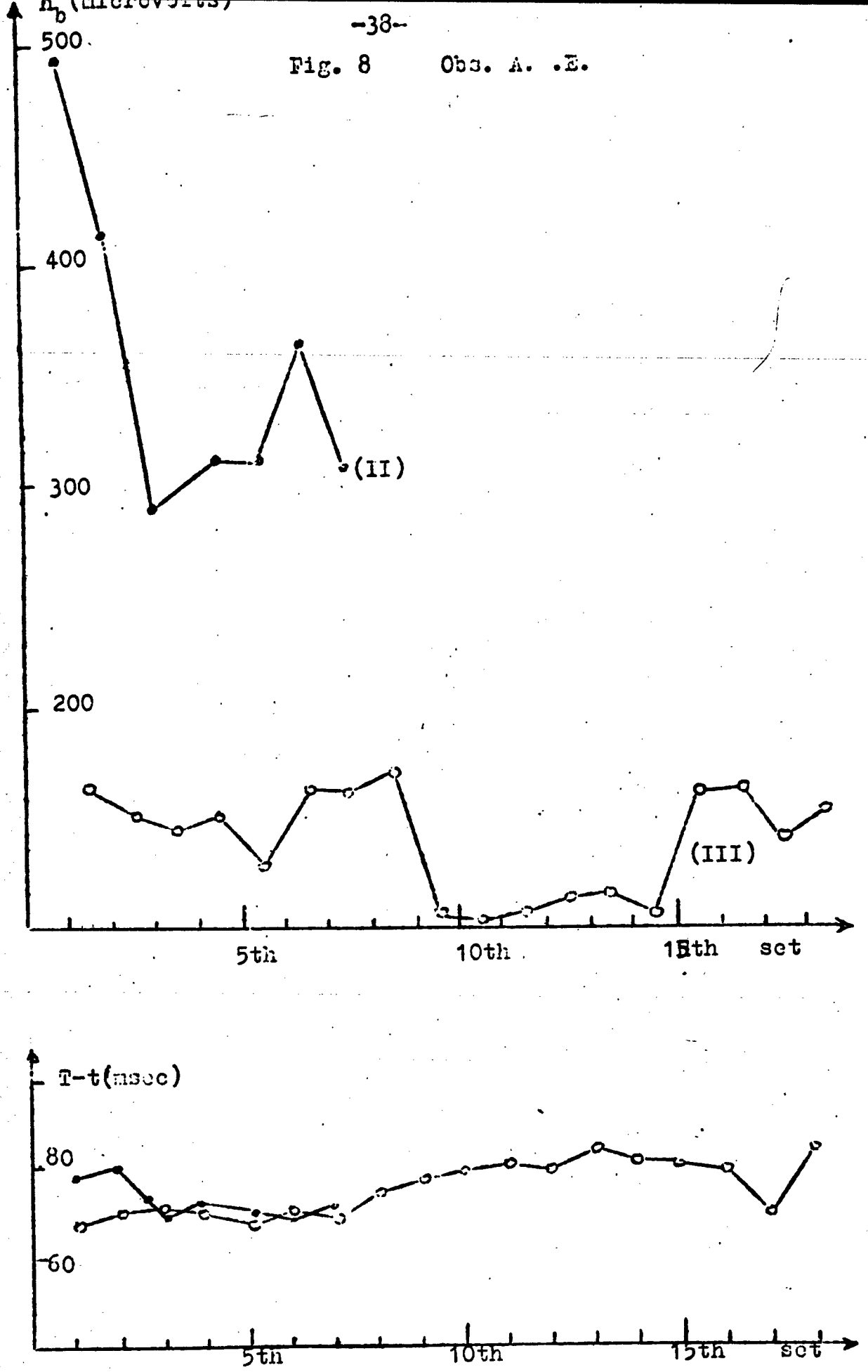
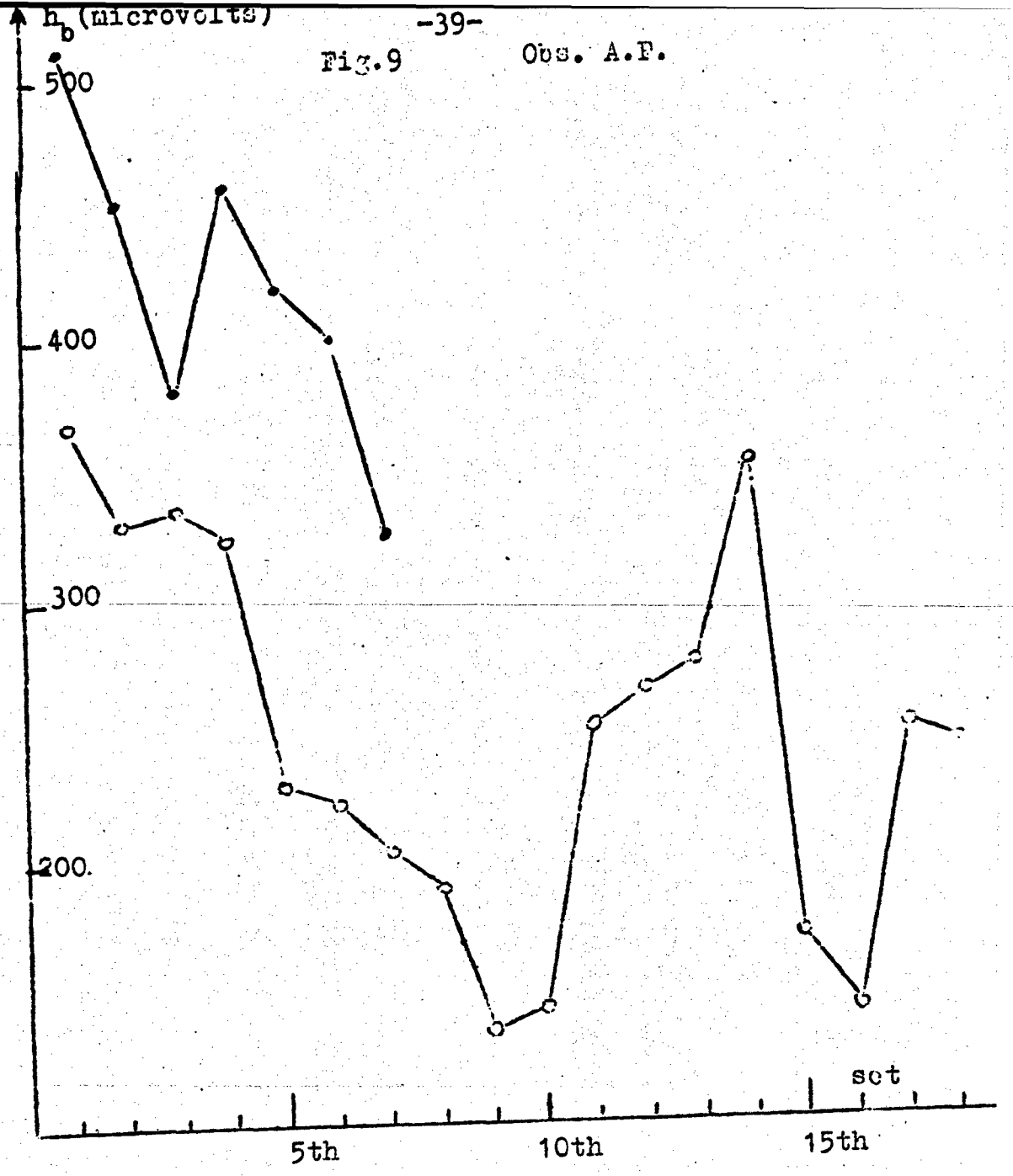
