

AN INVESTIGATION OF VOLUNTARY AS DISTINGUISHED
FROM REFLEX ACCOMMODATION*

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What is *voluntary* accommodation? Webster's New International Unabridged Dictionary, second edition, gives one definition for *voluntary* as "Of or pertaining to the will; subject to, or regulated by, the will; as, the *voluntary* motions or muscles." The connotation is that the act is done consciously.

When one ordinarily accommodates in response to the optical stimulus and apparent distance of a blurred image, there may be a desire to see the object clearly but generally there is no conscious effort. This is termed *reflex* accommodation since it appears to be a direct non-volitional response to a blur stimulus and apparent distance just as the quadriceps respond to a sudden stretch of the patellar tendon in the well known simple knee jerk reflex.

Accommodation may be termed voluntary if a successful voluntary effort is made to change accommodation from that of the usual foveal reflex accommodation for the optical stimulus and apparent distance. Voluntary accommodation may be divided into two types, positive and negative. Positive voluntary accommodation can be defined as a greater accommodation than that which would ordinarily or reflexly be found for a given optical and apparent distance. Negative voluntary accommodation can be defined as that accommodation which is less than that found reflexly in a given individual.

For example, if a letter chart is placed 33 cm. before a subject, the optical stimulus to accommodation is 3.00 D. Let it be assumed that the apparent (psychic) distance is such that it does not conflict with this optical stimulus. The actual accommodation, i. e., the accommodative response to this chart, is measured and found to be 2.50 D. in this subject for this particular stimulus situation. The 2.50 D. is his normal reflex accommodation. If the subject now makes a successful effort to accommodate for a point nearer to himself than the fixated chart, for example 6.00 D., he is said to exhibit positive voluntary

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accommodation. Similarly negative voluntary accommodation is said to be demonstrated if the subject can wilfully relax his accommodation so that the point conjugate to his fovea moves more distant than the point found in ordinary reflex accommodation for the particular stimulus-subject situation. As an example it may be said that the accommodative response is 1.00 D. which is a voluntary inhibition of 1.50 D. from the original reflex accommodation of 2.50 D.

There is no simple way to assess what part of accommodation remains reflex accommodation while voluntary accommodation is active. The reflex stimulus must change with the increased blur concomitant with voluntary accommodation. For simplicity in terminology, however, the *total* accommodation in force when a successful effort is made to change accommodation will be called voluntary accommodation.

Judging from the literature, there has been little study of voluntary accommodation. Even the few investigations we find have not determined the actual accommodation of the eye but only stimulus values. It was therefore deemed worthwhile to review the literature and make a quantitative investigation of voluntary accommodation.

HISTORY

Psychologists have been interested in voluntary accommodation as a cue to the role of accommodation in the perception of visual space. Carr and Allen (1906) reported both positive and negative voluntary accommodation in one subject (Allen). A screen was placed at 290 cm. from the subject and a pair of vertical parallel wires whose separation from each other was adjustable was put a few inches in front of her eyes. The images of the wires were kept fused to show a constant convergence while accommodation was varied voluntarily. Changes in voluntary accommodation were reported associated with concomitant changes in apparent distance. When objects seemed nearer, positive voluntary accommodation was shown by pupillary constriction and by the higher dioptric indications of a phakoscope. Conversely, when pupillary dilation and lower dioptric indications were evident, objects receded in space. The conclusion was that depth is a function of accommodation for this subject. Voluntary accommodation could not be elicited definitely in other subjects (Carr, 1907, 1908).

Sisson (1937) described a subject with voluntary control of accommodation similar to the one of Carr and Allen. She differed from Allen in that she could exhibit positive but not negative voluntary accommodation. She also reported that accommodation played no essential part in her depth perception.

