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ABSTRACT

VERGENCE EYE MOVEMENT PARAMETERS FOR PRE/POST-OBVAT AND SHAM THERAPY ON BINOCULARLY NORMAL CONTROLS

by
Joel V. Rajah

Vergence is the disjunctive movement of the eyes to maintain single binocular vision. Vergence eye movements are necessary to maintain the object of interest on the fovea of each eye as an individual looks from one object to another. Recent studies show that office based vergence/accommodative therapy (OBVAT) is an effective treatment for the binocular dysfunction known as convergence insufficiency. This study was performed to investigate the changes in oculomotor parameters parameter data for pre- and post-therapy subjects who are binocularly normal controls. A haploscope was used to collect eye movement data pre- and post-therapy. The analysis of the eye movements was done in MATLAB. Fifty binocularly normal controls participated in 12 hours of office-based therapy where half participated in OBVAT and the remaining half participated in office-based placebo therapy (OBPT) therapy. The latency, time to peak velocity, peak velocity, response amplitude, final amplitude, and main sequence ratio were measured for participant's responses to 4-degree and 6-degree ramps, 4- and 6-degree disappearing steps, 6- and 10-degree stepramps, and 5- and 10-degree saccades. Peak velocity was significantly greater post OBVAT therapy compared to baseline, most of them having a $p \leq .001$. Clinically meaning differences were not observed post OVPT compared to baseline. Results support that OBVAT significantly changes vergence dynamics and may be used for sports enhancement.

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by
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Dedicated to those who got me here, especially my mother, who supported my passion for reading and science. I know none of you will read this.
Semper Ad Meliora

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LIST OF TERMS

NPC	Near Point of Convergence
CISS	Convergence Insufficiency Symptom Survey
PFV	Positive Fusional Vergence
BNC	Binocularly Normal Control
FFPS	Fast-Fusional Phasic System
SFTS	Slow-Fusional Tonic System
FIC	Fusion Initiating Component
FSC	Fusion Sustaining Component
OBVAT	Office-Based Vergence/Accommodation Therapy
OBPT	Office-Based Placebo Therapy

CHAPTER 1

INTRODUCTION

1.1 Objective

This study will determine the effect of OBVAT vs OBPT (active vs sham therapy) on subjects with normal binocular vision. A haploscope will be used to capture eye movements during the assessment protocol which occurs before and after respective therapies are given. It is hypothesized that subjects participating in the active OBVAT therapeutic intervention will exhibit significant improvements in oculomotor parameters in comparison to the subjects who participated in sham therapy.

1.2 Eye Physiology

The eye is a complicated organ with many components required to allow normal vision to occur. There are some shortfalls that arise due to the way the components work together but are compensated for by eye movements. The conjunctiva is a thin layer in the front of the eye that prevents bacteria and foreign material from entering[1]. The sclera is the white part of the eye that surrounds the eye and gives it its shape (Fig 1.1). The cornea is at the front and center of the eye and helps focus light as it enters the eye (Fig 1.1)[1]. The iris controls the amount of light that enters the pupil, which allows light to reach the back of the eye (Fig 1.2). The lens and its controlling muscle ring, the ciliary body, finely focus light as it enters the eye, also helping the cornea focus light onto the retina (Fig 1.2) [1]. The retina is the light detecting part of the eye and is made up of layers (Fig 1.3) [1]. The neural layer contains nerve cells, some blood vessels, and cones and rods (photoreceptors). Signals travel from the photoreceptors via

interneurons then ganglion cells (the axons of which make the optic nerve) to the optic chasm then the lateral geniculate nucleus (LGN) and finally the visual cortex[39]. Cones are responsible for color vision while rods are used for low light vision. The optic disk is where the optic nerve exits the eye and has no photoreceptors, creating a "blind spot" in vision[1]. The fovea has a high concentration of photoreceptors and is responsible for high acuity vision[1]. Eye movements are used to project the images of interest to the fovea which has the highest acuity within the retina. These parts of the eye are vital in binocular vision, and the shortfalls of the physiology is counteracted by eye movements.

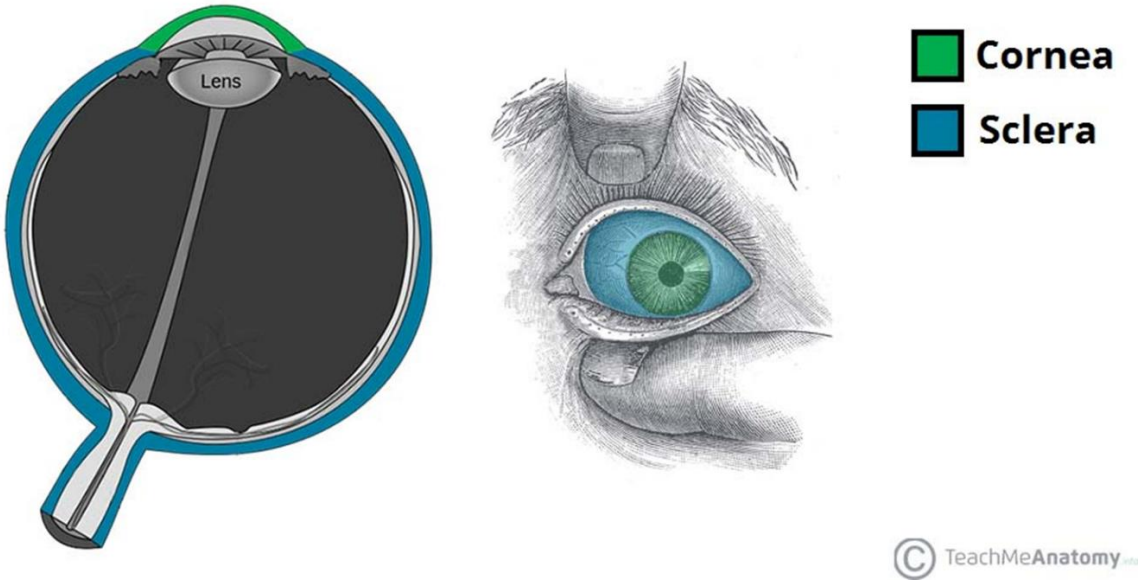

Figure 1.1 This figure shows the location of the cornea (green) and sclera (blue) in the eye.

Source [1]

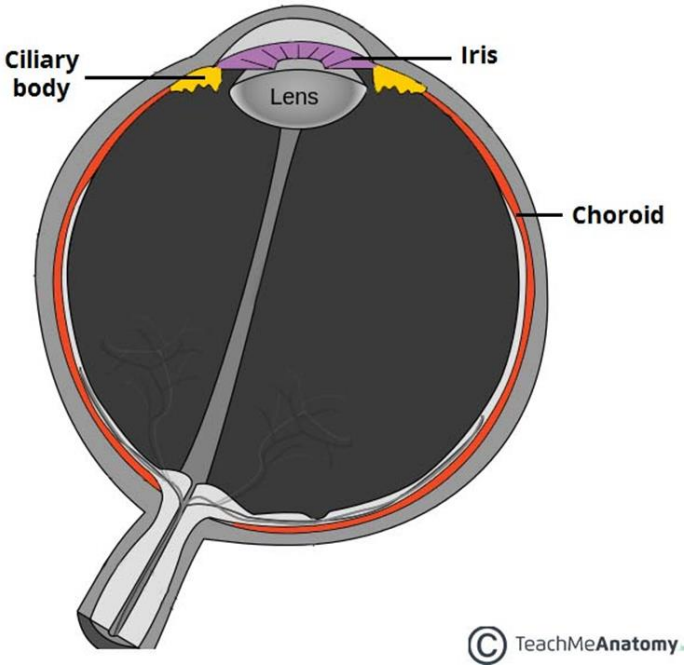

Figure 1.2 This figure shows the location of the choroid (red), iris (purple) and ciliary body (yellow) in the eye.

Source [1]

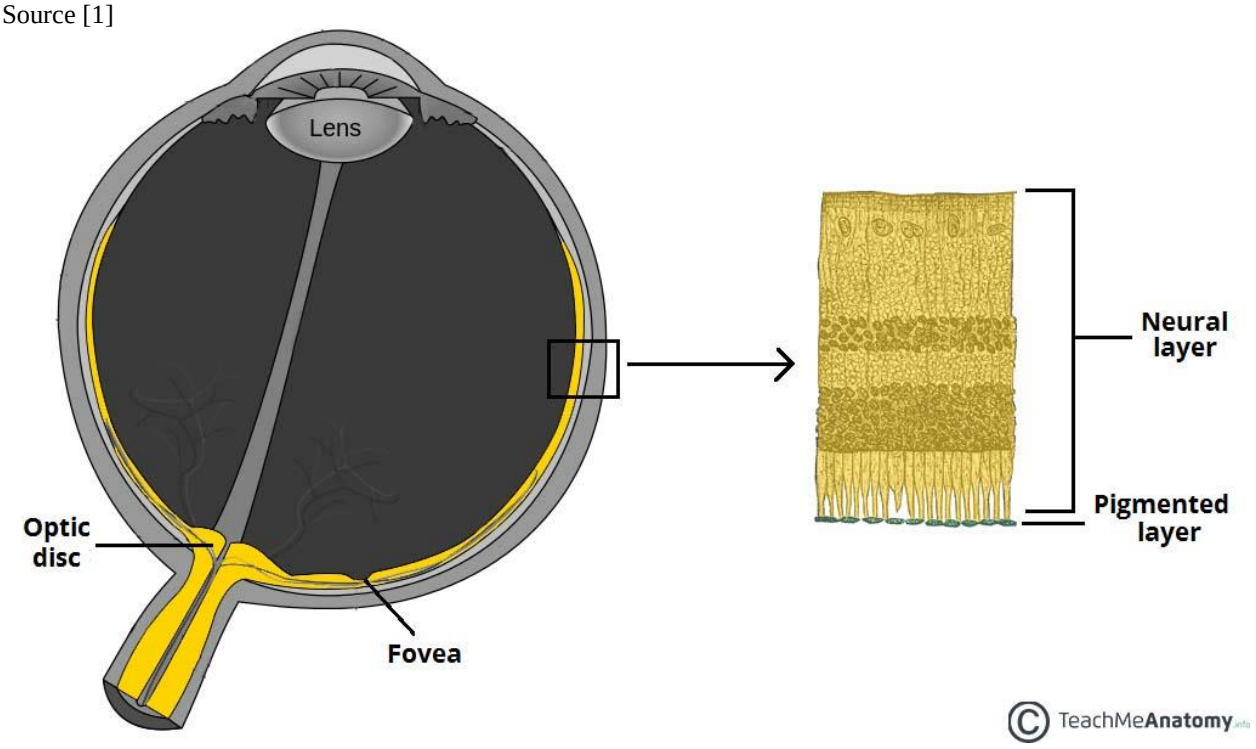

Figure 1.3 This figure shows the optic disc and fovea.

Source [1]

Eye movements require muscles to rotate the eyes in certain directions. The six muscles that control eyeball position can be divided into two groups: two oblique (superior and inferior oblique muscles[2]) and four recti muscles (superior rectus, inferior rectus, medial rectus and lateral rectus muscles) (Fig 1.4) [2]. The superior and inferior rectus are principally responsible for elevation and depression respectively. The medial rectus mainly adducts the eye, while the lateral rectus mainly abducts the eye[2]. The superior and inferior oblique muscles respectively medially and laterally rotate the eye. The muscles of import are the medial and lateral recti, being used in the rotation of the eyes to the left and right. Without these rotations, no vergence or version eye movements can occur.

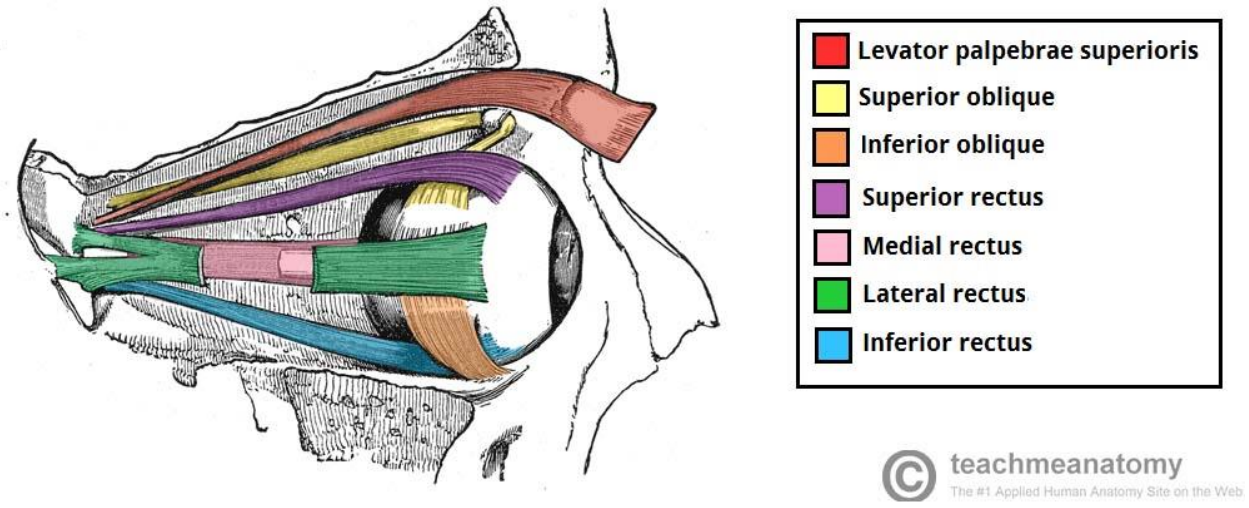

Figure 1.4 This illustrates the six muscles that control the movement of the eye and the muscle in control of the upper eyelid.

Source [2]

1.3 Vergence System

The vergence system is one of the ways the eyes' physiological shortfalls are counteracted. Vergence is a disjunctive (both eyes move in opposition, inward or outward) eye movement, while saccadic eye movements are a version eye movement (they are conjunctive, meaning eyes move in parallel) [3-5]. There are two types of vergence movements: convergence (eye rotate outward) and divergence (eyes rotate inward) [3-5]. Convergence allows tracking a target located far away from a person to an object located close to a person while divergence tracks objects located near to those far. Vergence and version movements were both used in the assessment procedure.

1.4 Control of Disparity Vergence

Vergence has been described using two systems: a fast-fusional phasic system (FFPS) and a slow-fusional tonic system (SFTS)[14] (shown in Figure 1.5). The SFTS may also be called the phoria, or the resting eye level. The phoria is typically measured when the eyes are dissociated. Phoria can be classified as esophoria, exophoria, hyperphoria, or cyclophoria[3,24]. Esophoria is a condition in which the eyes have a tendency to turn in, while in exophoria the eyes have a tendency to drift outward. Hyperphoria the eyes tend to drift up or downward and in cyclophoria the top of the eye rotates clockwise or counter clockwise. Heterophoria is the generic term used to describe all of these conditions in which the eyes have a tendency to drift from alignment when vergence is open-looped which can be done when the eyes are dissociated, such as with occlusion, or associated, such as with polarized lenses. The visual system adjusts for phoria alignment using fusional vergence. Version movements, when the eyes move in the

same direction as opposed to vergence movements in which the eye move in opposite directions, may have a connection to slow fusional vergence[24]

The FFPS has been described by the Dual Mode Theory has having two parts, the fusion initiating component (FIC) and the fusion sustaining component (FSC) [14,28-31]. The FIC is the preprogrammed component that allows the eyes to align near the target while the feedback component (FSC) moves the eyes the rest of the way to the target[14,28-31]. The FIC determines the velocity components (time to peak velocity, peak velocity, and response amplitude) of the movement while the FSC facilitates eye alignment reaching the final amplitude of the movement. This study will investigate the Dual Mode components of vergence.

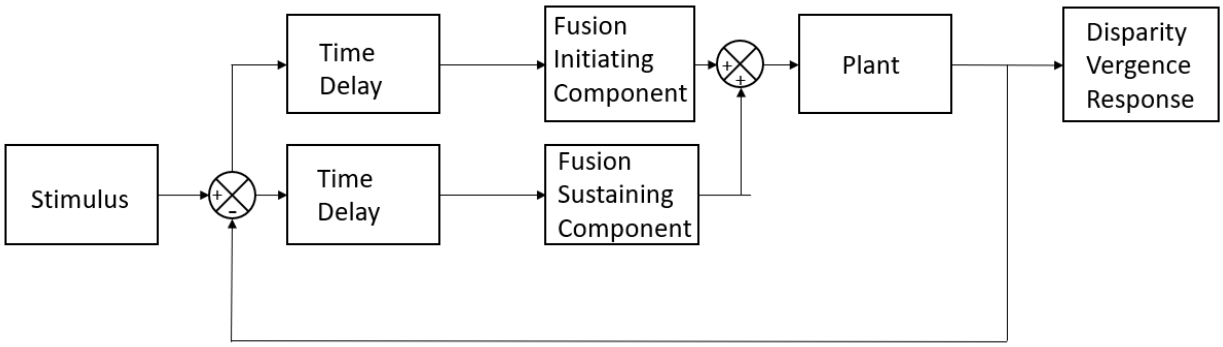

Figure 1.5 This is a figure of the Dual Mode Model.

1.5 Convergence Insufficiency Treatment Trial

The Convergence Insufficiency Treatment Trial (CITT) was a study designed to compare different vision therapeutic interventions as treatments for convergence insufficiency (CI) in children ranging from 9-17 years of age[6]. The randomized clinical trial had 221 children with symptomatic CI randomly assigned to office-based vergence/accommodative therapy with home reinforcement (OBVAT), office-based placebo therapy with home

reinforcement (OBPT), home-based computer vergence/accommodative therapy and pencil push-ups (HBCVAT+), or home-based pencil push-ups (HBPP) for 12 weeks. At the end of the study, it was shown that the group that underwent the OBVAT had a mean Convergence Insufficiency Symptom Survey (CISS) score statistically significantly ($p<.001$) lower than that of the OBPT, HBPP, and the HBCVAT+ groups[6]. The OBVAT group also saw a significant improvement in mean NPC and PFV at near compared to the other groups. A "successful outcome" was defined as a score of <16 on the CISS, a normal NPC (less than 6 cm), and normal PFV (greater than 15Δ and passing Sheard's criterion), while an "improved outcome" was defined as a score of <16 or a 10 point decrease in the CI Symptom Survey score, and at least one of the following: normal NPC, an improvement in NPC of more than 4 cm, normal PFV or an increase in PFV of more than 10Δ[6]. 73% of the OBVAT group showed a successful or improved outcome, while 43%, 33%, and 35% of the HBPP, HBCVAT+, and OBPT saw a successful or improved outcome respectively. OBVAT and the other therapies can be assessed using objective parameters such as latency, time to peak velocity, peak velocity, response amplitude, final amplitude, and main sequence ratio[18,22]. The OBVAT and OBPT procedures were used in this study, with half of the subjects being randomly placed in one with the other half of the subjects being placed in the other.

1.6 Prior Research of Vision Therapy in Binocularly Normal Controls

Research has been conducted studying vision therapy on binocularly normal controls. Daum[42] conducted a study with 35 young adults BNCs in which subjects were trained for 10 minutes a day for 5 days. All subjects were initially assessed, with 23 being evaluated

(assessed again) after one week of training and 12 being evaluated 6 months after training was complete. Another study by Semmlow, Hung, and Ciuffreda[43] utilizing two experienced subjects and one naïve subject studied the vergence response to ramp stimuli. A retrospective study was done by Ciuffreda et al.[43] which found people with TBI present with oculomotor dysfunction. 90% of subjects saw improvement or remediations of visual symptoms after vision therapy. Yang, Bucci, and Kapoula[44] found that latency was longer in adults than in children, and that convergence latency was longer than divergence latency studying 15 binocularly normal children and 15 binocularly normal adults. Talasan et al. [21] performed a similar study to this present study, except instead of a sham cohort the study included a cohort who did not participate in therapy but had two assessment session separated by several weeks. This study expands on this previous work.