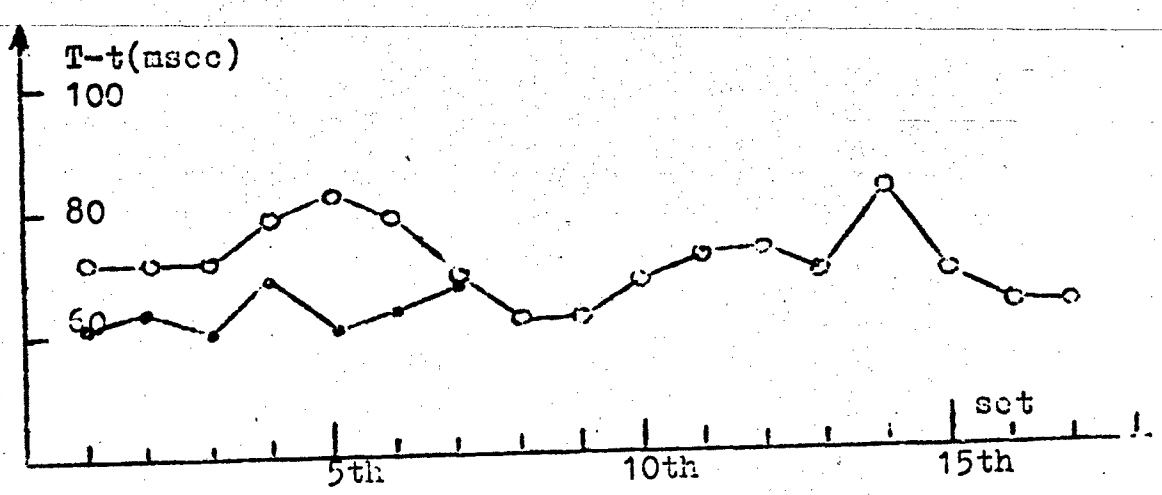