Not satisfied with a single subject, Sisson (1938) decided to

achieve voluntary control of accommodation himself. To this end he constructed a pair of sighting tubes with sights at both the far ends, about 23 inches away, and near the center, about 13 inches from the eyes. The tubes were converged for fixation at a point 75 inches distant. While maintaining this fixation, Sisson attempted to accommodate for the two pair of nearer sights. Success came quickly to him. By getting the "feel" of the act, he was soon able to elicit voluntary accommodation without the binocular tubes.

Sisson reported that with the greatest effort, he could see sharply at 6 to 8 inches (6.6 to 4.9 D.) with a fixation object at 10 feet, with diplopia. No spatial changes were evident with changes of accommodation.

The refractionist also is interested in voluntary accommodation for its clinical manifestations rather than for its possible significance in depth perception. Zentmayer (1935) reported on two hyperopic patients who had continuous spasms of accommodation. One might also describe this as latent hyperopia.

In one case the spasm was probably between 4.25 and 5.50 D. of accommodation and no asthenopia was reported. This patient was able to read clearly only by straining with great effort to see clearly. Apparently this was a negative voluntary accommodation. There is a difference between the mode of this voluntary accommodation and the experimental method discussed in the introduction and in the sections below. Zentmayer's patient voluntarily relaxed accommodation and made the optical stimulus clearer. He had the aid of reflex accommodation rather than, as in the experimental approach used here, having reflex and voluntary accommodations in opposition. It is not known if or how reinforcement and antagonism of reflex and voluntary accommodations differ.

It is now apparent that the literature on voluntary accommodation is very brief. No effort has been made to graph the actual response of accommodation when voluntary and optical stimuli were in conflict. This paper was undertaken to help fill this void.

APPARATUS AND PROCEDURE

The left eye was occluded and remained so throughout the experiment. The usual correction lens of the subject was placed before his right eye. A half-reflecting mirror at a 45° angle to the fixating eye reflected the point source of a stigmatoscope. The subject manipulated this instrument which yielded the accommodative response of his eye to the various stimuli presented.

Fixation targets were used at distances of 5, 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ and $\frac{1}{5}$ meters. This allowed optical and proximal stimuli to accommodation of 0.20, 1.00, 2.00, 3.00, 4.00, and 5.00 D. The targets were two parallel black bars on a white ground photographically reproduced to present a space between them of about one minute of arc measured from the eye. Targets were presented in order; in some experimental runs from far to near and in others from near to far.

Seven subjects were chosen from the students and faculty of the school of optometry of the University of California. They ranged in age from 20 to 39 years with all the subjects but one between 20 and 29. Subjects were chosen for their professed ability to change voluntarily their accommodation either positively or negatively and thus blur the object of regard.

First each subject was told to regard with attention each of the six targets presented to him as he normally looks at any object of interest. For each target, five measurements were made with the stigmatoscope which were later averaged to show the accommodative response from the stimulus mentioned. This response is reflex accommodation.

Then each subject was instructed to attempt to accommodate for a point beyond the target, viz, negatively, while fixating the parallel bar target at each fixation distance. The same type of measurements were made by stigmatoscopy for the accommodative response.

The same procedure was followed for attempted accommodation for a point nearer than the target, viz, positively, while constantly fixating the target.

Subjects were instructed to fixate the target and not the point-source image of the stigmatoscope. Hence, this image should not have provided any appreciable stimulus to accommodation.

RESULTS

All the results are graphed in Figures 1 and 2. All subjects exhibit normal reflex accommodation as originally demonstrated by Ames & Gliddon (1928) and also, monocularly, by Morgan (1944). Characteristically they show up to 1.25 D. of "myopia" when measured by a stigmatoscope with fixation at 5 meters. The theory behind this apparent discrepancy, which is fundamental in accommodation, has been discussed elsewhere (Morgan, 1944).* Most of the subjects,

*Emmetropia as measured clinically has what might be called a "plus lens bias." This is an obvious consequence of the general clinical procedure in refraction of the selection of maximum convex or minimum concave lens for maximum visual acuity. It is believed that the eye may utilize its depth of focus when part of it is anterior to

however, show less than 0.50 D. of this added refractive power of the eye by stigmatoscopy with 5 meter fixation.

