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Abstract

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Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Subject Categories

Optometry

ACCOMMODATIVE RESPONSE IN ASYMMETRIC CONVERGENCE

Original research paper
presented to the faculty of the

College of Optometry
Pacific University

in partial fulfillment
of the requirements for the degree
Doctor of Optometry

by

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and
W. Keith Wilson

January 1954

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INTRODUCTION

The possibility that the two eyes may respond differently to unequal accommodative stimuli has been discussed for a good many years. Usually two approaches have been made to the investigation of this problem. The first has been to study accommodation in response to unequal stimuli in the mid-sagittal plane. The second has been to measure accommodation in asymmetric convergence, where the difference in distance to the entrance pupils should be associated with a different accommodative stimulus to the two eyes.

Fick[1] believed he was able to accommodate unequally when reading small print with + and - 1.00D. spheres before one eye. Hess and Neuman[2] believed that they were not able to compensate for a stimulus difference of as little as 0.12D. Grimm[3] repeated Hess and Neuman's work and concluded that he was able to accommodate unequally for a difference in refraction of about 1.50D. He also repeated the experiment with like results when the stimuli were at unequal distances. Using a haploscope Stoddard and Morgan[4] considered monocular accommodation possible, but found that the response was always less than the stimulus. According to these investigators unequal accommodation may occur to the

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The writers wish to thank Dr. Mathew Alpern of the College of Optometry for his invaluable assistance in the preparation of this manuscript.

extent of 0.50D., yet 0.12D. was found to be the average for stimuli from ± 0.25D to ± 1.00D. Ball[5] found the mean difference in unequal accommodation by adding lenses before one eye and determining the response retinoscopically to be 0.106D. and subjectively to be 0.213D. Goldman[6] measured accommodative response in a number of subjects when one eye was partially paralysed with a cycloplegic. He used a modification of Scheiner's experiment. The results indicated to him that the law of equal innervation which applies to the extraocular muscles also applies to the ciliary muscles at least for symmetric convergence.

It has been known for some time that differences in size between the retinal images of the eyes may arise in asymmetric convergence because the object fixated will be at a different distance from the two eyes.[7] With this size difference it would be expected that binocular stereoscopic spatial localization might be distorted, nevertheless, in the normal use of the eyes no apparent difficulties arise in the act of looking to one side. One of the possible compensating processes suggested by Ogle is an actual change in the dioptric systems of the eyes. His experiments suggested, however, that if differences in accommodation occured they were too small to account for the effect. Rosenberg, Flax, Brodsky, and Abelman, on the other hand, found marked differences in accommodation for the two eyes in asymmetric convergence (for 20° asymmetric convergence of the order of 1.00D.) which was even in excess of the differences in the stimuli. These investigators suggest that the differences between their results and those obtained by Ogle[9] were due to the differences in the experimental arrangement, The present experiments were designed to test this possibility. The experimental arrangement was such as to attempt to duplicate that of Rosenberg, Flax, Brodsky and Ableman as closely as possible. Further experiments were carried out in which the differences in accommodative response were measured in different monocular version positions.

APPARATUS

The haploscope used in these experiments is illustrated in Figure 1. The Badal optometer consists of a light source and an aperature of 0.5mm diameter which moves along the optical axis of the lens C. This tract is calibrated with a scale S. It is assumed in these experiments that the position of the light source (stigmatoscope target) when it is seen at its smallest possible diameter represents the optical point of conjugacy to the eye. The optical accommodative response was determined by this measurement.

The lens wells, B, are located at the spectacle plane 14mm from the corneal apicies. To each side of these wells (not shown) are corneal aligning devices which consist of hair line sights. The subjects head is held in a chin cup and rests against a forehead bar. The arms rotate about a point 13mm behind the corneal apicies which approximates the centers of rotations for the observer's eyes.

