THE BI-BO VERGENCE FACILITY TEST: A PROBE INTO THE VERGENCE SYSTEM

Senior Project Presented to

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ABSTRACT

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The vergence system is the stepchild of the oculomotor system in that it has recieved considerably less attention from researchers than has the versional system. Vergence facility is one aspect of the vergence system which will be examined in this paper. Average responses to one type of vergence facility test using a BI-BO prism bar are given. In addition, data is analysed relative to the subjects' age and near phoria positions.

INTRODUCTION

Vergence eye movements help provide the binocular animal with the ability to fixate points in visual space at various distances from the organism. Given an arbitrary fixation point in space, the fixation of any point closer to the organism would require a convergence movement. To fixate a point farther from the given point would require a divergence movement. These eye movements (often referred to as disjunctive eye movements) have not been shown to exist in animals other than primates and certain other higher mammals (Zuber 1971).

The human vergence system has been examined by many investigators in great detail. Its importance in achieving proper binocular alignment was noted and recorded by early clinicians (Fechner 1860). Much of the more recent experiments have been directed toward scientific and physiological studies to find the exact sensory processes which control and direct the eyes during a vergence movement.

Recent studies have shown that vergence responses can be elicited by disparate stimuli in the absence of any actual changes in target distance. This fact was demonstrated by Westheimer and Mitchell (1956) and replicated by Jones (1981). Their experiments used a $+1^{\circ}$ lateral stimulus which called for the subject to make a convergence movement. The response began after a latency period of 160 msec. and was followed by a period of uniform velocity equal to the latency period. In addition, the response concluded with a deceleration period and was shown to take approximately 1 sec. to be completed.

The relationship of vergence velocity to disparity magnitude is subject to large individual differences and varies slightly according to different published reports. In the above described experiment, Jones reported that vergence velocity was 7° to 10° per second per

METHOD

degree of disparity over a range of $\pm 5^{\circ}$. Mitchell (1970) found that convergence and divergence responses are often unequal, but either may be more responsive to equal disparity magnitudes. By contrast, Schor (1980) reported the velocity of a convergence movement to be 2.5 deg^2/sec (127 msec. latency) and the velocity of a divergence movement as 1.25 deg^2/sec. (119 msec. latency). Regardless of the exact velocity, it is clear from nearly all reports that the larger the disparity stimulus, the greater the vergence velocity.

Vergence facility can be described as the ease in which a person makes consecutive vergence changes. It is one area which has recieved little attention by investigators. Although an improper relationship between vergence and accommodation can result in certain visual difficulties (Schor 1982), it is unknown whether continual vergence changes alone are a potential scource of problems for the human visual system.

This paper will discuss one disparity driven vergence facility test which utilizes a prism-flipper bar system. This system will call for the subject to make twenty consecutive vergence movements, alternating divergence and convergence.

In addition to providing base-line data relative to the test, a comparison of two different disparity magnitudes will be discussed. These amounts are proportional to the prism powers used in the test and are 6.8° (4^{Δ}BI to 8^{Δ}BO) and 5.7° (4^{Δ}BI to 6^{Δ}BO).

A flipper bar was obtained which was designed such that a prism could be inserted and removed easily. Placed into one side of the bar was a 4^{Δ}BI prism and on the other side either a 6^{Δ} or 8^{Δ}BO prism.

Both the 4^{Δ}- 6^{Δ} and the 4^{Δ}- 8^{Δ} prism combinations were to be tested on the same subject, alternating the one tested first from one subject to another. The 4^{Δ}- 6^{Δ} combination was tested first on the initial subject with that decision made by a coin toss. Regardless of which combination was being used, the BI side of the bar was presented before the BO side.

The target used was the 20/50 line on a small near point chart. The chart was glued to a tongue depressor and held at 40cm. Lighting on the target was kept relatively constant with both the room lights and the overhead reading lamp illuminating the target.

The subjects for this study were primary care patients examined at the Ferris State College of Optometry, or at one of its off-campus clinic sites. The subjects were selected at random and no attempt was made to exclude a patient because of age or refractive error. However, all the subjects tested were required to have at least 20/30 near acuity and have some binocular abilities (in order to sccomplish a fusional eye movement). For those subjects wearing a spectacle or contact lens correction, the test was run with the correction in place.