Accommodative response generally remains no more than 0.75 D. behind the stimulus as represented on the graph by the unit ratio line.† In one subject there is about a 1.50 D. lag of accommodation behind the 5.00 D. stimulus.

Six of the seven subjects could exhibit large amounts of negative voluntary accommodation whereas the seventh subject (K.G.) exhibited it to a small but obviously significant degree. This subject appears to demonstrate that while a voluntary effort to inhibit accommodation may show some minor success, the optical and proximal stimuli are relatively more dominant in this subject. It seems likely that with the proper training the optical and proximal stimuli could be subordinated to the effort of the will to relax accommodation.

Another interesting phenomenon seems evident. It is an apparent increase of negative voluntary accommodation as the optical stimulus is increased. This means that some individuals appear to be able to relax more accommodation voluntarily when the optical and proximal stimuli to positive accommodation are increased. This seeming paradox is best illustrated in the graph of G. D. where the negative voluntary accommodation is more than 0.25 D. greater with 5.00 D. fixation than with 0.20 D. fixation. This apparent effect may not be statistically significant, and it will require more refined techniques to be reasonably certain of its existence.

The repeatability of reflex and negative voluntary accommodation is seen by a comparison of the graph of R. H. in Figure 1 and the same subject taken on another day, R. H. retake in Figure 2. The two pair of curves show the same general form and any difference between them is of questionable significance.

The subjects may be divided into three rather arbitrary groups on the basis of their positive voluntary accommodation: (1) Those who exhibited voluntary positive accommodation without being influenced by the optical and apparent distance stimuli. (2) Those who were so

the receptive outer segments of the foveal cones. Hence, little or no change of shape of the crystalline lens may occur for the first half diopter or so of "accommodation."

†The term "unit ratio line" describes the diagonal on a graph (as illustrated in the figures above) showing the monocular function of equal units of accommodative stimulus and response. The same terms may be used for the diagonal on another graph showing the binocular function of equal units of accommodation in diopters and convergence in meter angles. This is what Donders called "the line of convergence" and subsequent investigators have called "Donders' line." Donders in his time was not aware of the stimulus-response graph of accommodation. It would seem better, therefore, to use "unit ratio" rather than Donders' name as has been done to describe the line in the type of graphs illustrated in this paper.

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influenced. (3) Those who could not effect positive voluntary accommodation.