CHAPTER 2

METHODOLOGY

An assessment protocol was developed to quantitatively assess the results of the treatments. All subjects underwent the assessment before and after they participated in OBVAT (active therapy) or OBPT (sham therapy). A haploscope was used for the assessment protocol and clinical parameters as described by CITT were collected for all participants. Data were preprocessed, calibrated, classified, and analyzed in MATLAB. This section describes the experimental setup and protocol setups used in this study.

2.1 Subject/Screening

Binocularly normal subjects (N=50) were used in this study. They range from age 18-34 years. There were 15 female and 35 male subjects. All subjects signed informed consent approved by the NJIT review Board in accordance to the Declaration of Helsinki. They were naïve as to which therapy they would be undergoing. 25 BNC (26 ± 8 years 19 M) were assigned using the consort to OBVAT and 25 (22 ± 4 years 16 M) were assigned to sham therapy using CONSORT agreement.

To be eligible for the study, subjects were required to have normal binocular vision defined as 20/20 (corrected if needed) acuity diagnosed by an optometrist, a near point of convergence of less than 6 cm, near phoria less than 4 prism diopters compared to far phoria, stereopsis less than 70 sec of arc, a normal positive fusional vergence (greater than 15 prism diopters and passing Sheard's criterion), and no history of neurological or eye

disease or dysfunction. These parameters were tested using, in order, the near point of convergence (NPC) test, Maddox rod test, and stereopsis tests.

The NPC is the distance, in cm, along the midline that a person sees double vision when trying to focus on a target. The Maddox rod test measures a subject's phoria level in prism diopters. To convert prism diopters to degrees, the equation degrees = $\tan^{-1}(^{\Delta}/100) \times 180/\pi$ is used[34].

The Convergence Insufficiency Symptom Survey (CISS) was used to determine subject use in the study. The survey detects that a subject possibly has CI via the subject's symptoms. In order to determine whether or not the subject has CI, they would need to get diagnosed by an optometrist. Scores below 21 indicate a binocularly normal subject. Scores above 21 indicate that the person is visually symptomatic. The survey is also used as an outcome measure in treatment of CI.

The stereopsis test was used to determine whether the subject has normal depth perception. The active therapy BNC had a CISS of 7.37 ± 4.95, NPC of 3.82 ± 1.33, and PFV of 31.76 ± 8.83 before therapy (Table 2.1). The sham therapy BNC had a CISS of 8.96 ± 5.56, NPC of 3.76 ± 1.15, and PFV of 30.92 ± 8.4 before therapy (Table 2.1). The groups averaged out to be nearly identical in scores for CISS, NPC, and PFV.

Table 2.1 Table of Subject Averages

	Age	Gender	CISS	NPC	PFV
OBVAT Subjects	26 ± 8	19M, 6F	7.37	3.82	31.76
OBPT Subjects	22 ± 4	16M, 9F	8.96	3.76	30.92

2.2 Experimental Setup

2.2.1 Instrumentation

Figure 2.1 shows the assessment setup. This study utilizes the ISCAN RK-826PCI binocular tracking system (Burlington, MA) to record horizontal eye movements using the pupil as a natural anatomical marker. The device also records pupil diameter, vertical eye movements, and the movements of the reflection from the corneal surface. The eye movements are recorded using an infrared emitter and specialized infrared cameras. The emitters are used to bathe the eyes in light with a 950 nm wavelength and a power of 1.2 mW/cm^2. Using one camera per eye, the absence of infrared light from the pupil is used to locate the centroid of the pupil with the ISCAN software. The average accuracy of 0.3 degrees over a ±20 degrees horizontal/vertical range is reported by the manufacturer.

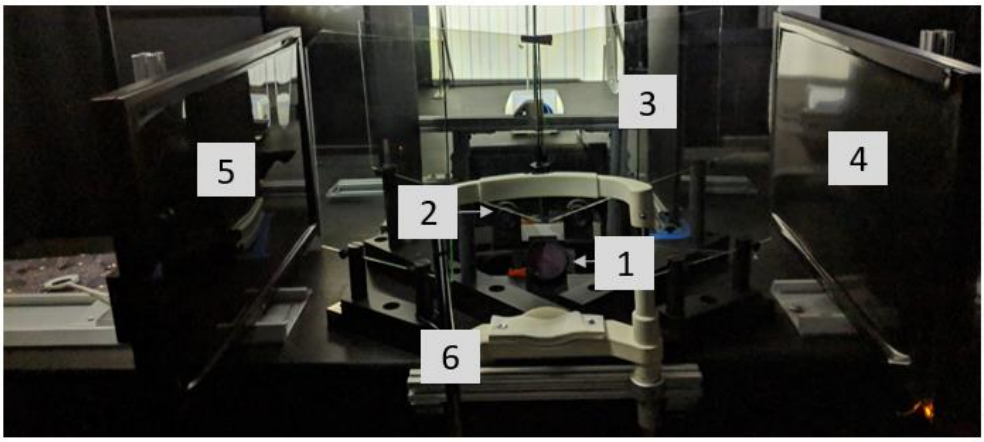

Figure 2.1 Haploscope experimental setup: presents vergence movement targets while the eye tracking instrumentation record the resulting eye movements.

2.2.2 VisualEyes Software, Stimuli Presentation, and Data Collection

VisualEyes is a custom LabVIEW™ (National Instruments, Austin, TX) program that controls the stimuli presentation and data collection from the experimental instrumentation.

The software separately presents visual stimuli to the left and right eye using two monitors, one for each eye, and partially reflective mirrors[11]. As shown in Figure 2.1, each monitor produces a stimulus which is transposed onto and reflected by the mirrors. The reflection simulates a symmetrical disparity vergence stimulus along the midline of the subject. In order to keep accommodation constant, the total distance that the stimulus (the focal length) travels is 40 cm for the entire experiment. This study was to only examine disparity vergence. This was achieved using a Gabor patch (Fig 2.2). The digitization of the eye movement data recorded from each eye from the ISCAN instrumentation is done by a 12-bit digital acquisition (DAQ) card (National Instruments 604 E series, Austin, TX) with a sampling frequency of 500 Hz.

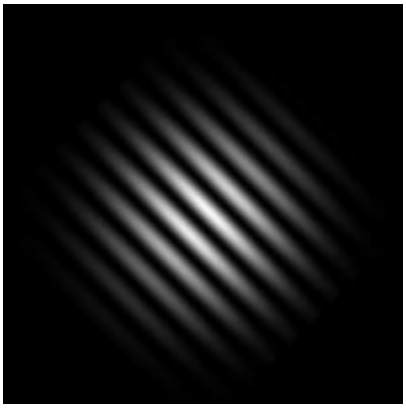

Figure 2.2 This is a figure of a Gabor Patch.

Source [38]

2.3 Experimental Procedure

2.3.1 Assessment Procedure

An assessment procedure was required to determine whether changes to the vergence oculomotor system would occur. This assessment was given before and after the therapy procedure. The assessment and therapy procedures were different to reduce potential procedural learning. The 12 weeks in between the first and final assessment also reduced

the potential of procedural learning. Phoria level was not accounted for in the assessment and was not individualized for each subject. Four types of movements were presented with the using the stimuli presented in table**:** ramps, disappearing steps, step ramps, and saccades. These are shown in Figure 2.3. They are notated as the type of movement followed by the degree change (Table 2.2).

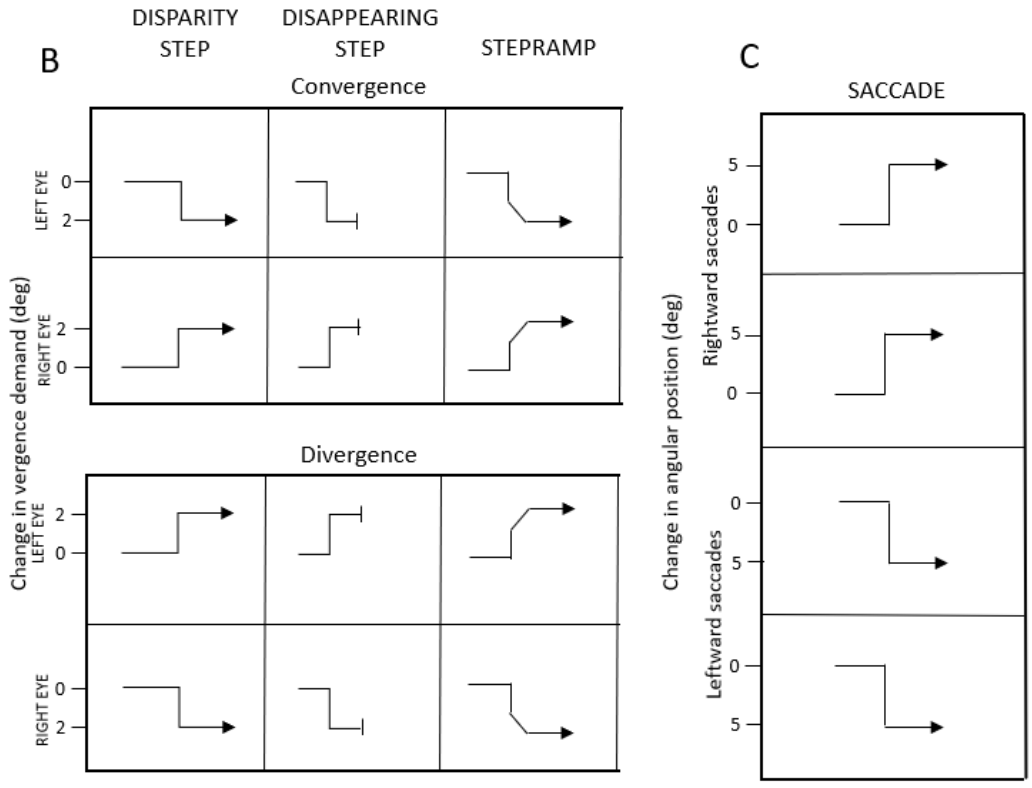

Figure 2.3 There are different types of stimuli movements, shown above. Convergence (Left, top), Divergence (left, bottom), and Saccadic (right) movement are shown. Convergence and divergence show different stimuli to each eye (disjunctive) while saccades show the same stimuli (conjunctive). 0 represents the baseline degree in which the stimuli are initially placed while 2 denotes the stimuli's final degree. B: Schematic representation of 4 deg symmetrical disparity step, disappearing step (with the stimulus disappearing after 100 milliseconds), and stepramp disconjugate stimuli. (6 deg disparity stimuli also studied but not shown) C: Schematic representation of 5 deg saccadic stimuli (10 deg stimuli also studied but not shown).

Table 2.2 Table of Movement Abbreviations

Type of Movement	Example	Full Name of Example	Degree of Movement
Disparity Step	Con48	Convergence	4 to 8 degrees
Disappearing Step	DSCon26	Convergence Disappearing Step	2 to 6 degrees
Stepramp	FastCon212	Fast Convergence Stepramp	2 to 12 degrees
Saccade	L2M5	Left to Middle	5 degrees

2.3.2 Therapy Procedure

There was an OBPT and an OBVAT utilized. The OBPT consisted of changing techniques weekly. Necker Cube, HTS Placebo Accommodation and Vergence, Monocular Brock String, Visual Closure, Double Maddox rod, and more techniques were used. These techniques are normally designed to improve monocular inputs, eye focusing, ability to detect targets, visual response speed, eye teaming skills, and visual processing skills. These are not designed to be used for improving vergence or accommodation but are designed to give subjects the impression that they are receiving the appropriate therapy. The schedule is shown in Figure 2.4. The OBVAT consisted of three phases, shown in Figure 2.5. Phase One consisted of gross convergence, positive fusional vergence, and monocular accommodative therapy. Phase two consisted of ramp fusional vergence and monocular accommodative therapy. Phase three consisted of jump fusional vergence and binocular accommodative facility. These phases included such techniques such as vectograms, Brock String, Barrell Card, Loose Lens Accommodative Rock, Letter Chart Accommodative Rock, Life Saver Cards, Eccentric Circles, HTS, and more. These techniques used in OBVAT are designed to improve both vergence and accommodation.

Initial Training Visit

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo Accommodation	8 minutes	Improve focusing and speed of response
Ductions	4 minutes	Equalize monocular inputs
Monocular Brock String – level one	6 minutes	Equalize monocular inputs
Visual Closure – Lines and Boxes	10 minutes	Eye teaming
At Home		
Monocular Brock String and TV Trainer	15 minutes	

Week 1

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo Accommodation	8 minutes	Improve focusing and speed of response
Ductions	4 minutes	Equalize monocular inputs
Monocular Brock String –level two	6 minutes	Equalize monocular inputs
Visual Closure – Lines and Boxes	10 minutes	Eye teaming
At Home		
Monocular Brock String and TV Trainer	15 minutes	

Week 2

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo Accommodation	8 minutes	Improve focusing and speed of response
Bailey-Lovie Acuity	4 minutes	Equalize monocular inputs
Monocular Brock String-level two	6 minutes	Equalize monocular inputs
Visual Closure – Closing on Center	10 minutes	Eye teaming
At Home		
Monocular Brock String and TV Trainer	15 minutes	

Week 3

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo Accommodation	8 minutes	Improve focusing and speed of response
Bailey-Lovie Acuity	4 minutes	Equalize monocular inputs
Monocular Brock String – level three	6 minutes	Equalize monocular inputs
Visual Closure – Closing on Center	10 minutes	Eye teaming
At Home		
Monocular Brock String and TV Trainer	15 minutes	

Weeks 4 & 5

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo Accommodation	8 minutes	Improve focusing and speed of response
After Image	4 minutes	Equalize monocular inputs
Red/Red Activities	6 minutes	Eye teaming
Visual Figure Ground – Hidden Characters (level 1)	10 minutes	Eye teaming
At Home		
HTS Vergence/Accommodation (or Red Lens Activities) and TV Trainer	15 minutes	

Weeks 6 & 7

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo vergence	8 minutes	Improve eye teaming and speed of response
Strobismo Trainer	4 minutes	Eye teaming
Yoked Prism Flippers	6 minutes	Eye teaming
Visual Figure Ground – Figuring Words (level 2)	10 minutes	Eye teaming
At Home		
HTS Vergence/Accommodation (or Red Lens Activities) and Polaroid Playing Cards	15 minutes	

Weeks 8 & 9

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo Vergence	8 minutes	Improve eye teaming and speed of response
Modified Thorington	4 minutes	Eye teaming
Bernell-o-scope level 1	6 minutes	Eye teaming
Visual Spatial Skills	10 minutes	Eye teaming
At Home		
HTS Vergence/Accommodation (or Red Lens Activities) and Polaroid Playing Cards	15 minutes	

Weeks 10 & 11

Technique	Time	Goal
In Office		
Necker Cube	12 minutes	
HTS - Placebo Vergence	8 minutes	Improve eye teaming and speed of response
Double Maddox Rod	4 minutes	Eye teaming
Bernell-o-scope level 2	6 minutes	Eye teaming
Visual Spatial Skills	10 minutes	Eye teaming
At Home		
HTS Vergence/Accommodation (or Red Lens Activities) and Polaroid Playing Cards	15 minutes	

Maintenance Therapy

Technique	Time	Goal
At Home		
TV Trainer	10 minutes	To improve eye teaming ability by using visual and motor inputs.
Polaroid Playing Cards	5 minutes	

Figure 2.4 This is the schedule of the entirety of sham therapy.

Source [36]

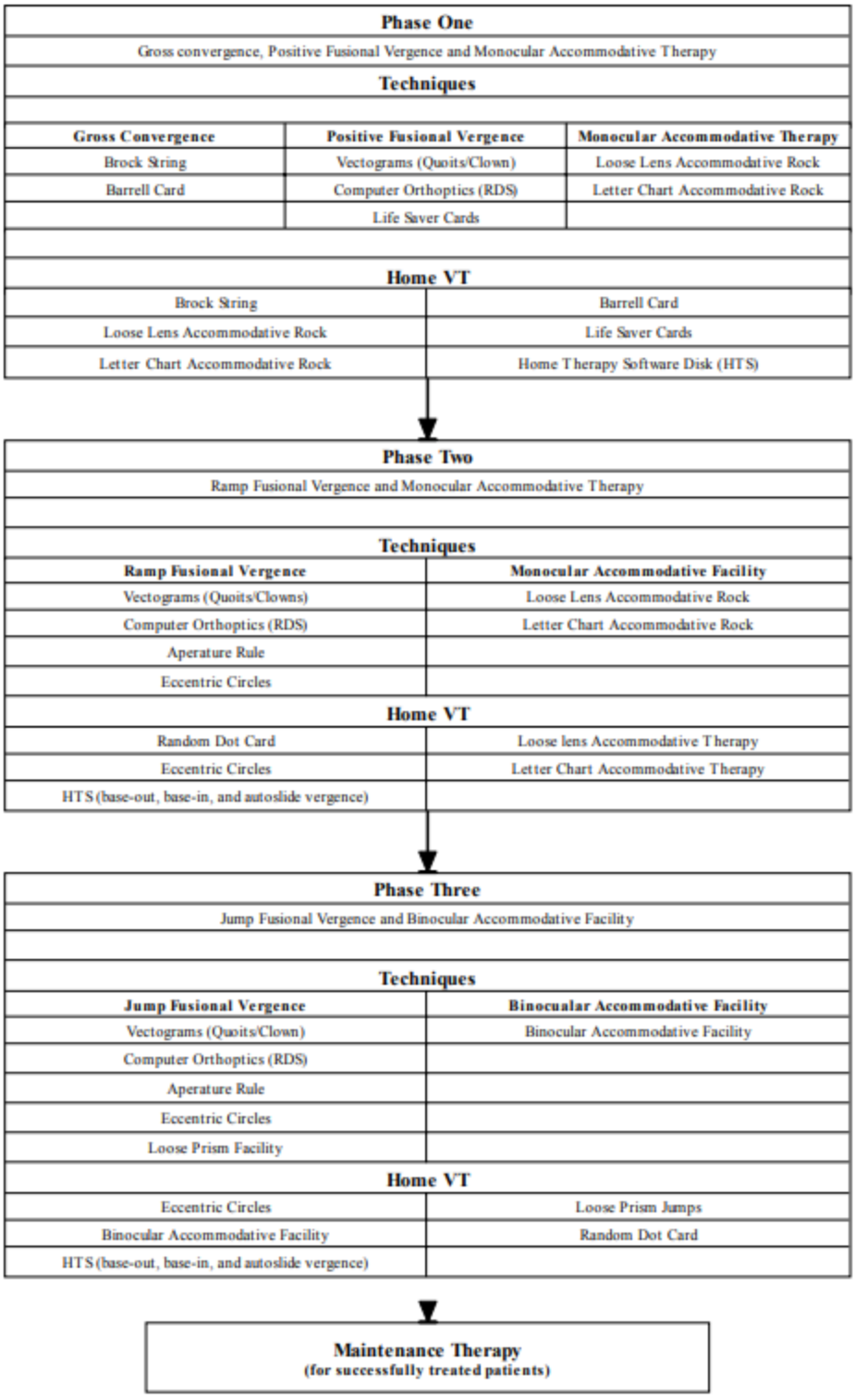

Figure 2.5 These are the OBVAT therapy phases.

Source [37]

2.4 Data Analysis

2.4.1 Data Processing

MATLAB was used to import and analyze the eye movement data. The raw right eye positional data subtracted from the left eye positional data to compute the vergence movement. This required the assumption that the resolutions of both eyes were the same when the data were collected. Far vergence step response calibration consisted of a six-point, monocular calibration. The 1°, 3°, and 5° monocular, corresponded to the 2°, 6°, 10° binocular vergence angle demand. Near vergence step response calibration consisted of a six-point, monocular calibration. The 4°, 5°, and 6° monocular, corresponded to 8°, 10°, 12° binocular vergence angle demand. These calibrations were performed before and after completion of each experimental group. Other steps in the data analysis included the removal of outliers (2 standards deviations away from the mean), blink removal (easily identified by the large signal seen as the camera loses the eye image due to the closing of the eyelids), and the acquiring of the velocity trace of each movement. Any movements with a saccade in the transient were removed.