The subject was asked to look at the 20/50 target and told when the lens (BI prism) was placed in front of his eyes, he would see double. He was to try and make the image single again and when this was accomplished say "single". The bar was then flipped to the BO side with the same instructions holding true. This was done for 10 complete cycles and the completion time recorded (in seconds). Immediately following the test, the BO prism was exchanged for a BO prism of a diff-erent amount (as was noted earlier) and the test repeated.

Along with the completion time, the subjects age and near phoria (von Graefe) were recorded. The near point plus power was also noted for the subjects who were wearing a near prescription.

RESULTS

DISCUSSION

The described vergence facility test was run on 44 subjects ranging from 7 to 72 years in age. The average completion time for the 10 cycles was 57.1 sec. for the 4^{Δ}- 8^{Δ} test (hence referred to as test A), and 56.2 sec. for the 4^{Δ}- 6^{Δ} test (test B). Two subjects could not complete the entire 10 cycles for either prism combination. The data collected is listed in Table I.

The results were grouped relative to the von Graefe near phoria measurements. For those subjects with a near phoria of 5 exo and greater, the mean for completion was 60.4 sec. (test A), and 59.8 sec. (test B). Subjects whose near phorias were 4 exo to 1 eso averaged 56.0 sec. (test A) and 55.7 (test B), while those with near phorias of 2 eso and greater had a mean completion time of 54.1 sec. (test A) ond 52.5 sec. (test B). The results are represented in Table II.

One of the variables in this study was which prism combination was tested first. Therefore, averages were calculated for those receiving test A first and those getting test B first. The results are shown in Table III.

The subjects' ages were compared to their completion time for each test. These relationships are illustrated in Graphs I and II. The apparent increase in time relative to increasing age is to be discussed later.

A factor which affected all of the recorded completion times was the time taken to make 20 flips (10 cycles) of the prism bar. To account for this component, a series of 20 consecutive $\frac{1}{2}$ turns of the bar was timed. The average for 3 trials was 15.3 sec.

The human vergence system is a very complex oculomotor sub-system since either fusional or accommodative stimuli may be used to drive the system (Zuber 1971). In addition, data collected in a scientfic laboratory experiment is frequently different from that derived from clinical studies. This fact, plus large individual differences in subject response, has made it difficult to predict exactly what the normal response to the test should be. However, if we consider past studies concerning vergence response time and relate the amount of the disparities tested, we can draw certain conclusions.

In the previously mentioned studies, both Jones (1981) and Schor (1980) measured the response time for the completion of a vergence movement to be approximately 1 second. Although the velocities they predicted for the disparity magnitudes used in this study are different, it is important to note from both that an increase in disparity results in an increase in vergence velocity. For this reason, we will assume that the time from the initial presentation of the stimulus to the end of the maximum velocity period is similar to their findings.

The response deceleration time however, may be a source of a slight difference in the total response time. It is logical to assume that an eye movement of a much greater velocity might take slightly longer than a lesser one to reach a speed of zero. Since the vergence mechanism is a continuously monitored and controlled system (Rashbass and Westheimer 1961), this difference is probably not greater than 80 msec. Therefore, the predicted time to accomplish a single vergence shift over the given disparity is 1.08 sec.

A series of 20 vergence movements were completed by the majority of the subjects in the study. Considering the average time to make 20 ½ turns of the test bar (15.3 sec.) and the above expected time for a single vergence, the predicted time for the completion of the test is (1.08 sec. X 20) + 15.3 sec. or 36.9 sec. Of the 2 subjects failing to complete the test, one (#4) was later diagnosed as having convergence insufficiency while the other (#15) complained greatly of giddiness and nausea during the test.

A significant observation from the data collected was the tendency for longer test times to correlate with higher ages. This may be due to the slower, reflective, more laid-back approach to things in life commonly found in older persons. Another possibility to consider is that the longer times are due to actual decreases in vergence facility or velocity. This might be explained by the lack of an accommodative drive component to vergence common to post-presbyopia. In any case, the tendency also appears in Table II where the higher exophoric subjects had the highest average age and the highest average completion time.