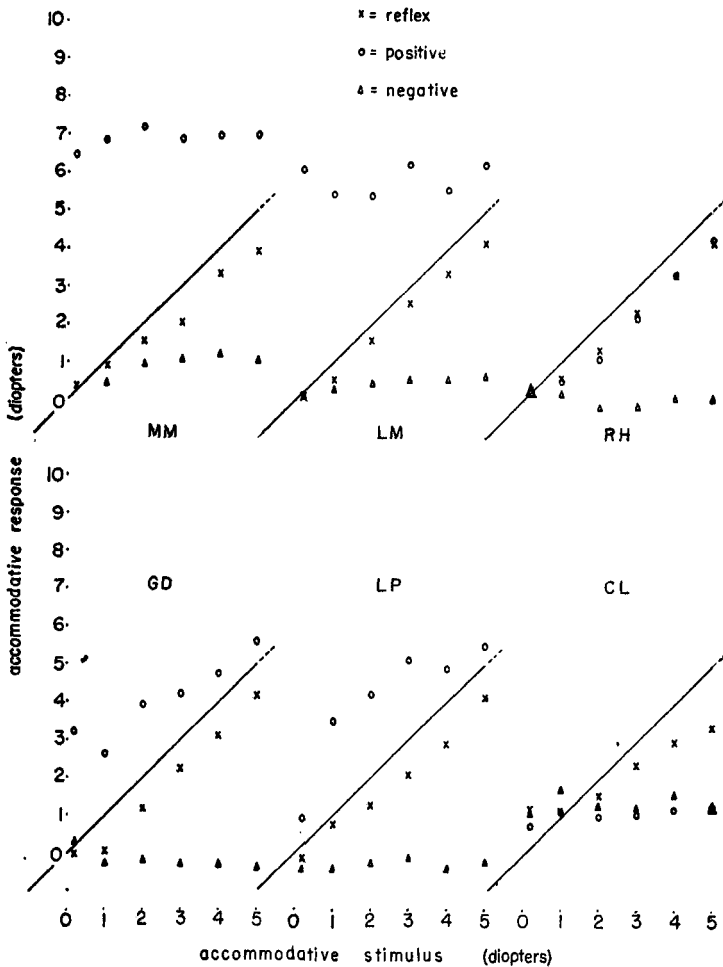


Fig. 1. The ordinates are accommodative response as determined by five readings of the stigmatoscope for each point. The abscissas are the optical stimuli. Voluntary stimulus cannot, of course, be measured. The voluntary response is evident by departure from the reflex response. The crosses signify ordinary reflex accommodation. Circles show attempted positive voluntary accommodation. Triangles stand for attempted negative voluntary accommodation. The diagonal line is the unit ratio line representing a 1:1 ratio between stimulus and response.

In Figures 1 and 2, subjects M. M., L. M., and K. G. show no effect of the target on their accommodative efforts. There is a fair degree of scatter in the points of the latter two subjects. This scatter

is to be expected since the degree of positive voluntary accommodation depends in part on the effort maintained which is in most subjects spasmodic and not smoothly sustained. It also depends on the practice one

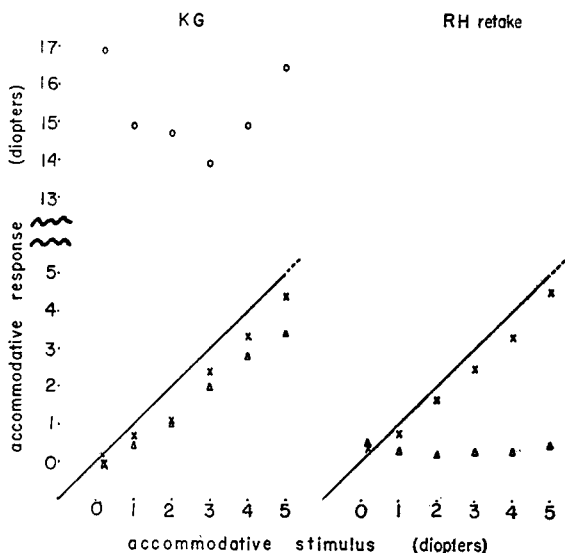


Fig. 2. See legend of Figure 1.

has had in controlling the normally "involuntary" eye functions. Practice reduces the effort involved. That is probably the reason that M. M. who has had many years of experience with free stereoscopy shows so little scatter. It is interesting to note that K. G. has an unusually large amplitude of voluntary accommodation averaging 15 D. This was about equal to his reflex amplitude.

Two subjects (L. P. and G. D.) gave an increase of voluntary positive accommodation with increased optical and apparent distant stimuli to accommodation. To put it in another way, their voluntary positive accommodation appeared to tend to be limited by the physical stimuli to accommodation.

Of the two remaining subjects, one (R. H.) showed no positive voluntary accommodation. In fact, if the difference in most of the points can be considered significant, there was slightly less accommodation with effort to increase it than under normal reflex conditions of stimulus. The other subject (C. L.) with a Herculean effort to increase his positive voluntary accommodation, actually manifested more negative voluntary accommodation than he had in previously attempting it. It would seem that the organism ordinarily cannot tell whether a blur is from

the image falling in front of the retina or tending to fall behind the retina. If there are any cues from the apparent distance, the state of accommodation or the character of the blur "circles" on the retina, they do not seem to help in making conscious this great discrepancy between the intentions and the response of the subject.