2.4.2 Eye Movement Parameters Analyzed

There were 6 aspects of the eye movement that were measured: the latency, time to peak velocity, peak velocity, response amplitude, final amplitude, and main sequence ratio. The main sequence ratio in this case is the ratio of the peak velocity and response amplitude. These were compared for the before and after therapy data, between the sham and placebo therapy, and between genders using a mixed ANOVA. Figure 2.6 shows a typical vergence eye movement, with all parameters that were measured labelled on the graph. The peak

velocity and time to peak velocity is measured using the velocity graph. Figure 2.7 shows the phase plot of response amplitude, which is how response amplitude was determined.

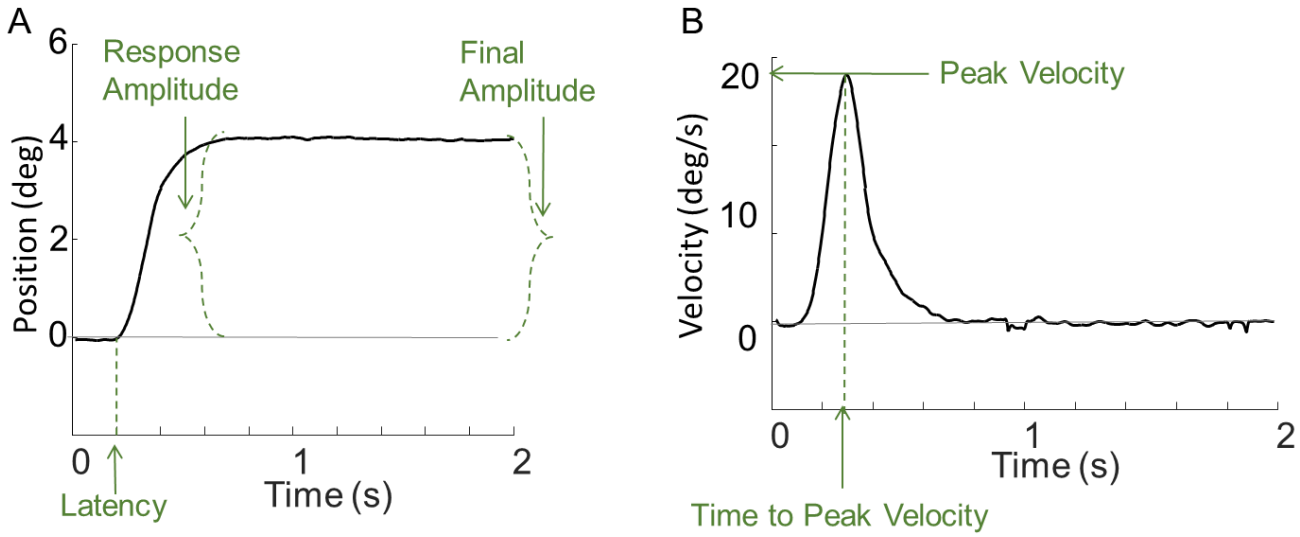

Figure 2.6 In this figure, A represents a typical 4-degree convergence eye movement, and B represents the velocity graph of the movement. The latency, response amplitude, and final amplitude can be measured on A while B is used to measure the time to peak velocity and peak velocity. Main sequence ratio is the ratio between the peak velocity and response amplitude.

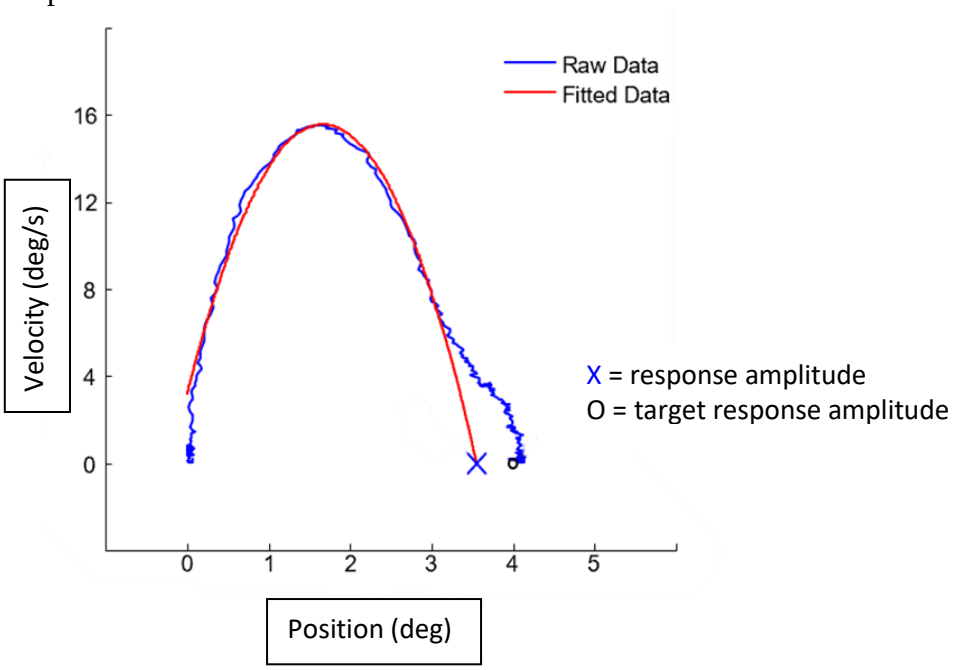

Figure 2.7 In this figure, the phase plot of response amplitude is shown. The raw data of velocity to position is plotted, with is then filtered. The new curve is then used to find the response amplitude.

CHAPTER 3

RESULTS

3.1 Clinical Results

Table 3.1 Table of Active Therapy Subject Information

Subject	Type	Therapy	Age/Gender	CISS Before/After	NPC Before/After	PFV Before/After
NIH021	BNC	Active	22/M	/15	4/4	35/45+
NIH022	BNC	Active	19/M	15/11	4/5	40/50
NIH058	BNC	Active	18/M	4/10	7/5.5	18/40
NIH059	BNC	Active	18/F	5/4	6/5.5	20/40
NIH063	BNC	Active	24/M	13/13	5/4	35/45
NIH070	BNC	Active	25/M	1/5	5/2	25/25
NIH082	BNC	Active	25/M	10/4	3/3	40/40
NIH085	BNC	Active	22/M	5/7	4/3.5	30/30
NIH086	BNC	Active	21/M	9/12	3/2	35/45
NIH090	BNC	Active	34/M	16/7	2.5/3	18/35
NIH092	BNC	Active	23/M	8/10	5/2.5	35/30
NIH096	BNC	Active	20/M	13/10	2.5/2	40/35
NIH100	BNC	Active	25/M	1/2	3/2.5	45/40
NIH104	BNC	Active	19/M	10/6	2.5/3	30/40
NIH134	BNC	Active	20/M	13/6	3/2	50/45
NIH139	BNC	Active	21/M	0/0	4/2.5	30/35
NIH141	BNC	Active	21/M	35/6	4/5	18/45
NIH142	BNC	Active	18/F	10/5	5/5.5	30/30
NIH148	BNC	Active	21/F	15/6	5/3	40/35
NIH153	BNC	Active	22/M	14/8	2/4.5	25/30
NIH157	BNC	Active	22/F	3/1	2/2	35/40
NIH160	BNC	Active	19/M	2/7	4.5/2	35/35
NIH180	BNC	Active	18/F	3/0	4.5/7	20/12
NIH184	BNC	Active	18/M	6/6	2/2	30/50
NIH185	BNC	Active	32/F	0/3	3/3	35/35
Averages				7.37/6.56	3.82/3.44	31.76/36.96
Paired T Test (Within Subject) Significance				t=1.396 df=23 p=0.176	t=1.378 df=24 p=0.181	t=-2.622 df=23 p=0.015

Table 3.2 Table of Sham Therapy Subject Information

Subject	Type	Therapy	Age/Gender	CISS Before/After	NPC Before/After	PFV Before/After
NIH016	BNC	Placebo	20/F	17/10	5.5/4.5	35/45+
NIH023	BNC	Placebo	18/M	17/15	5/3.5	25/45
NIH030	BNC	Placebo	22/M	4/2	3/3.5	16/20
NIH052	BNC	Placebo	23/M	10/11	4/4	35/18
NIH053	BNC	Placebo	18/F	11/7	2/3	30/35
NIH054	BNC	Placebo	19/M	19/23	2/3	45+/20
NIH060	BNC	Placebo	18/M	12/22	5.5/4	25/40
NIH064	BNC	Placebo	21/F	11/19	5/3.5	20/35
NIH068	BNC	Placebo	18/M	3/8	4/2.5	40/30
NIH083	BNC	Placebo	22/M	7/6	3/4	40/45
NIH084	BNC	Placebo	22/M	10/9	2.5/2	30/30
NIH091	BNC	Placebo	24/M	3/5	2/2.5	25/30
NIH094	BNC	Placebo	21/M	9/8	4.5/4.5	30/35
NIH099	BNC	Placebo	22/F	3/6	4/3.5	25/40
NIH101	BNC	Placebo	25/M	9/4	4/4.5	45/45
NIH135	BNC	Placebo	21/F	0/0	2/4	20/30
NIH136	BNC	Placebo	18/F	16/13	3/3.5	16/12
NIH143	BNC	Placebo	25/F	9/4	5/5.5	40/30
NIH146	BNC	Placebo	21/M	9/2	5/5	40/35
NIH147	BNC	Placebo	23/F	7/26	3/2	40/35
NIH149	BNC	Placebo	23/F	6/2	4/3.5	40/30
NIH150	BNC	Placebo	26/M	3/13	4/6.5	30/20
NIH158	BNC	Placebo	23/M	57/5	3/3.5	35/35
NIH159	BNC	Placebo	23/M	26/0	5/5.5	35/35
NIH179	BNC	Placebo	25/M	3/2	4/3	25/20
Averages				8.96/8.88	3.76/3.78	30.92/31.25
Paired T Test (Within Subject)				t=0.083 df=24 p=0.934	T=-0.093 df=24 p=0.927	t=-0.497 df=22 p=0.624

The active therapy BNC had a CISS of 6.56 ± 3.94, NPC of 3.44 ± 1.47, and PFV of 36.96 ± 8.61 after therapy (Table 3.1). The sham therapy BNC had a CISS of 8.88 ± 7.33, NPC of 3.78 ± 1.09, and PFV of 31.25 ± 9.04 after therapy (Table 3.2). OBVAT therapy subjects saw slight improvement in CISS, NPC, and PFV while the sham therapy saw almost no change. The subjects where changes occurred were primarily from the OBVAT cohort.

3.2 Latency Results and Time to Peak Velocity Results

Table A1 and A2 summarizes the values of latency and time to peak velocity respectively. These tables also show the results of the mixed ANOVA. For latency, out of 38 movements there were 11 (Con 28, Con 48, Div 126, DS Con 26, DS Con 812, DS Div 126, DS Div 128, DS Div 84, FastCon 212, L2M5, and M2L5) movements that showed significant difference. 3 of the 11 (Div 126, DS Con 812, DS Div 128) showed difference by sex, 4 (Con 28, Con 48, DS Div 126, and FastCon 212) showed by before/after therapy, and 5 (DS Con 26, DS Div 84, FastCon212, L2M5, and M2L5) showed by therapy type. For time to peak velocity, there were 13 out of 38 (Con26, Con 28, Con 48, Div 62, DS Con 26, DS Div 84, FastCon 212, FastDiv 122, SlowDiv 126, SlowDiv 82, L2M5, M2L5, and R2M5) that had significant difference. 1 of the 13 (Con 28) showed difference by sex, 7 (DS Con 26, DS Div 84, FastCon 212, FastDiv 122, SlowDiv 126, SlowDiv 82, and R2M5) showed by before/after therapy, and 6 (Con26, Con 28, Con 48, Div 62, L2M5, and M2L5) showed by therapy type. Post hoc analysis was only done on movements that showed significance in both before/after therapy and therapy type. There was one (FastCon212) for latency and none for time to peak velocity. When the post-hoc analysis was done, the one movement (FastCon 212) showed that OBVAT therapy made a significant difference in the latency before/after therapy. The mean latency from the fast convergence step ramp that was from 2 to 12 degrees showed a statistically significant decrease in latency due to OBVAT therapy. Though the sham FastCon212 mean latency decreases, it is not statistically significant. The divergence movements with the same degrees of movement are also not statistically significant.

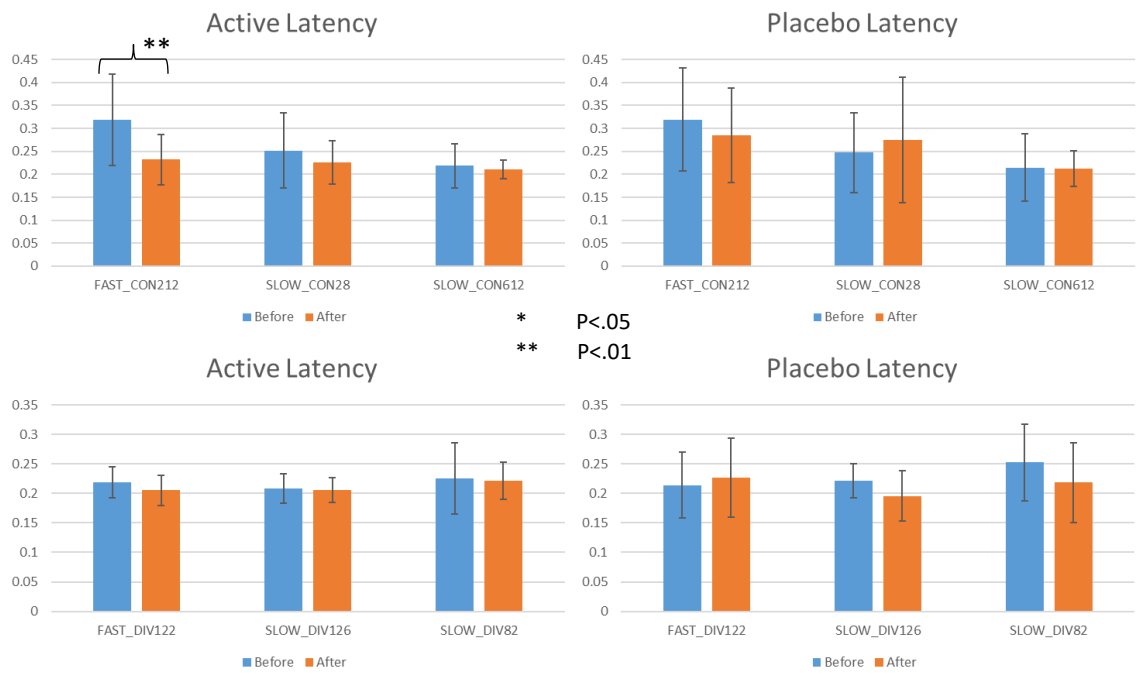

Figure 3.1 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

3.3 Peak Velocity Results

Table A3 summarizes the values of peak velocity. These tables also show the results of the mixed ANOVA. For time to peak velocity, there were 20 out of 38 (Con 26, Con 28, Con 48, Con 610, Con 612, Con 812, Div 62, Div 84, DS Con 26, DS Con 28, DS Con 48, DS Con 612, DS Div 106, DS Div 126, DS Div 84, FastCon 212, SlowCon 28, SlowCon 612, SlowDiv 126, and SlowDiv 82) that had significant difference. 16 out of 20 (Con 26, Con 28, Con 610, Con 612, Con 812, DS Con 26, DS Con 28, DS Con 48, DS Con 612, DS Div 126, DS Div 84, FastCon 212, SlowCon 28, SlowCon 612, SlowDiv 126, and SlowDiv 82) showed difference by before/after therapy, 3 (DS Con 612, DS Div 106, and SlowDiv 82) showed difference by sex, and 14 (Con 26, Con 28, Con 48, Con 610, Con 812, DS Con 26, DS Con 28, DS Con 48, DS Div 106, FastCon 212, SlowCon 28, and SlowCon 612) showed by therapy type. Post hoc analysis was only done on movements that showed

significance in both before/after therapy and therapy type. There was 10 for peak velocity. When the post-hoc analysis was done, all ten movements (Con 26, Con 28, Con 610, Con 812, DS Con 26, DS Con 28, DS Con 48, FastCon 212, SlowCon 28, and SlowCon 612) showed that OBVAT therapy made a significant difference between the before/after data. All ten movements showed a statistically significant increase in the peak velocity. The subjects that underwent the placebo therapy showed either no improvement or statistically insignificant changes (mostly negligible increases). Though the divergence movements saw, for the most part, higher peak velocities as well they were statistically insignificant.

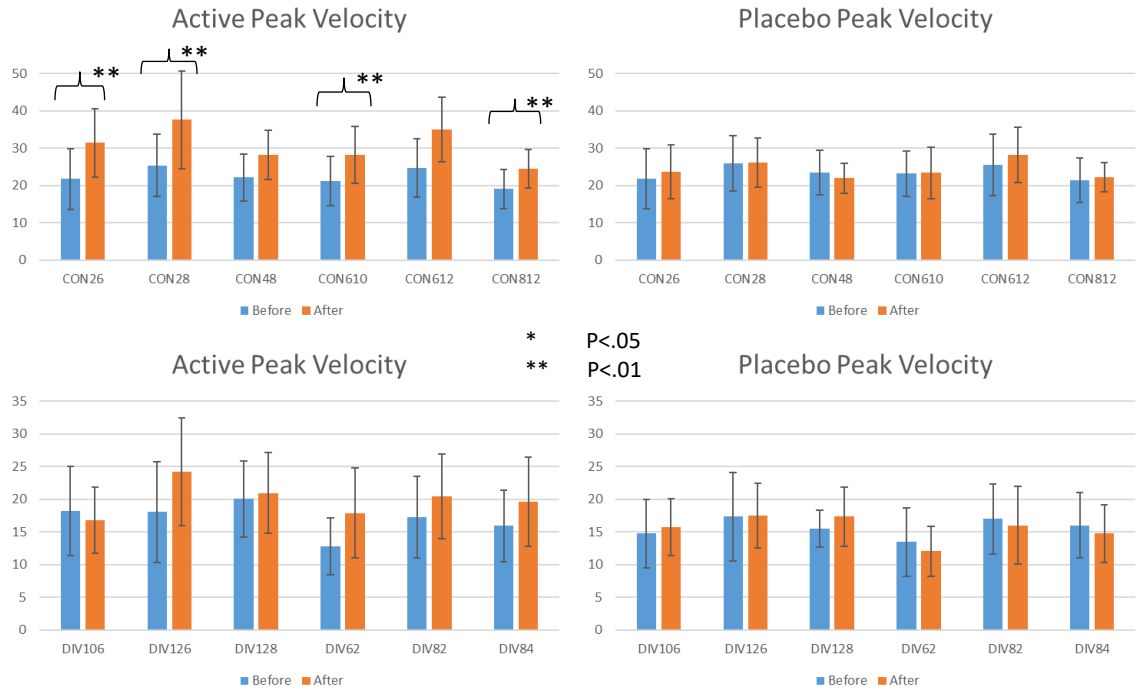

Figure 3.2 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

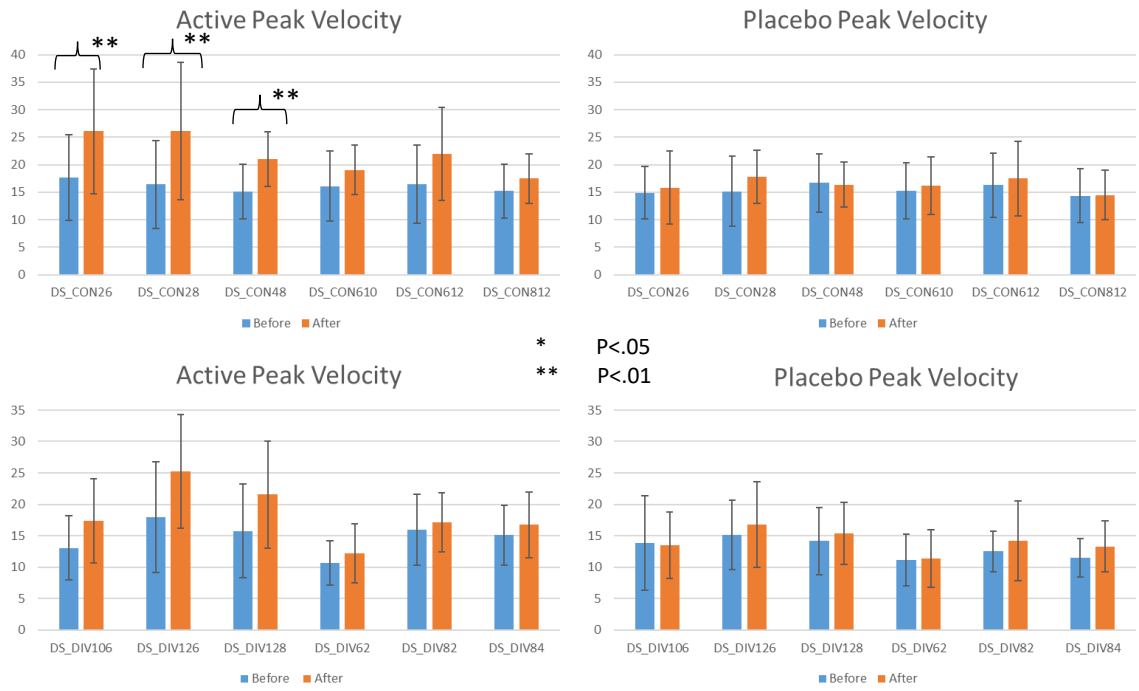

Figure 3.3 This figure shows the means and standard deviations for disappearing step convergence and disappearing step divergence movements for both the active and placebo therapies.