The fixation target consisted of a line of six Es in close

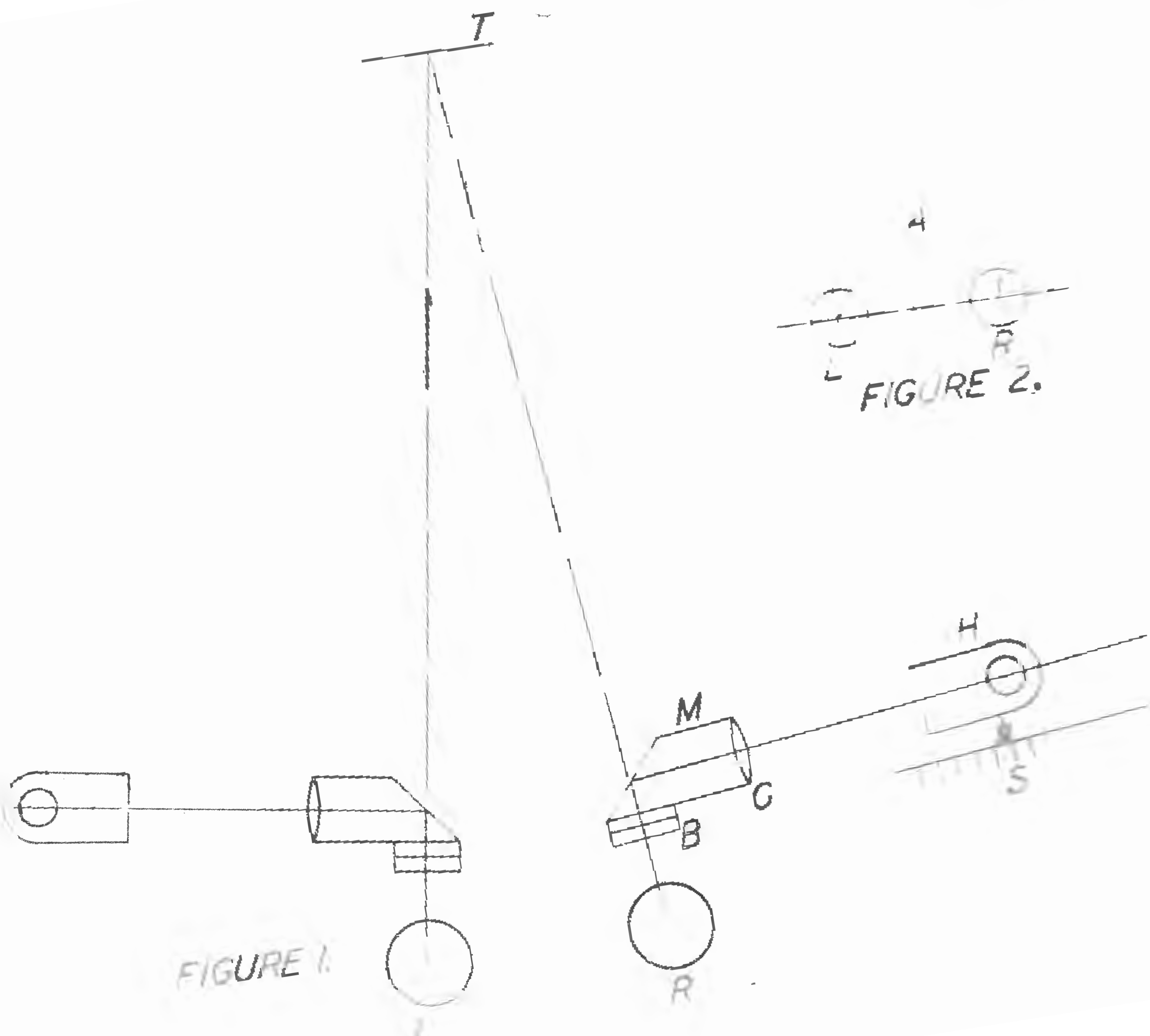

FIGURE 2.

FIGURE 1.

approximation, 0.85mm high, located in the center of a white card 8 x 14". The target was attached to a stand which could be moved in an arc of 25cm radius from the mid-point of the spectacle plane. The degrees of asymmetric convergence could be read from a scale on the haploscope. The target had a luminance of 75 foot-lamberts.

PROCEDURE

Two experienced observers were subjects in this experiment.

The instrument was adjusted so that the centers of rotation for the arms of the haploscope coincided with points 13mm behind the apicies of the corneas on the optical axes of the lenses. This was accomplished by two individuals aligning the hairlines from opposite sides and changing the positioning of the chin cup and the forehead rest until the subjects corneal apicies were in line with the sights.

Before each set of readings was taken the subject was allowed to view the fixation target for a period of thirty seconds during this time he was asked to place the stigmatoscope targets to the right and left sides of the fixation target by adjusting the arms of the instrument.