DISCUSSION

Voluntary accommodation, both positive and negative appears to be much more common than would be judged by its infrequent appearance in the literature. A cursory poll yielded the surprising information that nearly half of a class of 50 optometry students claimed that with a little practice they could elicit it to an appreciable degree. This would agree with Sisson (1938) who said, "The whole procedure [of voluntary accommodation] seems to be identical with that involved in learning to wiggle ones ears or move one's scalp, etc., i. e., getting the 'feel' of muscular adjustments involved, so that these can later be duplicated at will."

Carr and Allen and also Sisson were interested and succeeded in eliciting voluntary accommodation during single binocular vision with a constant total convergence. Their aim was to vary accommodation while maintaining convergence constant, thus separating accommodation and convergence. If total convergence is divided into the components proposed by Maddox and quantified by others since the investigation of Sisson, fixed total convergence appears to be an unnecessary limiting and perhaps complicating element which is better omitted. For these reasons it was felt that monocular observation was sufficient throughout the experiments reported here.

It is not at all likely that the stigmatoscope image acts as the stimulus of the large changes in voluntary accommodation. The heavy blurring, which occurred with attempts to change accommodation, occurred even with the stigmatoscope set for the target distance or even without any apparatus at all so that the stigma could not have acted as the primary stimulus for the phenomenon. However, it is entirely conceivable that the instrument may have had a minor effect in the results. The measuring instrument would be expected to have no effect as long as the subject fixates the parallel bar target and as long as the target remains clear enough to provide the optical and proximal stimuli to accommodation. Future investigators of small amounts of voluntary accommodation could avoid this possible criticism, however, by using an optometer that cannot stimulate any accommodation such as the slit or the coincidence optometer of Fry flashed on for very brief exposures.

It may be of interest to some to mention incidentally that none of the subjects experienced any change in their appraisal of spatial relationships in either positive or negative voluntary accommodation.

Various symptoms associated with attempted positive voluntary accommodation were reported such as "tension in abdomen" (R. H.), "burning in eyes" (C. L.), "eyes hurt a bit" (M. M.), "eyes do not hurt but there is a feeling of tension or pull on them" (L. M.). Reports of these common clinical asthenopic symptoms occurred when a voluntary effort was made to elicit positive accommodation. It did not occur in the demand for reflex accommodation or for attempted negative voluntary accommodation. Therefore, this lends support to the old clinical theory that symptoms arise from the *need* to exert effort to reinforce a reflex function that is inadequate. Training which facilitates the voluntary function might then relieve the symptoms. One must be cautious in any interpretation of the data given here since, as already mentioned, the voluntary effort was opposed to the reflex and not in harmony with it. ~~And why two subjects (R. H. and C. L.) had symptoms with attempted positive voluntary accommodation which they could not achieve is an interesting unanswered question.~~

SUMMARY

Voluntary accommodation may be defined as accommodation which can be varied by conscious effort from the zero point of ordinary or reflex accommodation while the reflex (optical and apparent distance) stimuli remain unchanged. A division may be made into positive voluntary accommodation where there is accommodation for a point nearer than that found reflexly, and negative voluntary accommodation where there is accommodation for a point more distant than that ordinarily found.

Seven subjects who professed to have either positive or negative voluntary accommodation were measured and the results were graphed for their reflex and attempted voluntary accommodations. Reflex accommodation was normal. Six of the seven subjects exhibited large amounts of negative voluntary accommodation; one subject showed only a small degree of it. Five subjects exhibited positive voluntary accommodation in varying degrees. Of the other two subjects, one subject unknowingly elicited a large amount and the other subject a small amount of negative accommodation while attempting positive voluntary accommodation.

The possible clinical significance of the asthenopic symptoms associated with attempted positive voluntary accommodation is discussed.

Two subjects (R.H. and C.L.) had symptoms with attempted positive voluntary accommodation which indicates that accommodative asthenopia may be of central rather than peripheral origin.

The ability to control accommodation voluntarily is far more common than one would believe from the very few instances cited in the literature.*

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