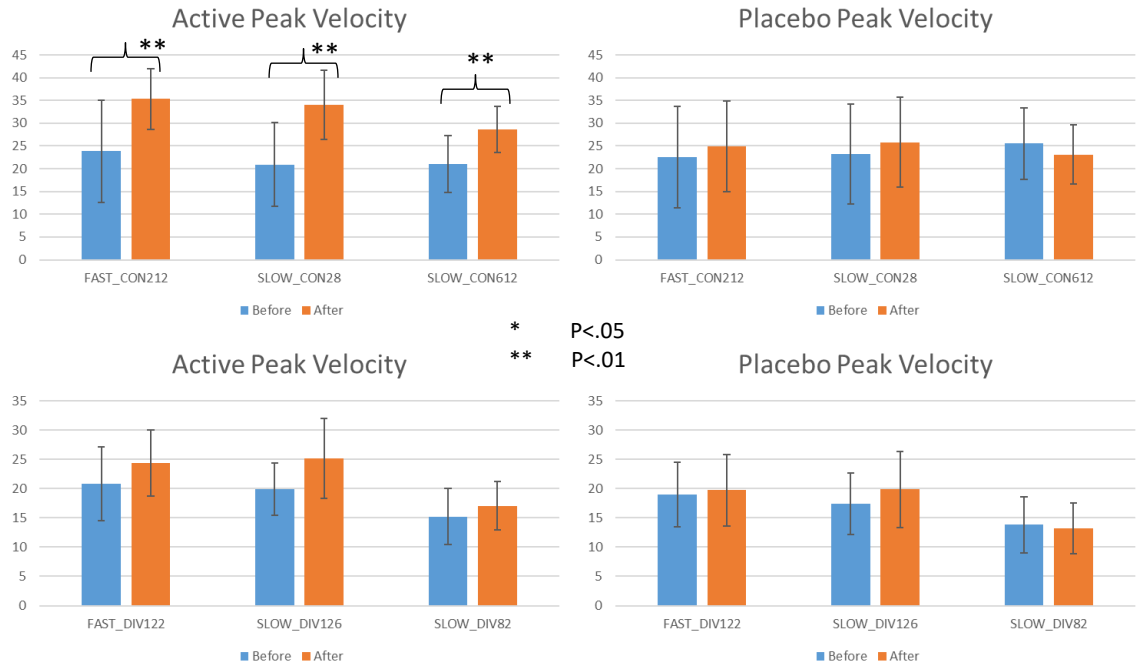

Figure 3.4 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

3.4 Response Amplitude and Final Amplitude Results

Table A4 and A5 summarizes the values of response amplitude and final amplitude respectively. These tables also show the results of the mixed ANOVA. For response amplitude, there were 10 out of 38 (Con 28, Con 612, Con 812, DS Con 48, DS Con 612, DS Div 106, DS Div 128, SlowCon 28, M2L10, M2R5) that had significant difference. 7 out of 10 (Con 28, Con 612, Con 812, DS Con 612, SlowCon 28, M2L10, and M2R5) showed difference by before/after therapy, 2 (DS Div 106 and DS Div 128) showed difference by sex, and 1 (DS Con 48) showed by therapy type. For final amplitude, there were 11 (Con 48, Div 82, Div 84, FastCon 212, SlowCon 28, FastDiv 122, SlowDiv 82, L2M10, M2L10, M2R10, R2M10) out of 38 that had significant difference. 10 out of 11 (Con 48, Div 82, FastCon 212, SlowCon 28, FastDiv 122, SlowDiv 82, L2M10, M2L10, M2R10, R2M10) showed difference by before/after therapy, 3 (Con 48, Div 84, and SlowCon 28) showed difference by sex, and 7 (FastCon 212, FastDiv 122, SlowDiv 82, L2M10, M2L10, M2R10, R2M10) showed by therapy type. Post hoc analysis was only done on movements that showed significance in both before/after therapy and therapy type. There was none for response amplitude and seven for final amplitude. When the post-hoc analysis was done, all seven movements (FastCon 212, FastDiv 122, SlowDiv82, L2M10, M2L10, M2R10, and R2M10) showed that OBVAT therapy made a significant difference between the before/after data. The seven movements showed amplitudes closer to the target, if not at the target, amplitude post therapy. Their sham therapy counterparts showed negligible change in amplitude.

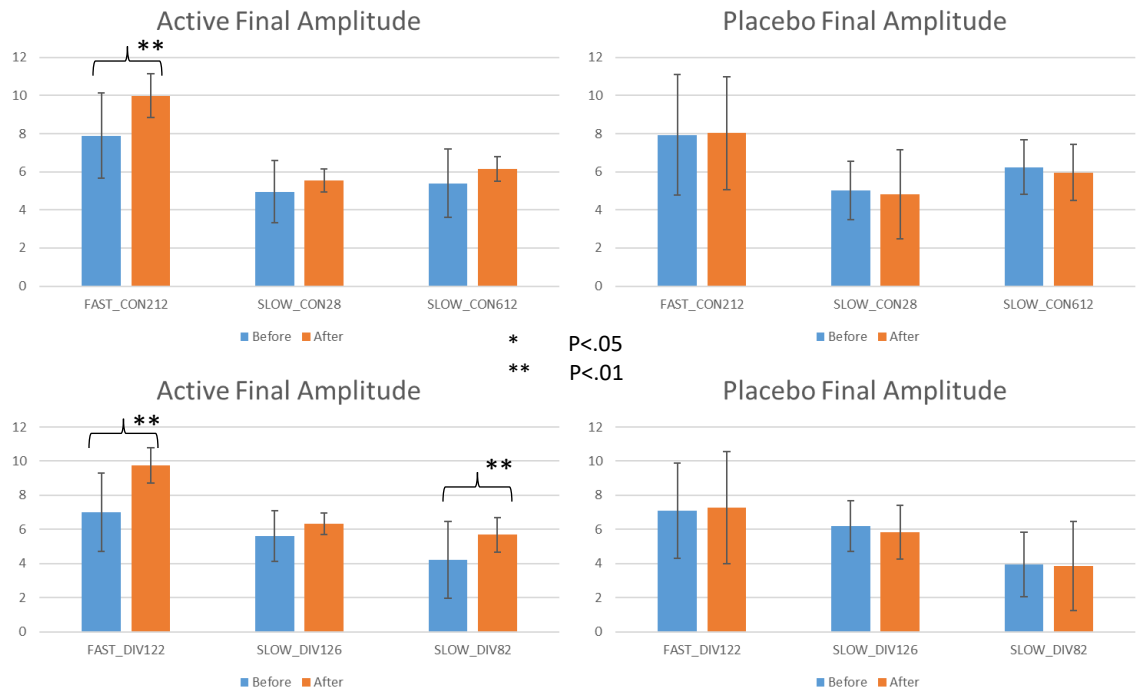

Figure 3.5 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

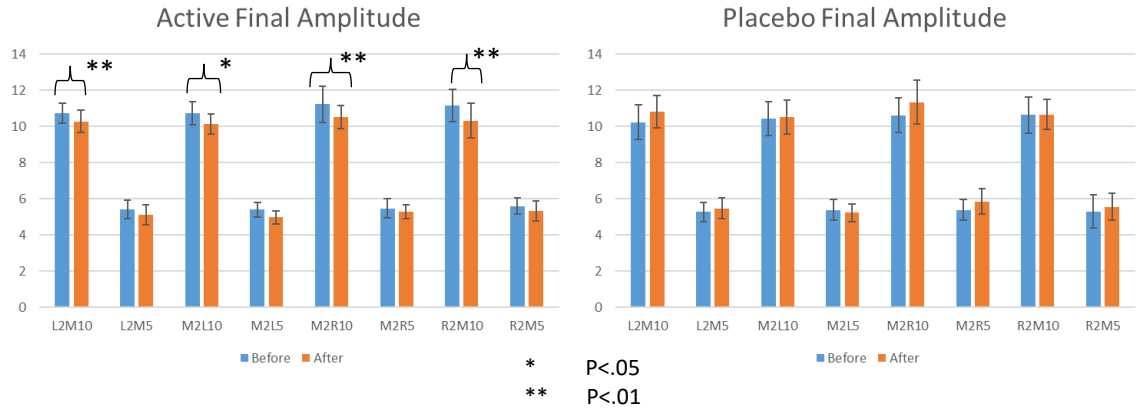

Figure 3.6 This figure shows the means and standard deviations for saccadic movements for both the active and placebo therapies.

3.5 Main Sequence Ratio Results

Table A6 summarizes the values of main sequence ratio. These tables also show the results of the mixed ANOVA. For main sequence ratio, there were 15 out of 38 (Con 28, Con 48, Con 610, Con 612, Div 62, Div 84, DS Con 48, DS Con 612, DS Div 128, DS Div 84,

FastCon 212, SlowCon 612, M2L5, M2R10, R2M5) that had significant difference. 5 out of 15 (Con 48, Con612, DS Con 48, DS Div 84, and SlowCon 612) showed difference by before/after therapy, 2 (DS Div 128 and M2R10) showed difference by sex, and 11 (Con 28, Con 48, Con 610, Div 62, Div 84, DS Con 612, DS Div 84, FastCon 212, SlowCon 612, M2L5, and R2M5) showed by therapy type. Post hoc analysis was only done on movements that showed significance in both before/after therapy and therapy type. There was three for main sequence ratio. When the post-hoc analysis was done, only three movements (Con 48, DS Div 84, and SlowCon 612) showed that OBVAT therapy made a significant difference between the before/after data. OBVAT subject's Con 48 showed a statistically significant increase in main sequence ratio, with their other convergence movements also increased but not significantly. Placebo subjects saw insignificant changes, either marginally increasing or decreasing. Placebo DS Div 84 and SlowCon 612 showed significant increases in their ratios as well. All other movements showed insignificant increases or decreases.

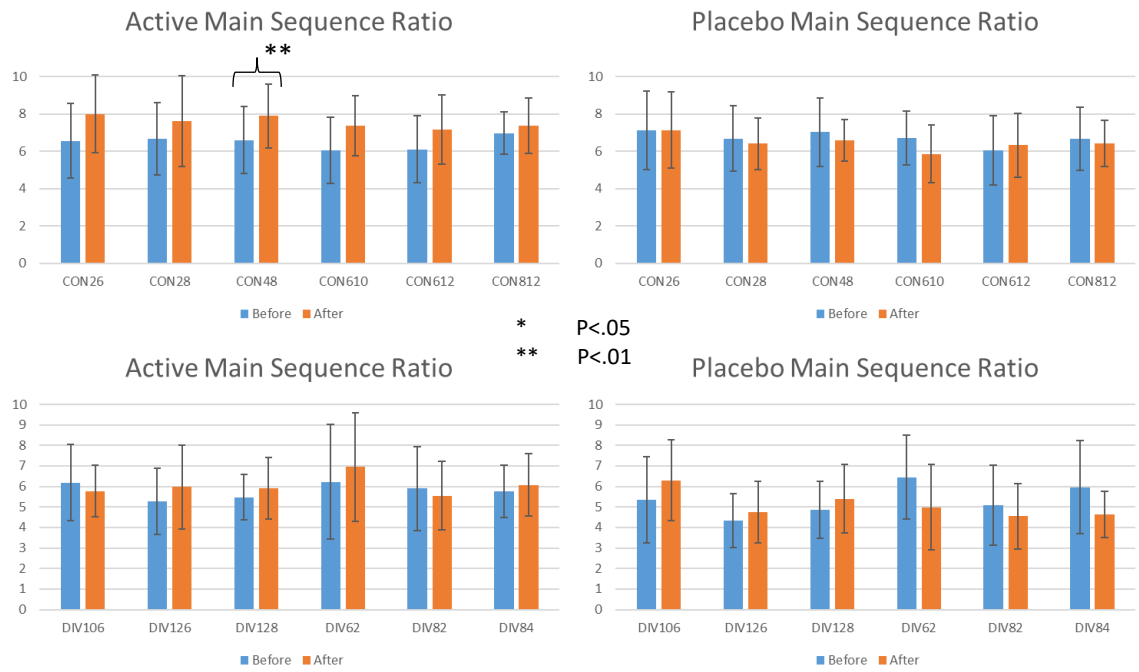

Figure 3.7 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

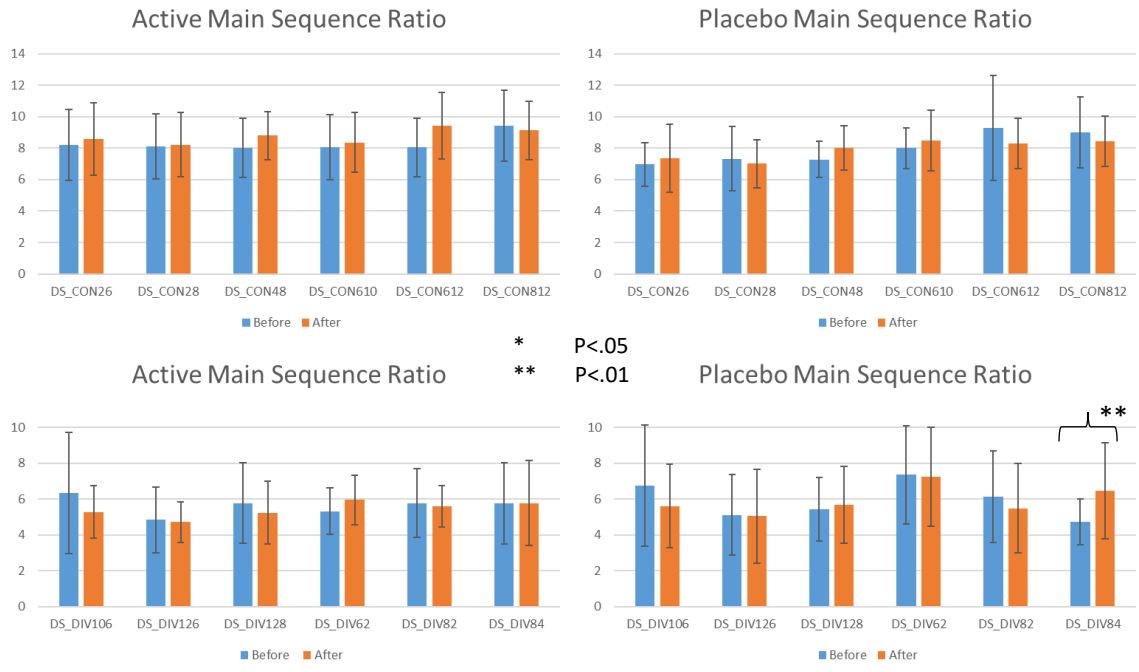

Figure 3.8 This figure shows the means and standard deviations for disappearing step convergence and disappearing step divergence movements for both the active and placebo therapies.

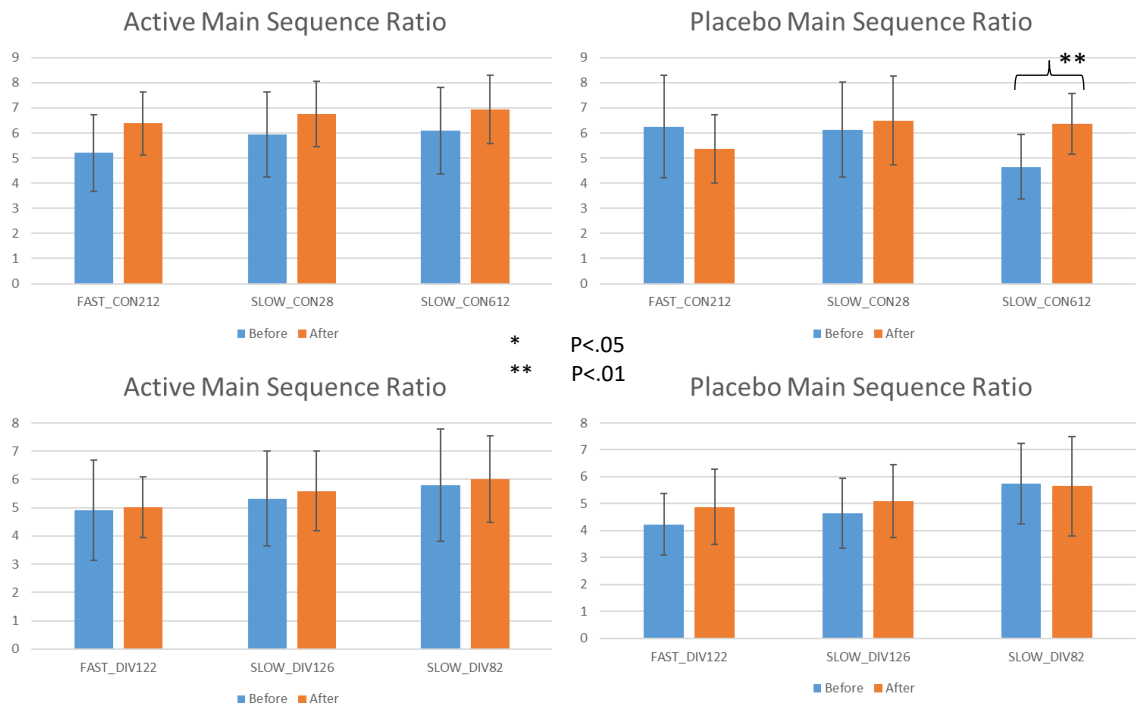

Figure 3.9 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

CHAPTER 4

DISCUSSION and CONCLUSIONS

4.1 Discussion

Peak Velocity showed significant differences in the before vs after therapy and the type of therapy in 10 of the 20 movements (Con 26, Con 28, Con 610, Con 812, DS Con 26, DS Con 28, DS Con 48, FastCon 212, SlowCon 28, and SlowCon 612). Response amplitude was significantly different in either before vs after, sex, or therapy type. This suggests that the FIC is improving. As seen in previous studies, near convergence movements were faster than far[15]. For divergence, the reverse was true. Near divergence movements were slower than far divergence movements. The increase in peak velocities and response amplitude closer to target post therapy matches results seen in previous studies[25]. Final amplitude also saw the OBVAT subjects achieving the target amplitudes.