The following sets of measurements were made:

I. With the fixation target in the mid-sagittal plane 25cm from the mid-point of the spectacle plane, the subject was instructed to move first the right then the left stigmatoscope targets to the position of maximum clarity and minimum size while keeping the fixation clear. Five readings were made at this level, utilizing the psychophysical method of average error, and in a similar manner with the following lenses in the lens cells: + 0.50D, -0.50D, +1.00D and -1.00D. in that order. Thus a total of 25 readings were obtained for each eye.

II. The entire procedure was then repeated with the fixation target positioned 20° to the left at a distance of 25cm from the center of the spectacle plane. With an occluder inserted between the left eye and the fixation target such that the stigmatoscope target could still be viewed by the left eye the procedure was repeated. The right eye was then occluded in a similar manner and the procedure repeated.

III. The fixation target was moved to a position 20° to the right of the mid-sagittal plane with the distance of 25cm maintained and the entire procedure outlined in II was repeated.

The above measurements were made without interruption for both subjects.

RESULTS

Table I shows the differences in accommodation for binocular fixation in the mid-sagittal plane. Plus means that the right eye accommodated more than the left and minus means the left eye accommodated more than the right. The mean differences from Table I were used in all subsequent measurements to "correct" the differences obtained. The greater response for both observers was with the sighting eye.

Table II is similiar to Table I but for positions of 20° right and left asymmetric convergence. The average mean difference for RWS was 0.13D and for [illegible] was 0.1375D. The two subjects responded in different ways. For RWS the closer eye accommodated more while for WKW it accommodated less. The small values for the standard deviations indicate the precision of the measurements.

In Table III the differences in accommodation under conditions of monocular fixation in asymmetric convergence are given. For RWS the fixing eye always accommodated more and for WKW the fixing eye always accommodated less. This was found irrespective of the relative position of asymmetry to the fixing eye. These results suggest the possibility that differences in monocular fixation were more closely related to the eye occluded (or fixing) than to the position of asymmetry. In order to test this possibility the experiment was repeated with monocular fixation in the symmetrical position. These data are given in Table IV. It is apparent that the same patterns are followed for each observer in symmetrical convergence as in asymmetrical convergence thus confirming the hypothesis.

Calculation of the t values for each distribution showed that all of the differences obtained were statistically significant beyond the 0.001 level of confidence.

DISCUSSION

With bonocular fixation in asymmetric convergence the subjects responses were opposite. Subject RWS accommodated in a direction which would be predicted by stimulus differences, whereas, subject WKW accommodated in the opposite direction. Neither subject approached the calculated difference in the stimulus to accommodation for the two eyes of 0.31D when view-

TABLE I

DIFFERENCES IN ACCOMMODATION (A) FOR BINOCULAR FIXATION IN THE MID-SAGITTAL PLANE

SUBJECT	DIFFERENCE IN ACCOMMODATION IN DIOPTERS A	STANDARD DEVIATIONS S.D.
RWS	+ 0.I2 *	± 0.I2
WKW	+ 0.I75	± 0.03

* + indicates right eye accommodated more than left eye.

TABLE II

DIFFERENCES IN ACCOMMODATION FOR BINOCULAR FIXATION IN ASYMMETRIC CONVERGENCE

SUBJECT	DIRECTION OF FIXATION	A	S.D.
RWS	RIGHT	+ 0.I3	± 0.I4
	LEFT	- 0.I3	± 0.08
WKW	RIGHT	- 0.I8	± 0.08
	LEFT	+ 0.09	± 0.07

TABLE III

DIFFERENCES IN ACCOMMODATION FOR MONOCULAR FIXATION IN ASYMMETRIC CONVERGENCE

SUBJECT	FIXING EYE	DIRECTION	A	S.D.
RWS	OD	RIGHT	+ 0.43	± 0.I7
	OS	"	- 0.I7	± 0.I6
WKW	OD	"	- 0.I7	± 0.09
	OS	"	± 0.09	± 0.I7
RWS	OD	LEFT	+ 0.4I	± 0.II
	OS	"	- 0.22	± 0.07
WKW	OD	"	- 0.40	± 0.II
	OS	"	+ 0.06	± 0.I2

TABLE IV

DIFFERENCES IN ACCOMMODATION FOR MONOCULAR FIXATION IN SYMMETRIC CONVERGENCE

SUBJECT	FIXING EYE	DIFFERENCE IN ACCOMMODATION	STANDARD DEVIATION
RWS	OD	+ 0.37	± 0.06
	OS	− 0.15	± 0.06
VTV	OD	− 0.08	± 0.08
	OS	+ 0.34	± 0.03

ing binocularly.