Perhaps the most variable factor in the design of the test was the requirement of the subject verbalizing when the fusional movement was accomplished. This was influenced by the subjects' observation skills, motivation and ability to anticipate the diplopic image becoming single. This fact also explains the difference in the expected time for completion (36.9) and this study's average response time (56.0).

The ideal vergence facility test would have to eliminate the uncontrollable variables experienced in this study. It might incorporate instantaneous stimulus presentation and completely objective measures of a completed fusional movement. Other probes of disparity magnitudes greater than those tested for this paper might reveal even more information. Varying techniques of target size, distance and method of presentation also is indicated in later studies.

It is evident that many gaps still exist in our understanding of the vergence system. By searching for additional data, and knowing how it relates to the rest of the visual system, we can better serve the needs of our patients and our profession. Only through continued experimentation, both scientifically and clinically can we begin to fill in these remaining gaps.

TABLE II

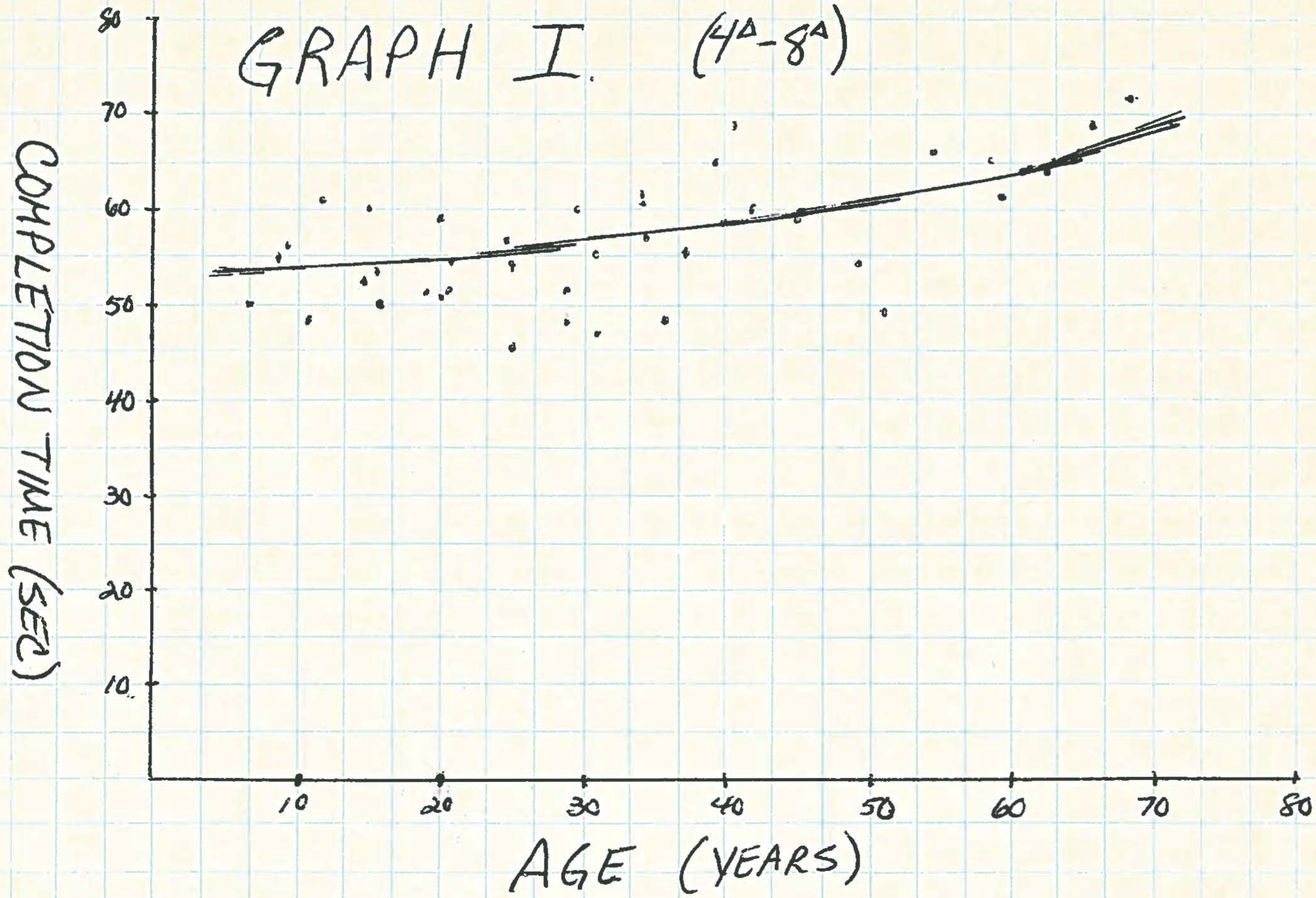
SUB. No.	AGE(S)	4Δ-8Δ (TEST A)	4Δ-6Δ (TEST B)	NEAR PHORIA	SUB. No.	AGE (SEX)	4Δ-8Δ (TEST A)	4Δ-6Δ (TEST B)	NEAR PHORIA	SUB No.	AGE (SEX)	4Δ-8Δ (TEST A)	4Δ-6Δ (TEST B)	NEAR PHORIA
1	19F	51s	46s	3ESO	16	48M	53s	54s	8EXO	31	7M	50s	46s	1ESO
2	40F	58s	59s	2EXO	17	33M	61s	58s	2ESO	32	11F	48s	45s	5ESO
3	15F	60s	63s	ORTHO	18	25M	45s	50s	2EXO	33	12F	61s	60s	2ESO
4	31M	COULD NOT FUSE AT 2ND CYCLE ON BI SIDE		10ESO	19	31M	55s	51s	4EXO	34	14M	53s	49s	5EXO
5	9M	56s	60s	1ESO	20	20M	59s	56s	8EXO	35	49F	54s	55s	6EXO (+1.25)
6	36F	48s	48s	4EXO	21	33M	62s	55s	4EXO	36	72F	69s	66s	6EXO (+2.25)
7	59F	62s	68s	11EXO (+2.00)	22	29M	60s	60s	3EXO	37	68F	72s	75s	ORTHO (+2.25)
8	21M	54s	52s	3EXO	23	20M	51s	54s	2ESO	38	63F	64s	60s	12EXO (+2.25)
9	58M	65s	68s	5EXO (+2.25)	24	41M	68s	70s	8EXO	39	16M	50s	47s	ORTHO
10	24M	57s	55s	ORTHO	25	32M	47s	50s	6EXO	40	64F	65s	62s	8EXO (+2.25)
11	37M	55s	51s	3ESO	26	39M	65s	61s	ORTHO	41	45M	59s	57s	3EXO
12	21M	52s	50s	6ESO	27	25M	54s	56s	6ESO	42	8M	55s	55s	ORTHO
13	52M	49s	50s	4EXO	28	28M	52s	50s	12EXO	43	66F	68s	67s	10EXO (+2.25)
14	34M	57s	63s	2EXO	29	28M	48s	45s	2EXO	44	42F	60s	62s	3EXO
15	57M	COULD NOT CONTINUE AFTER 5TH CYCLE		ORTHO	30	54M	66s	62s	6EXO (+1.75)					