An aspect to consider when analyzing the results of any data collected is to be wary that peak velocity can change as a function of the person's phoria level [8,10,12,13,16,21,26,27]. When trying to analyze, final amplitude is an excellent way to compare your results when there is no normative data. When shown, for example, a 4 degree step the response amplitude should be 4 degrees as well. This would be the ideal case.

One difference of interest is between the convergence and divergence peak velocities. As seen in previous studies, convergence movements have higher velocities than the divergence movements[9]. This evidence supports the hypothesis that the phoria (SFTS) acts as a "spring". This spring accelerates the convergence movements but slows the divergence movements. The Dual Mode Theory states that disparity vergence is a two-

component system [14,28-31]. The Fusion Initiating Component (FIC) is a preprogrammed response[18]. It is responsible for moving the eyes towards the new target quickly, but it may not be precise or accurate. Preprogrammed control is a predetermined series of actions that the brain executes without any feedback from the external sources once the series of actions is initiated. The Fusion Sustaining Component (FSC) is different in that it is feedback controlled. It is responsible for moving the eyes from where they are currently located to the desired target. Feedback control means the brain will determine where the target is and where the eyes are currently located. The FSC then rotates the eyes toward the intended target until the eyes are located at or very close to the target. FIC modelling and signal processing show[20] that it follows the velocity trace signal, and is hypothesized to be generated by the "velocity-encoding" burst cells as described in neurophysiology studies found near the oculomotor nucleus within the midbrain[32]. The FSC, on the other hand, mimics the "position-encoding" tonic cells which are distinct cells, also located in the midbrain[32]. The FIC is assessed using the vergence peak velocity. The FSC is assessed by the final amplitude.

This study improves and adds to previous studies in a few ways. Daum's[42] study did not have as many subjects trained for as long of time. Daum also did not have a sham to compare the active therapy results to. This study utilized ramp stimuli and knowledge of the vergence response in order to determine effectiveness of the therapies. Ciuffreda's[43] retrospective study revealed results about non-binocularly normal people undergoing therapy, while this study only studied BNCs (who did not have history of brain injury or any eye dysfunctions). This study expanded on Yang et al. [44] by testing not just latency, but 5 more parameters as well, all done using two groups of young adults placed into active

and sham therapy. This study built on Talasan et al. [21] by having a larger sample and by having the second group participate in sham therapy, helping to keep all of the subjects naïve as to whether or not they were receiving active therapy.

One area of possible utilization of vision therapy on binocularly normal people is for sports. Sports require quick and accurate target acquisition. Sports vision training is an evolving field, and there are new techniques always being developed. There are some training procedures that work in component skill training[33]. Low-level visual instruments, perceptual-cognitive training instruments, visual-motor reaction training, and integrated sensorimotor batteries of behavioral tasks. Others believe that simulating live game situations creates the best sports vision training. Stroboscopic visual training, eye tracking and quiet eye (QE) training, and sports simulations and virtual reality platforms are used in these situations. Training to improve the symmetry of the left and right eye movements has been shown to be possible[19] and might also improve their skills in their game. Previous studies have shown in baseball that the best hitters have the best "saccadic pursuit, and convergence abilities" [40]. It was also shown that training could significantly improve batting ability[41]. The improvements in the controls suggest that OBVAT vision therapy may be used for sports enhancement. This can be done to improve athletic performance in many sports, especially ball sports. Sports ranging from football to ping pong require quick and accurate visual acquisition of the ball in order to catch or hit it. From this study, the improvements to the peak velocities of the subjects in OBVAT suggest that OBVAT could be used to improve the speed in which athletes can see their target. It has been shown that even short periods of training can provide long-term improvement to those who undergo it[42]. Improvement in healthy subjects can be translated to direct personalized procedures

that athletes could undergo to improve their visual performance. Mild TBI/concussions that may occur during play that may cause CI which can then also be treated using OBVAT[17].

4.2 Conclusions, Future Work, and Limitations

This study shows that OBVAT on binocularly normal controls shows significant improvements to the vergence oculomotor system. Future work should include a similar study focused on subjects with CI to determine whether OBVAT significantly improves eye movements and therefore the visual system. This study could also be redone with people of different age groups. This study utilized mostly young adult students. This could be repeated with children or older adults to see how age affects a person's eye movement parameters, especially in older adults in which presbyopia may have an effect. Aging is associated with a decrease in the magnitude of phoria adaptation but not the rate of adaptation or disparity vergence, but more can be done with this[23]. The FIC improvements shown suggest that the midbrain may be changing regarding "velocity-encoding" burst cells. A functional imaging study of all participants should be conducted to determine if there is actual physiological change between the OBVAT and OBPT subjects. This should also be translated into personalized therapy to better suit an individual's needs.

Some limitations of the study included subjects having to sit at a traditional haploscope for a certain amount of time to do the eye movement assessment. This also may have happened at any time of day, meaning that the subject's alertness could affect their movements. A subject could get more tired as the assessment progressed, especially later in the day, which may negatively impact their movements. A future study could eliminate

that variable. Phoria was not controlled for each subject, meaning that they did not have personalized levels when doing the movements.

APPENDIX A

STATISTICAL ANALYSIS

Table A1 This table contains the statistics showing the factor, error df, and significance between-factor (before vs after therapy), between-sex (M vs F), and between-therapy (OBVAT vs sham) for each movement's latency. The tests with significant data are highlighted in green.

Latency				
		F	Error df	Sig
Con 26	Factor	0.008	42	.929
	Sex	0.38	42	0.846
	Therapy	0.684	42	0.413
Con 28	Factor	10.771	42	0.002
	Sex	0.002	42	0.964
	Therapy	2.44	42	0.126
Con 48	Factor	18.168	43	0
	Sex	0.415	43	0.523
	Therapy	0.206	43	0.652
Con 610	Factor	0.468	42	0.498
	Sex	0.686	42	0.412
	Therapy	0.337	42	0.565
Con 612	Factor	3.689[b]	43	0.061
	Sex	.570[b]	43	0.454
	Therapy	.040[b]	43	0.843
Con 812	Factor	2.504[b]	42	.121
	Sex	.824[b]	42	.369
	Therapy	.048[b]	42	.828
Div 106	Factor	.084[b]	42	.773
	Sex	.543[b]	42	.465
	Therapy	4.056[b]	42	.050
Div 126	Factor	1.737[b]	40	.195
	Sex	8.315[b]	40	.006
	Therapy	3.803[b]	40	.058
Div 128	Factor	1.702	43	.199
	Sex	1.748	43	.193
	Therapy	0.132	43	.718
Div 62	Factor	.176[b]	40	.677
	Sex	.051[b]	40	.823
	Therapy	.084[b]	40	.773
Div 82	Factor	.326[b]	43	.571
	Sex	.533[b]	43	.469
	Therapy	.004[b]	43	.947
Div 84	Factor	.337[b]	42	.565
	Sex	.095[b]	42	.760
	Therapy	.906[b]	42	.347
DS Con 26	Factor	.260[b]	42	.613
	Sex	1.513[b]	42	.226
	Therapy	6.775[b]	42	.013

DS Con 28	Factor	2.123[b]	45	.152
	Sex	.622[b]	45	.435
	Therapy	1.967[b]	45	.168
DS Con 48	Factor	.109[b]	45	.743
	Sex	.299[b]	45	.587
	Therapy	.056[b]	45	.815
DS Con 610	Factor	1.747894	41	.193
	Sex	.815[b]	41	.788
	Therapy	.062[b]	41	.805
DS Con 612	Factor	.015[b]	41	.903
	Sex	2.345[b]	41	.133
	Therapy	.656[b]	41	.423
DS Con 812	Factor	.003[b]	44	.959
	Sex	5.140[b]	44	.028
	Therapy	2.917[b]	44	.095
DS Div 106	Factor	.439[b]	44	.511
	Sex	.689[b]	44	.411
	Therapy	.850[b]	44	.361
DS Div 126	Factor	4.069[b]	44	.050
	Sex	.007[b]	44	.935
	Therapy	.765[b]	44	.386
DS Div 128	Factor	.248[b]	43	.621
	Sex	5.299[b]	43	.026
	Therapy	.437[b]	43	.512
DS Div 62	Factor	.624[b]	43	.434
	Sex	.031[b]	43	.860
	Therapy	1.235[b]	43	.273
DS Div 82	Factor	.000[b]	45	.993
	Sex	3.120[b]	45	.084
	Therapy	.829[b]	45	.367
DS Div 84	Factor	.248[b]	47	.621
	Sex	.817[b]	47	.371
	Therapy	4.204[b]	47	.046
FastCon 212	Factor	6.899[b]	39	.012
	Sex	.006[b]	39	.940
	Therapy	4.144[b]	39	.049
SlowCon 28	Factor	.063[b]	36	.803
	Sex	.295[b]	36	.590
	Therapy	1.440[b]	36	.238
SlowCon 612	Factor	2.549[b]	41	.118
	Sex	.038[b]	41	.846
	Therapy	.629[b]	41	.432
FastDiv 122	Factor	.007[b]	34	.931
	Sex	.040[b]	34	.843
	Therapy	3.462[b]	34	.071
SlowDiv 126	Factor	3.620[b]	34	.066
	Sex	.565[b]	34	.458
	Therapy	2.117[b]	34	.155

SlowDiv 82	Factor	2.971[b]	39	.093
	Sex	.009[b]	39	.923
	Therapy	2.233[b]	39	.143
L2M10	Factor	.002[b]	44	.966
	Sex	.032[b]	44	.859
	Therapy	2.511[b]	44	.120
L2M5	Factor	.110[b]	46	.741
	Sex	.014[b]	46	.907
	Therapy	6.677[b]	46	.013
M2L10	Factor	1.746[b]	42	.194
	Sex	.451[b]	42	.506
	Therapy	1.293[b]	42	.262
M2L5	Factor	.085[b]	45	.772
	Sex	.163[b]	45	.688
	Therapy	8.761[b]	45	.005
M2R10	Factor	3.259[b]	45	.078
	Sex	.046[b]	45	.831
	Therapy	.269[b]	45	.606
M2R5	Factor	.081[b]	44	.777
	Sex	.387[b]	44	.537
	Therapy	.099[b]	44	.755
R2M10	Factor	.810[b]	46	.373
	Sex	.043[b]	46	.837
	Therapy	.488[b]	46	.488
R2M5	Factor	2.478[b]	45	.122
	Sex	.154[b]	45	.697
	Therapy	.045[b]	45	.834

Table A2 This table contains the statistics showing the factor, error df, and significance for between-factor (before vs after therapy), between-sex (M vs F), and between-therapy (OBVAT vs sham) for each movement's time to peak velocity. The tests with significant data are highlighted in green.

Time To Peak Velocity				
		F	Error df	Sig
Con 26	Factor	1.417[b]	42	0.241
	Sex	.193[b]	42	0.663
	Therapy	10.651[b]	42	0.002
Con 28	Factor	3.780[b]	44	0.058
	Sex	5.471[b]	44	0.024
	Therapy	11.256[b]	44	0.002
Con 48	Factor	2.177[b]	47	0.147
	Sex	.049[b]	47	0.825
	Therapy	7.080[b]	47	0.011
Con 610	Factor	1.340[b]	43	0.253
	Sex	1.122[b]	43	0.295
	Therapy	.390[b]	43	0.535
Con 612	Factor	.804[b]	41	0.375
	Sex	.003[b]	41	0.956
	Therapy	1.869[b]	41	0.179
Con 812	Factor	.794[b]	41	0.378
	Sex	.779[b]	41	.383
	Therapy	2.883[b]	41	.097
Div 106	Factor	.514[b]	40	.478
	Sex	.063[b]	40	.803
	Therapy	1.934[b]	40	.172
Div 126	Factor	.293[b]	37	.592
	Sex	.072[b]	37	.789
	Therapy	2.996[b]	37	.092
Div 128	Factor	.187[b]	41	.668
	Sex	.298[b]	41	.588
	Therapy	2.046[b]	41	.160
Div 62	Factor	.322[b]	41	.573
	Sex	1.607[b]	41	.212
	Therapy	8.702[b]	41	.005
Div 82	Factor	.036[b]	42	.850
	Sex	.200[b]	42	.657
	Therapy	1.514[b]	42	.225
Div 84	Factor	.326[b]	40	.571
	Sex	.235[b]	40	.631
	Therapy	3.306[b]	40	.077
DS Con 26	Factor	5.311[b]	29	.029
	Sex	.001[b]	29	.974
	Therapy	1.290[b]	29	.265
DS Con 28	Factor	.350[b]	36	.558
	Sex	1.812[b]	36	.187
	Therapy	3.032[b]	36	.090

DS Con 48	Factor	2.869[b]	38	.099
	Sex	1.790[b]	38	.189
	Therapy	.045[b]	38	.834
DS Con 610	Factor	.609[b]	32	.441
	Sex	.044[b]	32	.834
	Therapy	.122[b]	32	.729
DS Con 612	Factor	1.447[b]	34	.237
	Sex	.757[b]	34	.391
	Therapy	.043[b]	34	.836
DS Con 812	Factor	.021[b]	30	.885
	Sex	.004[b]	30	.949
	Therapy	1.228[b]	30	.277
DS Div 106	Factor	.247[b]	30	.623
	Sex	.250[b]	30	.621
	Therapy	.016[b]	30	.900
DS Div 126	Factor	1.632[b]	38	.209
	Sex	2.982[b]	38	.092
	Therapy	1.400[b]	38	.244
DS Div 128	Factor	2.332[b]	28	.138
	Sex	.182[b]	28	.673
	Therapy	.539[b]	28	.469
DS Div 62	Factor	.308[b]	38	.582
	Sex	.122[b]	38	.729
	Therapy	.419[b]	38	.521
DS Div 82	Factor	1.312[b]	40	.259
	Sex	1.238[b]	40	.273
	Therapy	.946[b]	40	.337
DS Div 84	Factor	4.650[b]	42	.037
	Sex	.007[b]	42	.934
	Therapy	.020[b]	42	.889
FastCon 212	Factor	11.272[b]	39	.002
	Sex	.344[b]	39	.561
	Therapy	.395[b]	39	.533
SlowCon 28	Factor	.559[b]	35	.460
	Sex	1.869[b]	35	.180
	Therapy	1.719[b]	35	.198
SlowCon 612	Factor	1.776[b]	42	.190
	Sex	.123[b]	42	.727
	Therapy	1.852[b]	42	.181
FastDiv 122	Factor	4.472[b]	36	.041
	Sex	.176[b]	36	.677
	Therapy	.101[b]	36	.753
SlowDiv 126	Factor	4.275[b]	38	.046
	Sex	.216[b]	38	.645
	Therapy	.391[b]	38	.535
SlowDiv 82	Factor	5.861[b]	40	.020
	Sex	.048[b]	40	.827
	Therapy	.571[b]	40	.454

L2M10	Factor	.179[b]	43	.675
	Sex	2.220[b]	43	.144
	Therapy	.281[b]	43	.599
L2M5	Factor	.102[b]	43	.751
	Sex	.414[b]	43	.523
	Therapy	4.588[b]	43	.038
M2L10	Factor	.161[b]	43	.691
	Sex	.059[b]	43	.809
	Therapy	.267[b]	43	.608
M2L5	Factor	.010[b]	44	.920
	Sex	.329[b]	44	.569
	Therapy	6.912[b]	44	.012
M2R10	Factor	1.808[b]	47	.185
	Sex	.373[b]	47	.544
	Therapy	.008[b]	47	.931
M2R5	Factor	.001[b]	43	.972
	Sex	1.058[b]	43	.310
	Therapy	.229[b]	43	.635
R2M10	Factor	.013[b]	45	.908
	Sex	.257[b]	45	.615
	Therapy	.350[b]	45	.557
R2M5	Factor	6.739[b]	45	.013
	Sex	.263[b]	45	.610
	Therapy	.404[b]	45	.528

Table A3 This table contains the statistics showing the factor, error df, and significance for between-factor (before vs after therapy), between-sex (M vs F), and between-therapy (OBVAT vs sham) for each movement's peak velocity. The tests with significant data are highlighted in green.

Peak Velocity				
		F	Error df	Sig
Con 26	Factor	6.278[b]	41	0.016
	Sex	1.197[b]	41	0.280
	Therapy	6.386[b]	41	0.015
Con 28	Factor	8.910[b]	42	0.005
	Sex	.442[b]	42	0.510
	Therapy	13.090[b]	42	0.001
Con 48	Factor	2.998[b]	45	0.090
	Sex	.030[b]	45	0.864
	Therapy	10.359[b]	45	0.002
Con 610	Factor	4.094[b]	41	0.050
	Sex	.091[b]	41	0.765
	Therapy	4.438[b]	41	0.041
Con 612	Factor	13.188[b]	42	0.001
	Sex	.945[b]	42	0.337
	Therapy	2.644[b]	42	0.111
Con 812	Factor	6.755[b]	43	0.013
	Sex	.000[b]	43	.991
	Therapy	7.111[b]	43	.011
Div 106	Factor	.085[b]	41	.772
	Sex	.309[b]	41	.581
	Therapy	.254[b]	41	.617
Div 126	Factor	1.440[b]	41	.237
	Sex	2.973[b]	41	.092
	Therapy	3.127[b]	41	.084
Div 128	Factor	2.351[b]	42	.133
	Sex	.658[b]	42	.422
	Therapy	.513[b]	42	.478
Div 62	Factor	2.054[b]	41	.159
	Sex	.221[b]	41	.641
	Therapy	7.176[b]	41	.011
Div 82	Factor	.542[b]	44	.465
	Sex	.044[b]	44	.836
	Therapy	3.256[b]	44	.078
Div 84	Factor	1.187[b]	42	.282
	Sex	.017[b]	42	.897
	Therapy	4.504[b]	42	.040
DS Con 26	Factor	7.565[b]	39	.009
	Sex	.108[b]	39	.745
	Therapy	5.000[b]	39	.031
DS Con 28	Factor	4.691[b]	40	.036
	Sex	.232[b]	40	.633
	Therapy	4.910[b]	40	.032

DS Con 48	Factor	5.038[b]	40	.030
	Sex	.077[b]	40	.782
	Therapy	9.872[b]	40	.003
DS Con 610	Factor	3.494[b]	35	.070
	Sex	.306[b]	35	.584
	Therapy	.117[b]	35	.734
DS Con 612	Factor	8.895[b]	37	.005
	Sex	4.300[b]	37	.045
	Therapy	.818[b]	37	.372
DS Con 812	Factor	2.416[b]	40	.128
	Sex	.235[b]	40	.630
	Therapy	1.095[b]	40	.302
DS Div 106	Factor	.094[b]	40	.761
	Sex	4.121[b]	40	.049
	Therapy	4.531[b]	40	.039
DS Div 126	Factor	6.793[b]	41	.013
	Sex	.033[b]	41	.857
	Therapy	2.868[b]	41	.098
DS Div 128	Factor	2.724[b]	38	.107
	Sex	.877[b]	38	.355
	Therapy	2.484[b]	38	.123
DS Div 62	Factor	.448[b]	39	.507
	Sex	.001[b]	39	.981
	Therapy	.715[b]	39	.403
DS Div 82	Factor	1.428[b]	40	.239
	Sex	.258[b]	40	.615
	Therapy	.407[b]	40	.527
DS Div 84	Factor	11.147[b]	42	.002
	Sex	1.838[b]	42	.182
	Therapy	.053[b]	42	.818
FastCon 212	Factor	8.753[b]	44	.005
	Sex	.263[b]	44	.611
	Therapy	10.450[b]	44	.002
SlowCon 28	Factor	8.124[b]	40	.007
	Sex	.506[b]	40	.481
	Therapy	5.521[b]	40	.024
SlowCon 612	Factor	4.726[b]	42	.035
	Sex	.363[b]	42	.550
	Therapy	14.408[b]	42	.000
FastDiv 122	Factor	1.390[b]	45	.245
	Sex	.503[b]	45	.482
	Therapy	2.834[b]	45	.099
SlowDiv 126	Factor	10.455[b]	43	.002
	Sex	.230[b]	43	.634
	Therapy	1.598[b]	43	.213
SlowDiv 82	Factor	8.839[b]	42	.005
	Sex	4.481[b]	42	.040
	Therapy	3.627[b]	42	.064

L2M10	Factor	.389[b]	44	.536
	Sex	.232[b]	44	.633
	Therapy	.377[b]	44	.542
L2M5	Factor	.749[b]	43	.392
	Sex	1.725[b]	43	.196
	Therapy	.007[b]	43	.933
M2L10	Factor	1.234[b]	42	.273
	Sex	.042[b]	42	.839
	Therapy	3.910[b]	42	.055
M2L5	Factor	1.806[b]	42	.186
	Sex	1.275[b]	42	.265
	Therapy	.311[b]	42	.580
M2R10	Factor	3.939[b]	43	.054
	Sex	1.335[b]	43	.254
	Therapy	.531[b]	43	.470
M2R5	Factor	.650[b]	43	.424
	Sex	.191[b]	43	.664
	Therapy	.041[b]	43	.840
R2M10	Factor	.499[b]	44	.484
	Sex	1.587[b]	44	.214
	Therapy	.198[b]	44	.659
R2M5	Factor	2.372[b]	43	.131
	Sex	1.447[b]	43	.236
	Therapy	.511[b]	43	.479

Table A4 This table contains the statistics showing the factor, error df, and significance between-factor (before vs after therapy), between-sex (M vs F), and between-therapy (OBVAT vs sham) for each movement's response amplitude. The tests with significant data are highlighted in green.