Ogle suggests the possibility that differences in the direction shown by RWS may indicate a compensation for unequal retinal image sizes.* However, he also states that:

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*Although not stated by Ogle, two eyes accommodating unequally in asymmetric convergence may, if the one closer to the target is accommodating more, compensate for the inequality in the image sizes produced by the difference in distance. Assuming that both eyes are in "focus" for the object of regard and using the focal plane method of construction, it is apparent that increased accommodation would decrease the focal length of the system and thus decrease the image size. The validity of this would depend upon whether or not the positions of the principle planes remained the same. It can be shown[10] that the dioptric changes in the eye during accommodation produce a negligible shift in the positions of the principle planes with respect to the decrease in focal length.

> "the phenomenon could not be due to a differential accommodation but that the changes would have to be of a more complicated nature."

He cites as evidence an experiment conducted by him which was very similiar to the present one. A special haploscope was used with eikonic targets and small stigmatoscope lights for the detection of accommodative response. The distance of the target was 40cm but the degree of asymmetry was not given nor was the statistical significance of the differences obtained. However, the results showed for one observer that in either direction of asymmetric convergence, when the responses were "corrected" for differences in the mid-sagittal plane, that the left eye accommodated more. These differences were; 0.14D to the right and 0.09D to the left. Since Ogle used 40cm as the fixation distance his work is not quantitatively comparable to the present results. The difference found with the two observers in this experiment was not much greater for 25cm than those found by Ogle for 40cm. Neither observer showed differences which were in the same direction as that of Ogle for both left and right fixations.

The previously mentioned work of Rosemberg, Flax, Brodsky and Abelman, which this study attempted to duplicate gave decidedly conflicting results. Using the method of stigmatosco_y they measured the responses at different times for fixation distances of 12 and 20cm and for positions of asymmetric convergence of 5, 10, 15 and 20°. The averaged results for two subjects showed differences greater than the calculated differences in the stimulus of approximately 0.47D. The eye closer to the target always responded more than the other eye. It does not seem lkiely that the differences between results of these experiments and the present findings can be due to the differences in experimental design. It might be imagined that the differences between Ogle's results and those of Rosenberg, Flax, Brodsky and Abelman were due to the differences in testing distances. This explanation cannot account for the present findings which inspite of rather marked differences in testing distance tend to confirm Ogle's results.

In an experiment not directly comparable to the present one Ripple[11] found that for a group of 59 subjects, 43 showed an increase in the near point of accommodation on looking in and a decrease on looking out. Thirteen of these subjects showed no difference and the remaining three showed the opposite effect. It would follow that the difference in accommodative response for asymmetric convergence in the direction exhibited by WKW would be predicted by these data, if comparison is allowed.

The behaviour of RWS would also be predicted in accordance with the minority of Ripple's subjects.

Monocular fixation in asymmetric convergence produced differences which seemed more dependent upon the eye fixing than the direction of asymmetry. One observer always accommodated more with the fixing eye while the other always accommodated less. In general, larger differences were found under monocular conditions than under binocular conditions.

If one assumes that the accommodative response is a direct indication of the innervation to the ciliary muscle the law of equal innervation which is generally felt to be valid for these muscles, at least in symmetric convergence,[12] is shown here to be only approximately correct. For binocular fixation in asymmetric convergence differences in the accommodative responses of the two eyes of slightly less than 0.20D occured. However, with monocular fixation of a target in either symmetric or asymmetric positions slightly larger differences occured. For the subjects in this experiment this difference was never larger than 0.50D.

SUMMARY

Using a haploscope and the method of stigmatoscopy the accommodative response differences were determined for two subjects in symmetric and asymmetric (20°) convergence at a distance of 25cm. All differences were statistically significant.

For binocular fixation in asymmetric convergence these differences were approximately 0.13D for both subjects and much less than the stimulus difference of 0.31D. The responses were also opposite in nature with one subject accommodating more and the other accommodating less on the side closer to the target. The greater differences of accommodative response in binocular fixation in asymmetric convergence obtained by Rosenberg, Flax, Brodsky, and Abelman were not found in the present experiments. On the other hand, the results tended to confirm Ogle's findings.

The monocular measurements for an asymmetrically localized fixation target showed opposite responses for the two subjects of even larger differences (than found with binocular fixation) which seems to depend more on the fixing eye than on the direction of asymmetry. The implications of these findings for Hering's law of equal innervation are discussed.

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