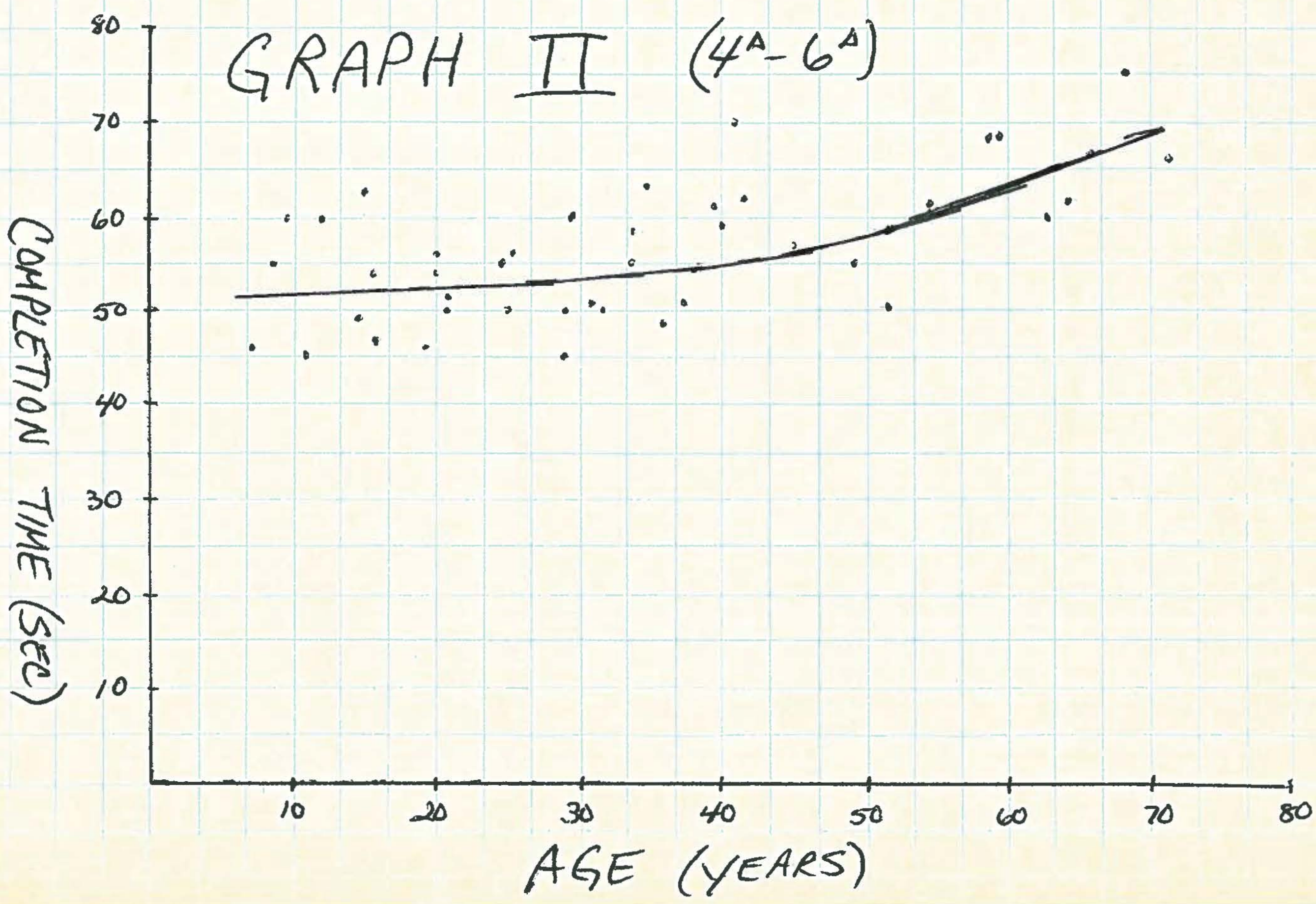
TABLE II

	4^Δ – 8^Δ (TEST A)	4^Δ – 6^Δ (TEST B)	AVERAGE AGE
PHORIAS GREATER THAN 4 EXO	60.4s	59.8s	47.7yrs
PHORIAS BETWEEN AND INCLUDING 4 EXO AND 1 ESO	56.0s	55.7s	30.1yrs
PHORIAS GREATER THAN 1 ESO	54.1s	52.5s	22.2yrs

TABLE III

	4^Δ – 8^Δ (TEST A)	4^Δ – 6^Δ (TEST B)	OVER-ALL AVERAGE
SUBJECTS RECEIVING TEST A FIRST	57.5s	56.6s	57.1s
SUBJECTS RECEIVING TEST B FIRST	56.7s	56.3s	56.7s


GRAPH I (4^Δ-8^Δ)
COMPLETION TIME (SEC)
AGE (YEARS)
10
20
30
40
50
60
70
80


GRAPH II (4^Δ-6^Δ)
COMPLETION TIME (SEC)
AGE (YEARS)
10
20
30
40
50
60
70
80

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