Response Amplitude				
		F	Error df	Sig
Con 26	Factor	3.132[b]	41	0.0842
	Sex	.001[b]	41	0.9758
	Therapy	.495[b]	41	0.4857
Con 28	Factor	6.665[b]	43	0.0133
	Sex	.655[b]	43	0.4229
	Therapy	3.153[b]	43	0.0829
Con 48	Factor	3.110[b]	42	0.0851
	Sex	.017[b]	42	0.8969
	Therapy	.268[b]	42	0.6076
Con 610	Factor	2.482[b]	40	0.1231
	Sex	.046[b]	40	0.8319
	Therapy	.726[b]	40	0.3991
Con 612	Factor	6.496[b]	40	0.0148
	Sex	1.710[b]	40	0.1984
	Therapy	1.556[b]	40	0.2195
Con 812	Factor	8.376[b]	44	0.0059
	Sex	2.049[b]	44	.159
	Therapy	.745[b]	44	.393
Div 106	Factor	.859[b]	44	.359
	Sex	1.508[b]	44	.226
	Therapy	1.184[b]	44	.283
Div 126	Factor	.588[b]	43	.447
	Sex	.006[b]	43	.940
	Therapy	1.766[b]	43	.191
Div 128	Factor	.170[b]	41	.682
	Sex	2.036[b]	41	.161
	Therapy	.010[b]	41	.920
Div 62	Factor	2.254[b]	44	.140
	Sex	.006[b]	44	.939
	Therapy	.108[b]	44	.745
Div 82	Factor	3.264[b]	44	.078
	Sex	.335[b]	44	.566
	Therapy	.326[b]	44	.571
Div 84	Factor	1.234[b]	42	.273
	Sex	.645[b]	42	.427
	Therapy	.002[b]	42	.961
DS Con 26	Factor	3.540[b]	39	.067
	Sex	.000[b]	39	.988
	Therapy	1.246[b]	39	.271
DS Con 28	Factor	1.223[b]	41	.275
	Sex	1.152[b]	41	.289
	Therapy	1.379[b]	41	.247

DS Con 48	Factor	.788[b]	41	.380
	Sex	.237[b]	41	.629
	Therapy	5.766[b]	41	.021
DS Con 610	Factor	2.009[b]	35	.165
	Sex	.153[b]	35	.698
	Therapy	.000[b]	35	.998
DS Con 612	Factor	4.904[b]	37	.033
	Sex	3.126[b]	37	.085
	Therapy	.083[b]	37	.775
DS Con 812	Factor	2.433[b]	40	.127
	Sex	1.389[b]	40	.245
	Therapy	.130[b]	40	.721
DS Div 106	Factor	2.163[b]	40	.149
	Sex	8.606[b]	40	.006
	Therapy	4.037[b]	40	.051
DS Div 126	Factor	3.939[b]	41	.054
	Sex	.003[b]	41	.954
	Therapy	.241[b]	41	.626
DS Div 128	Factor	1.120[b]	41	.296
	Sex	4.556[b]	41	.039
	Therapy	1.748[b]	41	.193
DS Div 62	Factor	1.286[b]	40	.264
	Sex	2.058[b]	40	.159
	Therapy	.388[b]	40	.537
DS Div 82	Factor	1.085[b]	43	.303
	Sex	.163[b]	43	.688
	Therapy	.037[b]	43	.848
DS Div 84	Factor	.030[b]	44	.863
	Sex	1.821[b]	44	.184
	Therapy	2.468[b]	44	.123
FastCon 212	Factor	.737[b]	44	.395
	Sex	.600[b]	44	.443
	Therapy	3.906[b]	44	.054
SlowCon 28	Factor	4.152[b]	41	.048
	Sex	.078[b]	41	.781
	Therapy	3.187[b]	41	.082
SlowCon 612	Factor	.250[b]	40	.620
	Sex	.256[b]	40	.616
	Therapy	.946[b]	40	.337
FastDiv 122	Factor	.131[b]	41	.719
	Sex	.856[b]	41	.360
	Therapy	.096[b]	41	.758
SlowDiv 126	Factor	1.691[b]	42	.201
	Sex	.051[b]	42	.823
	Therapy	.129[b]	42	.721
SlowDiv 82	Factor	3.284[b]	43	.077
	Sex	1.307[b]	43	.259
	Therapy	.005[b]	43	.941

L2M10	Factor	3.583[b]	43	.065
	Sex	.007[b]	43	.932
	Therapy	2.872[b]	43	.097
L2M5	Factor	1.068[b]	44	.307
	Sex	3.446[b]	44	.070
	Therapy	.378[b]	44	.542
M2L10	Factor	4.861[b]	44	.033
	Sex	.494[b]	44	.486
	Therapy	1.739[b]	44	.194
M2L5	Factor	2.699[b]	45	.107
	Sex	.772[b]	45	.384
	Therapy	2.531[b]	45	.119
M2R10	Factor	3.098[b]	42	.086
	Sex	.920[b]	42	.343
	Therapy	3.629[b]	42	.064
M2R5	Factor	7.159[b]	43	.011
	Sex	1.563[b]	43	.218
	Therapy	.656[b]	43	.422
R2M10	Factor	1.496[b]	42	.228
	Sex	.269[b]	42	.606
	Therapy	1.146[b]	42	.290
R2M5	Factor	2.042[b]	43	.160
	Sex	.544[b]	43	.465
	Therapy	.015[b]	43	.903

Table A5 This table contains the statistics showing the factor, error df, and significance for between-factor (before vs after therapy), between-sex (M vs F), and between-therapy (OBVAT vs sham) for each movement's final amplitude. The tests with significant data are highlighted in green. Disappearing steps do not present stimuli so there is no target present during the final amplitude.

Final Amplitude				
		F	Error df	Sig
Con 26	Factor	.028[b]	37	0.869
	Sex	.001[b]	37	0.979
	Therapy	1.168[b]	37	0.287
Con 28	Factor	2.692[b]	41	0.109
	Sex	.025[b]	41	0.876
	Therapy	.804[b]	41	0.375
Con 48	Factor	4.250[b]	41	0.046
	Sex	10.254[b]	41	0.003
	Therapy	.729[b]	41	0.398
Con 610	Factor	2.443[b]	38	0.126
	Sex	1.998[b]	38	0.166
	Therapy	.295[b]	38	0.590
Con 612	Factor	3.124[b]	40	0.085
	Sex	.634[b]	40	0.430
	Therapy	2.351[b]	40	0.133
Con 812	Factor	.079[b]	39	0.781
	Sex	.948[b]	39	.336
	Therapy	.334[b]	39	.567
Div 106	Factor	.070[b]	41	.792
	Sex	2.760[b]	41	.104
	Therapy	.342[b]	41	.562
Div 126	Factor	1.024[b]	40	.318
	Sex	.215[b]	40	.645
	Therapy	.394[b]	40	.534
Div 128	Factor	.001[b]	38	.974
	Sex	.038[b]	38	.846
	Therapy	2.796[b]	38	.103
Div 62	Factor	.926[b]	37	.342
	Sex	.092[b]	37	.764
	Therapy	.284[b]	37	.598
Div 82	Factor	8.535[b]	41	.006
	Sex	.851[b]	41	.362
	Therapy	1.006[b]	41	.322
Div 84	Factor	.275[b]		.603
	Sex	12.701[b]		.001
	Therapy	.396[b]		.533
DS Con 26	Factor			
	Sex			
	Therapy			
DS Con 28	Factor			
	Sex			
	Therapy			

DS Con 48	Factor			
	Sex			
	Therapy			
DS Con 610	Factor			
	Sex			
	Therapy			
DS Con 612	Factor			
	Sex			
	Therapy			
DS Con 812	Factor			
	Sex			
	Therapy			
DS Div 106	Factor			
	Sex			
	Therapy			
DS Div 126	Factor			
	Sex			
	Therapy			
DS Div 128	Factor			
	Sex			
	Therapy			
DS Div 62	Factor			
	Sex			
	Therapy			
DS Div 82	Factor			
	Sex			
	Therapy			
DS Div 84	Factor			
	Sex			
	Therapy			
FastCon 212	Factor	6.800[b]	40	.013
	Sex	.037[b]	40	.849
	Therapy	5.462[b]	40	.025
SlowCon 28	Factor	4.768[b]	38	.035
	Sex	4.375[b]	38	.043
	Therapy	.166[b]	38	.686
SlowCon 612	Factor	.322[b]	42	.574
	Sex	.000[b]	42	.991
	Therapy	3.576[b]	42	.066
FastDiv 122	Factor	13.310[b]	40	.001
	Sex	.056[b]	40	.814
	Therapy	6.678[b]	40	.014
SlowDiv 126	Factor	.094[b]	40	.761
	Sex	.043[b]	40	.836
	Therapy	3.670[b]	40	.063
SlowDiv 82	Factor	6.360[b]	44	.015
	Sex	.720[b]	44	.401
	Therapy	5.144[b]	44	.028

L2M10	Factor	4.176[b]	40	.048
	Sex	.031[b]	40	.860
	Therapy	8.542[b]	40	.006
L2M5	Factor	1.221[b]	42	.275
	Sex	.002[b]	42	.968
	Therapy	1.459[b]	42	.234
M2L10	Factor	4.731[b]	41	.035
	Sex	1.295[b]	41	.262
	Therapy	6.413[b]	41	.015
M2L5	Factor	3.558[b]	42	.066
	Sex	1.010[b]	42	.321
	Therapy	2.394[b]	42	.129
M2R10	Factor	5.191[b]	44	.028
	Sex	.388[b]	44	.537
	Therapy	11.945[b]	44	.001
M2R5	Factor	2.970[b]	42	.092
	Sex	2.270[b]	42	.139
	Therapy	3.286[b]	42	.077
R2M10	Factor	5.514[b]	41	.024
	Sex	.327[b]	41	.570
	Therapy	4.760[b]	41	.035
R2M5	Factor	.076[b]	44	.784
	Sex	.052[b]	44	.820
	Therapy	3.653[b]	44	.063

Table A6 This table contains the statistics showing the factor, error df, and significance for between-factor (before vs after therapy), between-sex (M vs F), and between-therapy (OBVAT vs sham) for each movement's main sequence ratio. The tests with significant data are highlighted in green.

Main Sequence Ratio				
		F	Error df	Sig
Con 26	Factor	.517[b]	43	0.476
	Sex	1.429[b]	43	0.239
	Therapy	3.300[b]	43	0.076
Con 28	Factor	.474[b]	43	0.495
	Sex	.170[b]	43	0.682
	Therapy	4.566[b]	43	0.038
Con 48	Factor	4.291[b]	45	0.044
	Sex	1.740[b]	45	0.194
	Therapy	7.270[b]	45	0.010
Con 610	Factor	.083[b]	40	0.775
	Sex	.972[b]	40	0.330
	Therapy	13.016[b]	40	0.001
Con 612	Factor	4.243[b]	45	0.045
	Sex	1.424[b]	45	0.239
	Therapy	.424[b]	45	0.518
Con 812	Factor	.158[b]	41	0.693
	Sex	.082[b]	41	.776
	Therapy	2.156[b]	41	.150
Div 106	Factor	.963[b]	40	.332
	Sex	.133[b]	40	.718
	Therapy	1.343[b]	40	.253
Div 126	Factor	3.198[b]	39	.082
	Sex	.059[b]	39	.810
	Therapy	.183[b]	39	.671
Div 128	Factor	1.059[b]	42	.309
	Sex	.274[b]	42	.603
	Therapy	.018[b]	42	.894
Div 62	Factor	.056[b]	40	.814
	Sex	.094[b]	40	.761
	Therapy	5.322[b]	40	.026
Div 82	Factor	2.243[b]	43	.141
	Sex	.291[b]	43	.592
	Therapy	.402[b]	43	.529
Div 84	Factor	1.931[b]	41	.172
	Sex	.046[b]	41	.831
	Therapy	9.195[b]	41	.004
DS Con 26	Factor	1.592[b]	37.000	.215
	Sex	.857[b]	37.000	.360
	Therapy	.012[b]	37.000	.914
DS Con 28	Factor	.000[b]	40.000	.996
	Sex	.065[b]	40.000	.800
	Therapy	.828[b]	40.000	.368

DS Con 48	Factor	7.320[b]	38.000	.010
	Sex	.613[b]	38.000	.439
	Therapy	.431[b]	38.000	.516
DS Con 610	Factor	.874[b]	34.000	.356
	Sex	.424[b]	34.000	.519
	Therapy	.000[b]	34.000	.985
DS Con 612	Factor	1.659[b]	34.000	.206
	Sex	.568[b]	34.000	.456
	Therapy	9.604[b]	34.000	.004
DS Con 812	Factor	1.054[b]	39.000	.311
	Sex	.085[b]	39.000	.772
	Therapy	.022[b]	39.000	.884
DS Div 106	Factor	1.836[b]	37.000	.184
	Sex	2.477[b]	37.000	.124
	Therapy	1.284[b]	37.000	.264
DS Div 126	Factor	.309[b]	38.000	.582
	Sex	.279[b]	38.000	.601
	Therapy	.029[b]	38.000	.866
DS Div 128	Factor	1.334[b]	37.000	.255
	Sex	7.205[b]	37.000	.011
	Therapy	1.572[b]	37.000	.218
DS Div 62	Factor	3.281[b]	40.000	.078
	Sex	3.603[b]	40.000	.065
	Therapy	.070[b]	40.000	.792
DS Div 82	Factor	.321[b]	41.000	.574
	Sex	.012[b]	41.000	.913
	Therapy	1.396[b]	41.000	.244
DS Div 84	Factor	9.879[b]	40.000	.003
	Sex	3.324[b]	40.000	.076
	Therapy	5.799[b]	40.000	.021
FastCon 212	Factor	.011[b]	38.000	.915
	Sex	.000[b]	38.000	.986
	Therapy	9.011[b]	38.000	.005
SlowCon 28	Factor	.988[b]	41.000	.326
	Sex	.229[b]	41.000	.635
	Therapy	.499[b]	41.000	.484
SlowCon 612	Factor	18.788[b]	39.000	.000
	Sex	3.271[b]	39.000	.078
	Therapy	4.280[b]	39.000	.045
FastDiv 122	Factor	1.847[b]	40.000	.182
	Sex	.801[b]	40.000	.376
	Therapy	1.229[b]	40.000	.274
SlowDiv 126	Factor	3.855[b]	42.000	.056
	Sex	1.987[b]	42.000	.166
	Therapy	.372[b]	42.000	.545
SlowDiv 82	Factor	.133[b]	43.000	.717
	Sex	.542[b]	43.000	.466
	Therapy	.083[b]	43.000	.775

L2M10	Factor	.296[b]	42.000	.590
	Sex	.563[b]	42.000	.457
	Therapy	1.282[b]	42.000	.264
L2M5	Factor	.047[b]	42.000	.830
	Sex	.114[b]	42.000	.737
	Therapy	1.213[b]	42.000	.277
M2L10	Factor	.009[b]	41.000	.925
	Sex	.396[b]	41.000	.533
	Therapy	1.631[b]	41.000	.209
M2L5	Factor	.059[b]	42.000	.809
	Sex	.388[b]	42.000	.537
	Therapy	4.278[b]	42.000	.045
M2R10	Factor	2.686[b]	43.000	.109
	Sex	4.688[b]	43.000	.036
	Therapy	1.900[b]	43.000	.175
M2R5	Factor	.919[b]	43.000	.343
	Sex	.168[b]	43.000	.684
	Therapy	.563[b]	43.000	.457
R2M10	Factor	.023[b]	41.000	.880
	Sex	1.314[b]	41.000	.258
	Therapy	.307[b]	41.000	.583
R2M5	Factor	.110[b]	43.000	.741
	Sex	1.196[b]	43.000	.280
	Therapy	4.204[b]	43.000	.046

Table A7 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for latency movements that show significance in either Factor (before vs after), between-Sex, and/or between-Therapy (OBVAT vs Sham). The tests with significant Factor data are highlighted in green. The tests with significant between-sex data are highlighted in blue. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in both Factor and Therapy are highlighted orange.

Latency				
		F	Error df	Sig
Con 28	Factor	10.771	42	0.002
	Sex	0.002	42	0.964
	Therapy	2.44	42	0.126
Con 48	Factor	18.168	43	0
	Sex	0.415	43	0.523
	Therapy	0.206	43	0.652
Div 126	Factor	1.737[b]	40	.195
	Sex	8.315[b]	40	.006
	Therapy	3.803[b]	40	.058
DS Con 26	Factor	.260[b]	42	.613
	Sex	1.513[b]	42	.226
	Therapy	6.775[b]	42	.013
DS Con 812	Factor	.003[b]	44	.959
	Sex	5.140[b]	44	.028
	Therapy	2.917[b]	44	.095
DS Div 126	Factor	4.069[b]	44	.050
	Sex	.007[b]	44	.935
	Therapy	.765[b]	44	.386
DS Div 128	Factor	.248[b]	43	.621
	Sex	5.299[b]	43	.026
	Therapy	.437[b]	43	.512
DS Div 84	Factor	.248[b]	47	.621
	Sex	.817[b]	47	.371
	Therapy	4.204[b]	47	.046
FastCon 212	Factor	6.899[b]	39	.012
	Sex	.006[b]	39	.940
	Therapy	4.144[b]	39	.049
L2M5	Factor	.110[b]	46	.741
	Sex	.014[b]	46	.907
	Therapy	6.677[b]	46	.013
M2L5	Factor	.085[b]	45	.772
	Sex	.163[b]	45	.688
	Therapy	8.761[b]	45	.005

Table A8 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for time to peak velocity movements that show significance in either Factor (before vs after), between-Sex, and/or between-Therapy (OBVAT vs Sham). The tests with significant Factor data are highlighted in green. The tests with significant between-sex data are highlighted in blue. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in both Factor and Therapy are highlighted orange.