$h_b$ (microvolts)
500
400
300
200
(II)
(III)
5th
10th
15th
set
T-t(msec)
80
60
5th
10th
15th
set

Fig.9 Obs. A.F.


$h_b$ (microvolts)
500
400
300
200
set
5th
10th
15th


T-t(msec)
100
80
60
set
5th
10th
15th

Captions to the figures 7 ,7 bis,8 and 9.

Upper portion:the size of the scotopic b-wave is plotted against the order number of the set.Each point refers to the average of about 100 responses,collected in a given set.

Lower portion:the time amplitude of the b-wave,that is the difference between implicit time and latency time, as a function of the order number of the set.

Labels I,II etc. refer to different periods of the year through which experiments were performed,as follows:

Fig.7-Observer L.R.-
(I)-from 31 Oct. to 1 Dec. 1961.
(II)-from 4 to 12 Dec.1961
(III)-from 20 Jan. to 14 March 1962.

Fig.7 bis-from 25 May to 2 June 1962.

Fig.8-(~~II~~)- ~~Osrevr~~ Observer A.M.E.
(II)-from 23 Jan. to 1 Feb. 1962.
(III)-from 28 May to 5 June 1962.

Fig.9-Observer A.F.
(I)-25 Sept.-6 Oct. 1961
(II)-25 May-2 June 1962.

Curves labeld IV(fig.7 bis),III(fig.8) and (II)(fig.9) were recorded by the aid of a repeated stimulation of 4.2 mL in intensityt.The others referr to slightly higher values.

## LIST OF TECHNICAL NOTES

(1)-M. Bittini-Subjective sharpness and contrast threshold-Atti Fond.G.Ronchi,17,387,(1962).

(2)-L.Ronchi-I.Adachi-On the sharpness of defocussed contours-Atti Fond.G.Ronhci,17,405,(1962).

(3)-L.Ronchi-M.Bittini-I.Adachi-Subjective sharpness of a contour as a function of luminance and contrast- 6th CIO Meeting,Munich,Aug.1962.

(4)-L.Ronchi-Quantitative data on the blur-to-sharp transition-Atti Fond.G.Ronchi,17,N°6 ,(1962).

(5)-L.Ronchi-A.M.Ercoles-Adaptational effects at photopic and mesppic luminances as a function of contrast-Atti Fond.G.Ronchi,17,185,(1962).

(6)-M.Conticelli-Memory for brightness:stimuli of small size,surrounded by dark.Atti Fond.G.Ronchi, 17,497 ,(1962).

(7)-M.Conticelli-Training and retinal location affecting the periodic fluctuation of apparent brightness during prolonged fixation-Atti Fond. G.Ronchi,17,396,(1962).

(8)-M.Conticelli-Quelques experiences sur la fluctuation de la brillance apparente-Optik,(in press).

(9)-G.Ferrara Mori-Eye dominance in an empty field-Atti Fond.G.Ronchi,17,55,(1962).

(10)-L.Ronchi-M.Conticelli-The "fading-out" of a fixated test-field.Monocular and binocular experiments. Atti Fond.G.Ronchi,16,643,(1961).

(11)-LRonchi-G.Bottai-Visual effects produced by a stimulus consisting og a variable number of black line segments viwed on a bright background-Atti Fond.G.Ronchi,17,507 ,(1962).

(12)-M.Bittini-A comparison between foveal and peripheral flicker sensitivity for colored lights at photopic levels-Atti Fond.G.Ronchi,17, N°6 ,(1962),in press.

(13)-A.M.Ercoles-Red and blue electroretinograms at various luminances-Atti Fond.G.Ronchi,17,N°6, (1962),in press.

(14)-L.Ronchi-S.J.Freedman-Adaptation and training effects in ERG:I-Long term adaptation-Atti Fond.G. Ronchi,17,381,(1962).

(15)-L.Ronchi-Nouveautés dans le champ des ERG-Paper presented at the Symp.Jub. d'Ophth.fonctionelle, Marseille,25-28 Nov.,(1962).

(16)-A.M.Ercoles and A.Fiorentini - Visibility of a steadily fixated or stabilized test object as a function of excentricity - Atti Fond. G.Ronchi, 17, N°6 (1962), in press.

(17) A.Fiorentini and A.M.Ercoles - On some factors influencing the disappearance of a stabilized object - Paper presented at the 6th CIO Meeting, Munich, August 1962

## TABLE OF CONTENTS


Abstract pg. 1

1. Investigation on the visual perception of contours

   On the visibility of stabilized contours " 3

   On the sensation of sharpness " 15

2. Investigation on the sensation of brightness " 20

3. Investigation on retinal response to lights of different spectral composition, by taking as an index both critical flicker frequency and electroretinographic intensity function " 28

4. Work on long-term adaptation and training relatively to ERG response " 31