Time to Peak Velocity				
		F	Error df	Sig
Con 26	Factor	1.417[b]	42	0.241
	Sex	.193[b]	42	0.663
	Therapy	10.651[b]	42	0.002
Con 28	Factor	3.780[b]	44	0.058
	Sex	5.471[b]	44	0.024
	Therapy	11.256[b]	44	0.002
Con 48	Factor	2.177[b]	47	0.147
	Sex	.049[b]	47	0.825
	Therapy	7.080[b]	47	0.011
Div 62	Factor	.322[b]	41	.573
	Sex	1.607[b]	41	.212
	Therapy	8.702[b]	41	.005
DS Con 26	Factor	5.311[b]	29	.029
	Sex	.001[b]	29	.974
	Therapy	1.290[b]	29	.265
DS Div 84	Factor	4.650[b]	42	.037
	Sex	.007[b]	42	.934
	Therapy	.020[b]	42	.889
FastCon 212	Factor	11.272[b]	39	.002
	Sex	.344[b]	39	.561
	Therapy	.395[b]	39	.533
FastDiv 122	Factor	4.472[b]	36	.041
	Sex	.176[b]	36	.677
	Therapy	.101[b]	36	.753
SlowDiv 126	Factor	4.275[b]	38	.046
	Sex	.216[b]	38	.645
	Therapy	.391[b]	38	.535
SlowDiv 82	Factor	5.861[b]	40	.020
	Sex	.048[b]	40	.827
	Therapy	.571[b]	40	.454
L2M5	Factor	.102[b]	43	.751
	Sex	.414[b]	43	.523
	Therapy	4.588[b]	43	.038
M2L5	Factor	.010[b]	44	.920
	Sex	.329[b]	44	.569
	Therapy	6.912[b]	44	.012
R2M5	Factor	6.739[b]	45	.013
	Sex	.263[b]	45	.610
	Therapy	.404[b]	45	.528

Table A9 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for peak velocity movements that show significance in either Factor (before vs after), between-Sex, and/or between-Therapy (OBVAT vs Sham). The tests with significant Factor data are highlighted in green. The tests with significant between-sex data are highlighted in blue. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in both Factor and Therapy are highlighted orange.

Peak Velocity				
		F	Error df	Sig
Con 26	Factor	6.278[b]	41	0.016
	Sex	1.197[b]	41	0.280
	Therapy	6.386[b]	41	0.015
Con 28	Factor	8.910[b]	42	0.005
	Sex	.442[b]	42	0.510
	Therapy	13.090[b]	42	0.001
Con 48	Factor	2.998[b]	45	0.090
	Sex	.030[b]	45	0.864
	Therapy	10.359[b]	45	0.002
Con 610	Factor	4.094[b]	41	0.050
	Sex	.091[b]	41	0.765
	Therapy	4.438[b]	41	0.041
Con 612	Factor	13.188[b]	42	0.001
	Sex	.945[b]	42	0.337
	Therapy	2.644[b]	42	0.111
Con 812	Factor	6.755[b]	43	0.013
	Sex	.000[b]	43	.991
	Therapy	7.111[b]	43	.011
Div 62	Factor	2.054[b]	41	.159
	Sex	.221[b]	41	.641
	Therapy	7.176[b]	41	.011
Div 84	Factor	1.187[b]	42	.282
	Sex	.017[b]	42	.897
	Therapy	4.504[b]	42	.040
DS Con 26	Factor	7.565[b]	39	.009
	Sex	.108[b]	39	.745
	Therapy	5.000[b]	39	.031
DS Con 28	Factor	4.691[b]	40	.036
	Sex	.232[b]	40	.633
	Therapy	4.910[b]	40	.032
DS Con 48	Factor	5.038[b]	40	.030
	Sex	.077[b]	40	.782
	Therapy	9.872[b]	40	.003
DS Con 612	Factor	8.895[b]	37	.005
	Sex	4.300[b]	37	.045
	Therapy	.818[b]	37	.372
DS Div 106	Factor	.094[b]	40	.761
	Sex	4.121[b]	40	.049
	Therapy	4.531[b]	40	.039

DS Div 126	Factor	6.793[b]	41	.013
	Sex	.033[b]	41	.857
	Therapy	2.868[b]	41	.098
DS Div 84	Factor	11.147[b]	42	.002
	Sex	1.838[b]	42	.182
	Therapy	.053[b]	42	.818
FastCon 212	Factor	8.753[b]	44	.005
	Sex	.263[b]	44	.611
	Therapy	10.450[b]	44	.002
SlowCon 28	Factor	8.124[b]	40	.007
	Sex	.506[b]	40	.481
	Therapy	5.521[b]	40	.024
SlowCon 612	Factor	4.726[b]	42	.035
	Sex	.363[b]	42	.550
	Therapy	14.408[b]	42	.000
SlowDiv 126	Factor	10.455[b]	43	.002
	Sex	.230[b]	43	.634
	Therapy	1.598[b]	43	.213
SlowDiv 82	Factor	8.839[b]	42	.005
	Sex	4.481[b]	42	.040
	Therapy	3.627[b]	42	.064

Table A10 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for response amplitude movements that show significance in either Factor (before vs after), between-Sex, and/or between-Therapy (OBVAT vs Sham). The tests with significant Factor data are highlighted in green. The tests with significant between-sex data are highlighted in blue. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in both Factor and Therapy are highlighted orange.

Response Amplitude				
		F	Error df	Sig
Con 28	Factor	6.665[b]	43	0.0133
	Sex	.655[b]	43	0.4229
	Therapy	3.153[b]	43	0.0829
Con 612	Factor	6.496[b]	40	0.0148
	Sex	1.710[b]	40	0.1984
	Therapy	1.556[b]	40	0.2195
Con 812	Factor	8.376[b]	44	0.0059
	Sex	2.049[b]	44	.159
	Therapy	.745[b]	44	.393
DS Con 48	Factor	.788[b]	41	.380
	Sex	.237[b]	41	.629
	Therapy	5.766[b]	41	.021
DS Con 612	Factor	4.904[b]	37	.033
	Sex	3.126[b]	37	.085
	Therapy	.083[b]	37	.775
DS Div 106	Factor	2.163[b]	40	.149
	Sex	8.606[b]	40	.006
	Therapy	4.037[b]	40	.051
DS Div 128	Factor	1.120[b]	41	.296
	Sex	4.556[b]	41	.039
	Therapy	1.748[b]	41	.193
SlowCon 28	Factor	4.152[b]	41	.048
	Sex	.078[b]	41	.781
	Therapy	3.187[b]	41	.082
M2L10	Factor	4.861[b]	44	.033
	Sex	.494[b]	44	.486
	Therapy	1.739[b]	44	.194
M2R5	Factor	7.159[b]	43	.011
	Sex	1.563[b]	43	.218
	Therapy	.656[b]	43	.422

Table A11 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for final amplitude movements that show significance in either Factor (before vs after), between-Sex, and/or between-Therapy (OBVAT vs Sham). The tests with significant Factor data are highlighted in green. The tests with significant between-sex data are highlighted in blue. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in both Factor and Therapy are highlighted orange.

Final Amplitude				
		F	Error df	Sig
Con 48	Factor	4.250[b]	41	0.046
	Sex	10.254[b]	41	0.003
	Therapy	.729[b]	41	0.398
Div 82	Factor	8.535[b]	41	.006
	Sex	.851[b]	41	.362
	Therapy	1.006[b]	41	.322
Div 84	Factor	.275[b]	39	.603
	Sex	12.701[b]	39	.001
	Therapy	.396[b]	39	.533
FastCon 212	Factor	6.800[b]	40	.013
	Sex	.037[b]	40	.849
	Therapy	5.462[b]	40	.025
SlowCon 28	Factor	4.768[b]	38	.035
	Sex	4.375[b]	38	.043
	Therapy	.166[b]	38	.686
FastDiv 122	Factor	13.310[b]	40	.001
	Sex	.056[b]	40	.814
	Therapy	6.678[b]	40	.014
SlowDiv 82	Factor	6.360[b]	44	.015
	Sex	.720[b]	44	.401
	Therapy	5.144[b]	44	.028
L2M10	Factor	4.176[b]	40	.048
	Sex	.031[b]	40	.860
	Therapy	8.542[b]	40	.006
M2L10	Factor	4.731[b]	41	.035
	Sex	1.295[b]	41	.262
	Therapy	6.413[b]	41	.015
M2R10	Factor	5.191[b]	44	.028
	Sex	.388[b]	44	.537
	Therapy	11.945[b]	44	.001
R2M10	Factor	5.514[b]	41	.024
	Sex	.327[b]	41	.570
	Therapy	4.760[b]	41	.035

Table A12 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for main sequence ratio movements that show significance in either Factor (before vs after), between-Sex, and/or between-Therapy (OBVAT vs Sham). The tests with significant Factor data are highlighted in green. The tests with significant between-sex data are highlighted in blue. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in both Factor and Therapy are highlighted orange.

Main Sequence Ratio				
		F	Error df	Sig
Con 28	Factor	.474[b]	43	0.495
	Sex	.170[b]	43	0.682
	Therapy	4.566[b]	43	0.038
Con 48	Factor	4.291[b]	45	0.044
	Sex	1.740[b]	45	0.194
	Therapy	7.270[b]	45	0.010
Con 610	Factor	.083[b]	40	0.775
	Sex	.972[b]	40	0.330
	Therapy	13.016[b]	40	0.001
Con 612	Factor	4.243[b]	45	0.045
	Sex	1.424[b]	45	0.239
	Therapy	.424[b]	45	0.518
Div 62	Factor	.056[b]	40	.814
	Sex	.094[b]	40	.761
	Therapy	5.322[b]	40	.026
Div 84	Factor	1.931[b]	41	.172
	Sex	.046[b]	41	.831
	Therapy	9.195[b]	41	.004
DS Con 48	Factor	7.320[b]	38	.010
	Sex	.613[b]	38	.439
	Therapy	.431[b]	38	.516
DS Con 612	Factor	1.659[b]	34	.206
	Sex	.568[b]	34	.456
	Therapy	9.604[b]	34	.004
DS Div 128	Factor	1.334[b]	37	.255
	Sex	7.205[b]	37	.011
	Therapy	1.572[b]	37	.218
DS Div 84	Factor	9.879[b]	40	.003
	Sex	3.324[b]	40	.076
	Therapy	5.799[b]	40	.021
FastCon 212	Factor	.011[b]	38	.915
	Sex	.000[b]	38	.986
	Therapy	9.011[b]	38	.005
SlowCon 612	Factor	18.788[b]	39	.000
	Sex	3.271[b]	39	.078
	Therapy	4.280[b]	39	.045
M2L5	Factor	.059[b]	42	.809
	Sex	.388[b]	42	.537
	Therapy	4.278[b]	42	.045

M2R10	Factor	2.686[b]	43	.109
	Sex	4.688[b]	43	.036
	Therapy	1.900[b]	43	.175
R2M5	Factor	.110[b]	43	.741
	Sex	1.196[b]	43	.280
	Therapy	4.204[b]	43	.046

Table A13 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for latency movements that show significance in both Factor (before vs after) and between-Therapy (OBVAT vs Sham). It also shows the t, df, and significance of the post hoc analysis done to determine whether OBVAT or sham therapy had significance before/after therapy. The tests with significant Factor data are highlighted in green. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in the post hoc analysis are highlighted orange.

Latency								
		F	Error df	Sig				
FastCon 212	Factor	6.800[b]	40	0.0127		t	df	sig
	Sex	.037[b]	40	0.8492	Active	-3.969	21	0.001
	Therapy	5.462[b]	40	0.0245	Placebo	-0.611	20	0.548

Table A14 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for peak velocity movements that show significance in both Factor (before vs after) and between-Therapy (OBVAT vs Sham). It also shows the t, df, and significance of the post hoc analysis done to determine whether OBVAT or sham therapy had significance before/after therapy. The tests with significant Factor data are highlighted in green. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in the post hoc analysis are highlighted orange.

Peak Velocity								
		F	Error df	Sig				
Con 26	Factor	6.278[b]	41	0.0163		t	df	sig
	Sex	1.197[b]	41	0.2803	Active	-5.368	21	.000
	Therapy	6.386[b]	41	0.0155	Placebo	-0.29	22	0.774
Con 28	Factor	8.910[b]	42	0.0047		t	df	sig
	Sex	.442[b]	42	0.5099	Active	-4.204	21	.000
	Therapy	13.090[b]	42	0.0008	Placebo	-0.956	21	0.35
Con 610	Factor	4.094[b]	41	0.0496		t	df	sig
	Sex	.091[b]	41	0.7646	Active	-3.472	21	0.002
	Therapy	4.438[b]	41	0.0413	Placebo	-0.356	21	0.726
Con 812	Factor	6.755[b]	43	0.0128		t	df	sig
	Sex	.000[b]	43	0.9909	Active	-4.443	22	.000
	Therapy	7.111[b]	43	0.0108	Placebo	-0.273	22	0.788
DS Con 26	Factor	7.565[b]	39	0.0090		t	df	sig
	Sex	.108[b]	39	0.7447	Active	-3.327	21	.003
	Therapy	5.000[b]	39	0.0311	Placebo	-0.663	19	0.515
DS Con 28	Factor	4.691[b]	40	0.0363		t	df	sig
	Sex	.232[b]	40	0.6327	Active	-2.931	21	0.008
	Therapy	4.910[b]	40	0.0325	Placebo	-0.863	20	0.398
DS Con 48	Factor	5.038[b]	40	0.0304		t	df	sig
	Sex	.077[b]	40	0.7825	Active	-4.163	21	.000
	Therapy	9.872[b]	40	0.0032	Placebo	0.458	20	0.652
FastCon 212	Factor	8.753[b]	44	0.0050		t	df	sig
	Sex	.263[b]	44	0.6108	Active	-3.901	22	0.001
	Therapy	10.450[b]	44	0.0023	Placebo	0.156	23	0.878
SlowCon 28	Factor	8.124[b]	40	0.0069		t	df	sig
	Sex	.506[b]	40	0.4812	Active	-4.423	21	.000
	Therapy	5.521[b]	40	0.0238	Placebo	-1.165	20	0.258
SlowCon 612	Factor	4.726[b]	42	0.0354		t	df	sig
	Sex	.363[b]	42	0.5500	Active	-4.738	21	.000
	Therapy	14.408[b]	42	0.0005	Placebo	1.175	22	0.253

Table A15 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for final amplitude movements that show significance in both Factor (before vs after) and between-Therapy (OBVAT vs Sham). It also shows the t, df, and significance of the post hoc analysis done to determine whether OBVAT or sham therapy had significance before/after therapy. The tests with significant Factor data are highlighted in green. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in the post hoc analysis are highlighted orange.

Final Amplitude								
		F	Error df	Sig				
FastCon 212	Factor	6.800[b]	40	0.0127		t	df	sig
	Sex	.037[b]	40	0.8492	Active	-3.969	21	0.001
	Therapy	5.462[b]	40	0.0245	Placebo	-0.611	20	0.548
FastDiv 122	Factor	13.310[b]	40	0.0008		t	df	sig
	Sex	.056[b]	40	0.8143	Active	4.417	20	.000
	Therapy	6.678[b]	40	0.0135	Placebo	1.667	21	0.11
SlowDiv 82	Factor	6.360[b]	44	0.0154		t	df	sig
	Sex	.720[b]	44	0.4007	Active	3.111	22	0.005
	Therapy	5.144[b]	44	0.0283	Placebo	0.07	23	0.945
L2M10	Factor	4.176[b]	40	0.0476		t	df	sig
	Sex	.031[b]	40	0.8605	Active	4.569	21	.000
	Therapy	8.542[b]	40	0.0057	Placebo	-0.302	20	0.766
M2L10	Factor	4.731[b]	41	0.0354		t	df	sig
	Sex	1.295[b]	41	0.2618	Active	-3.352	21	0.003
	Therapy	6.413[b]	41	0.0153	Placebo	0.543	21	0.593
M2R10	Factor	5.191[b]	44	0.0276		t	df	sig
	Sex	.388[b]	44	0.5366	Active	4.682	24	.000
	Therapy	11.945[b]	44	0.0012	Placebo	-0.777	21	0.446
R2M10	Factor	5.514[b]	41	0.0238		t	df	sig
	Sex	.327[b]	41	0.5704	Active	-3.319	21	0.003
	Therapy	4.760[b]	41	0.0349	Placebo	-0.109	21	0.914

Table A16 This table contains the statistics showing the factor, error df, and significance for factor, sex, and therapy for main sequence ratio movements that show significance in both Factor (before vs after) and between-Therapy (OBVAT vs Sham). It also shows the t, df, and significance of the post hoc analysis done to determine whether OBVAT or sham therapy had significance before/after therapy. The tests with significant Factor data are highlighted in green. The tests with significant between-therapy data are highlighted in yellow. Tests with significance seen in the post hoc analysis are highlighted orange.

Main Sequence Ratio								
		F	Error df	Sig				
Con 48	Factor	4.291[b]	45	0.0441		t	df	sig
	Sex	1.740[b]	45	0.1938	Active	-3.485	23	0.002
	Therapy	7.270[b]	45	0.0098	Placebo	0.836	23	0.412
DS Div 84	Factor	9.879[b]	40.000	0.0031		t	df	sig
	Sex	3.324[b]	40.000	0.0757	Active	-0.502	20	0.621
	Therapy	5.799[b]	40.000	0.0207	Placebo	-2.643	21	0.015
SlowCon 612	Factor	18.788[b]	39.000	0.0001		t	df	sig
	Sex	3.271[b]	39.000	0.0782	Active	-1.672	21	0.109
	Therapy	4.280[b]	39.000	0.0452	Placebo	-3.731	19	0.001

APPENDIX B

BEHAVIORAL PLOTS

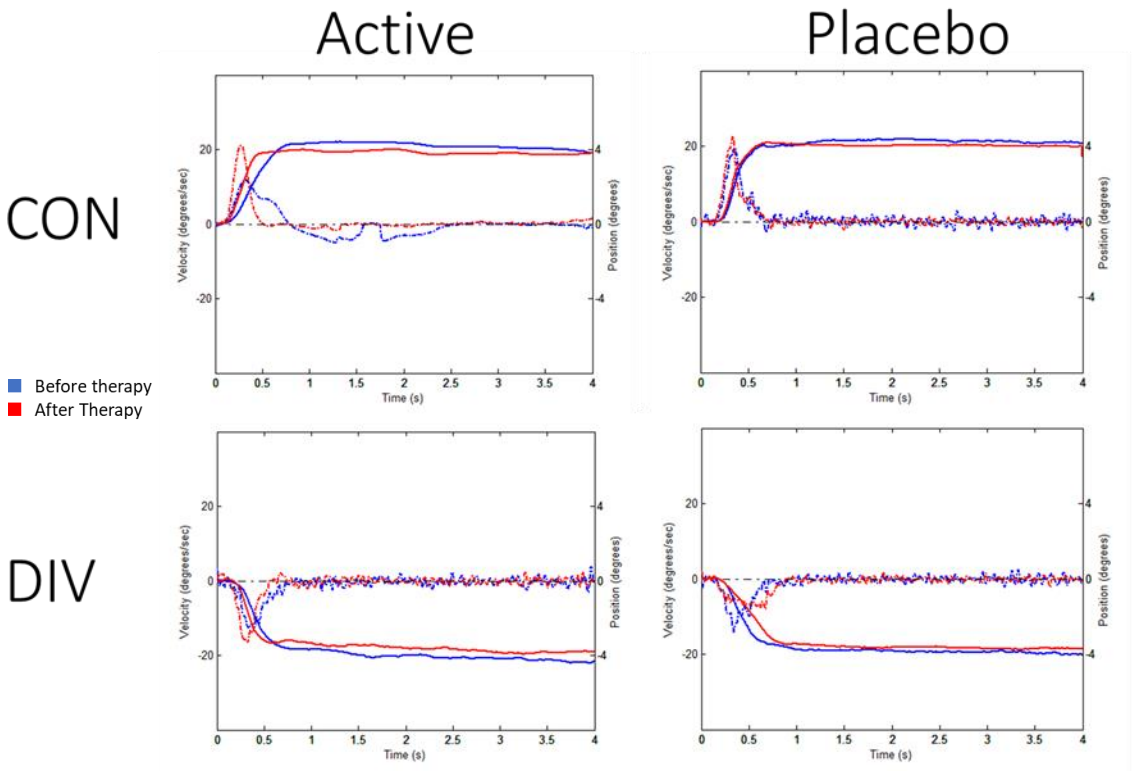

Figure B1 This figure shows comparison plots of subject step movements before and after therapy for both active and placebo therapies.

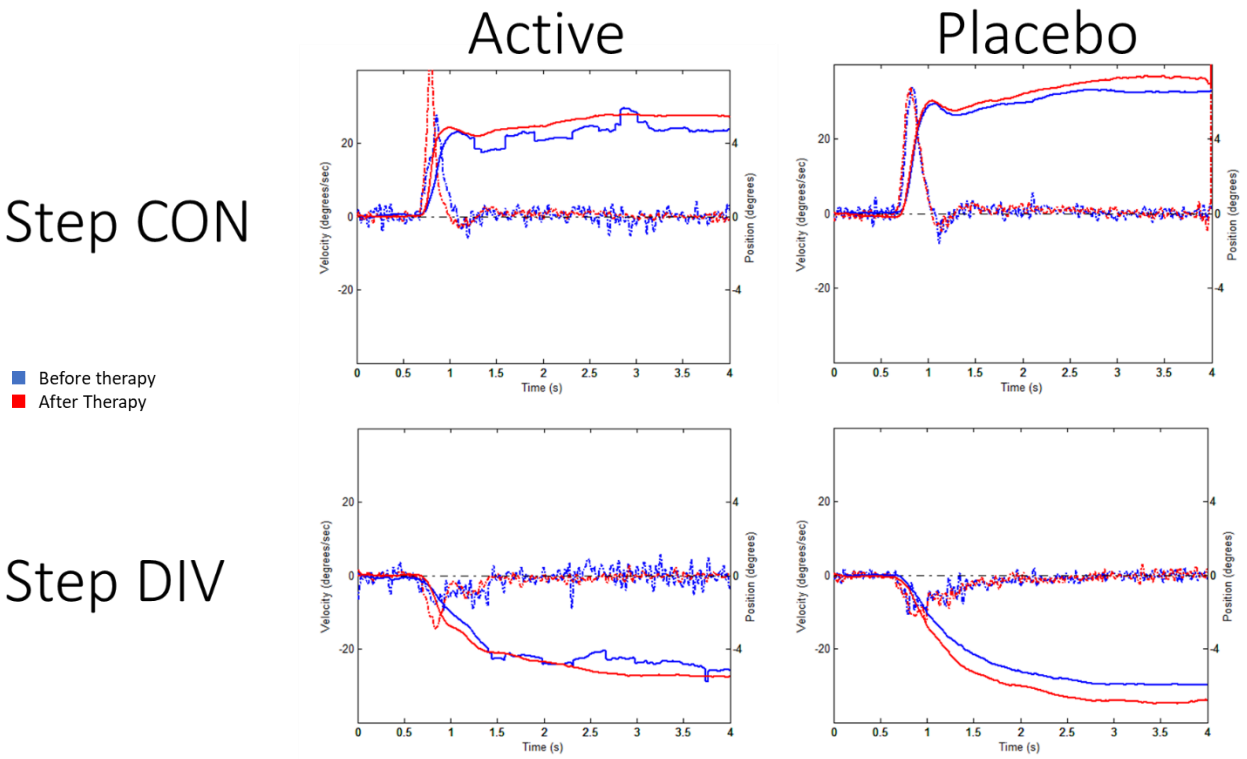

Figure B2 This figure shows comparison plots of subject step ramp movements before and after therapy for both active and placebo therapies.

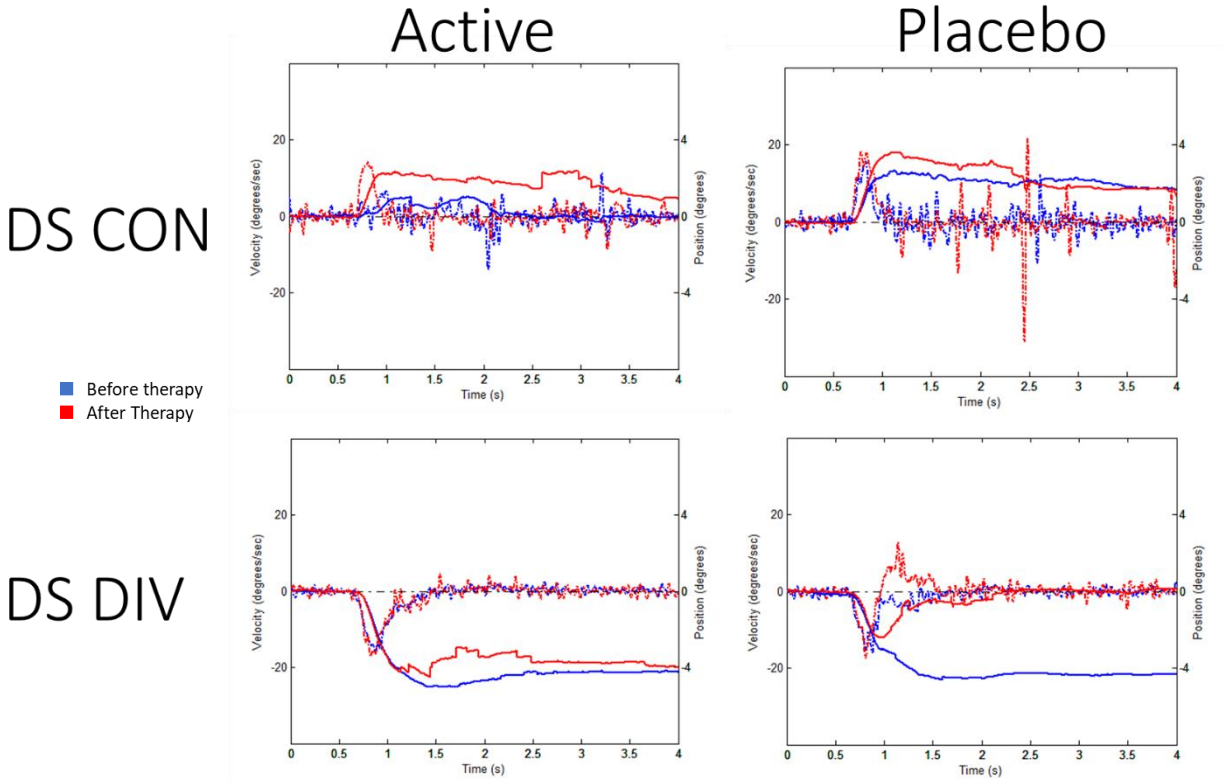

Figure B3 This figure shows comparison plots of subject disappearing step movements before and after therapy for both active and placebo therapies.

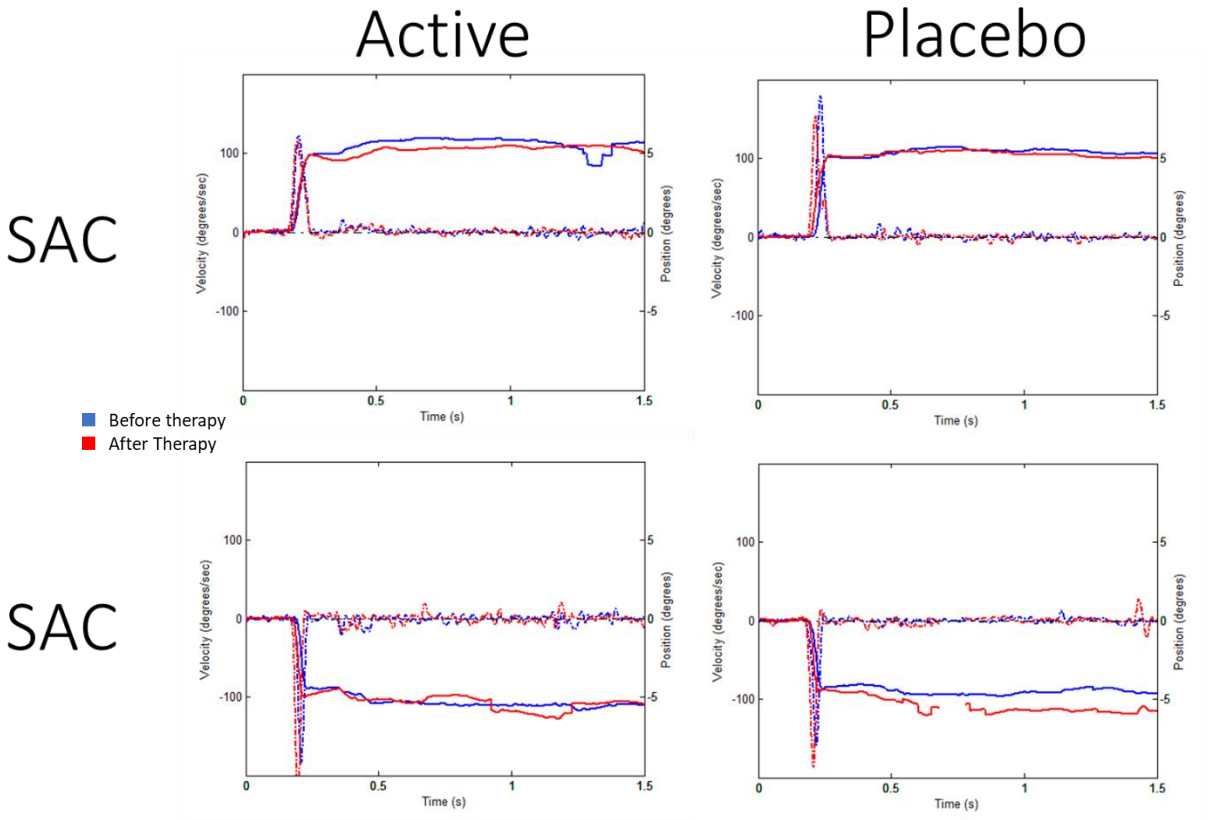

Figure B4 This figure shows comparison plots of subject saccade movements before and after therapy for both active and placebo therapies. The green trace is the average of all individual movements.

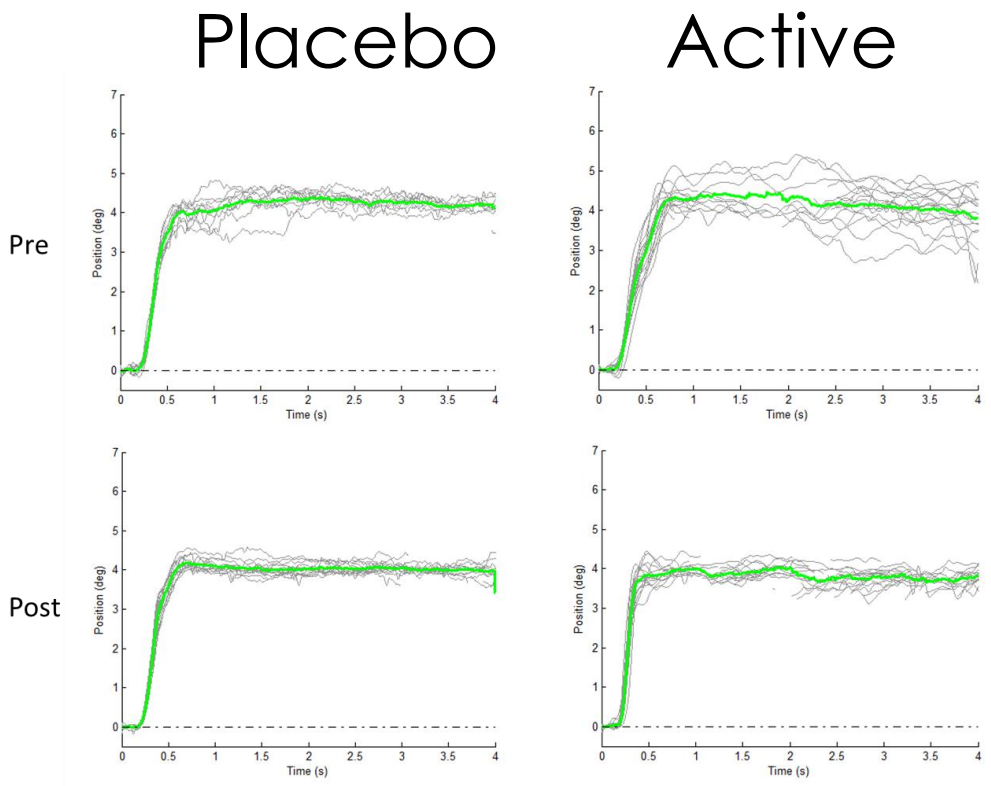

Figure B5 This figure shows ensemble plots of subject convergence movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

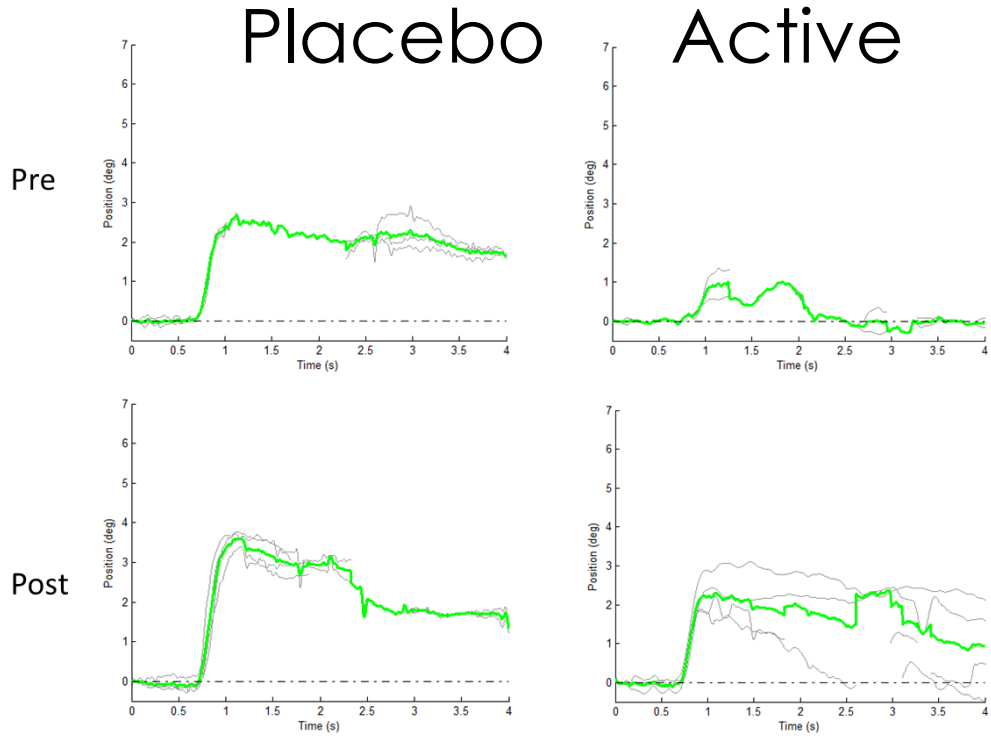

Figure B6 This figure shows ensemble plots of subject convergence disappearing step movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

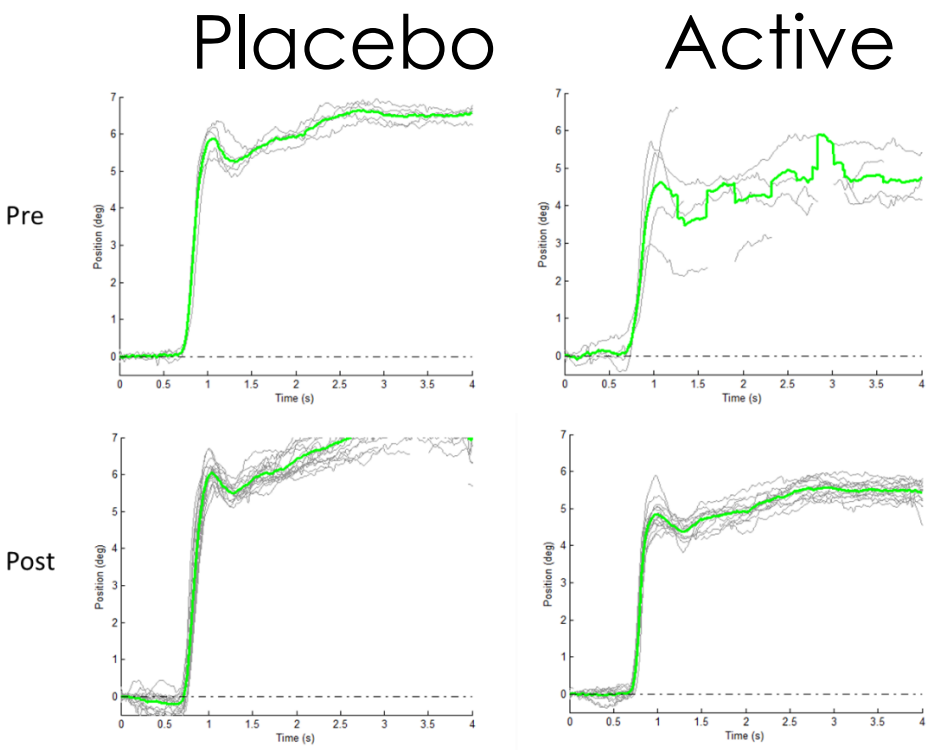

Figure B7 This figure shows ensemble plots of subject convergence stepramps movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

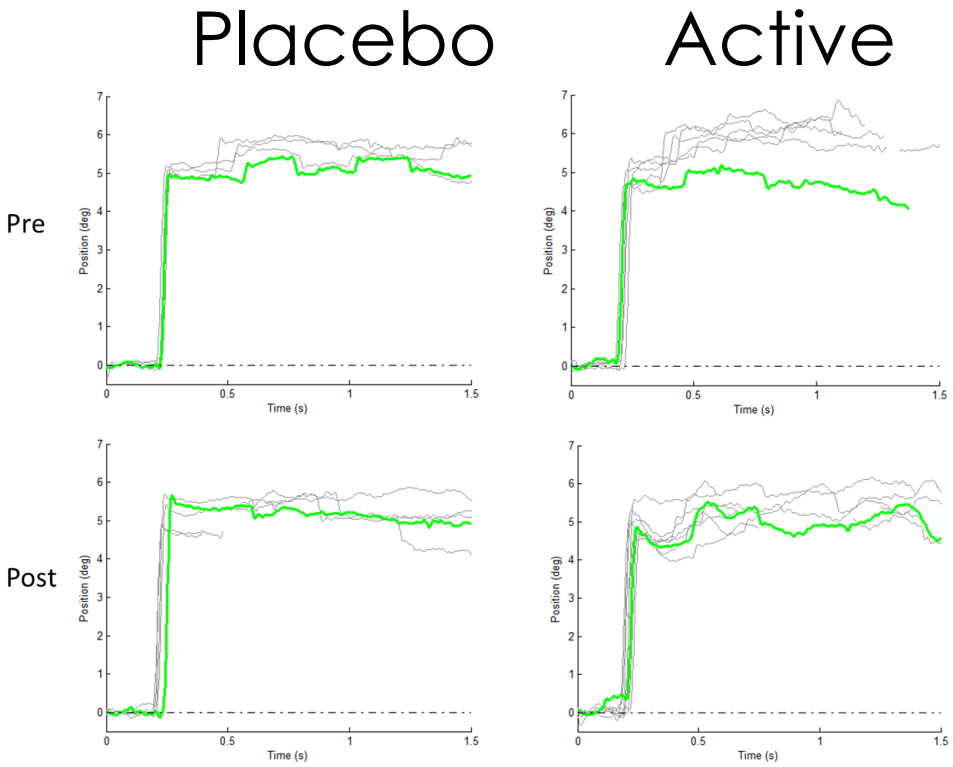

Figure B8 This figure shows ensemble plots of subject saccade movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

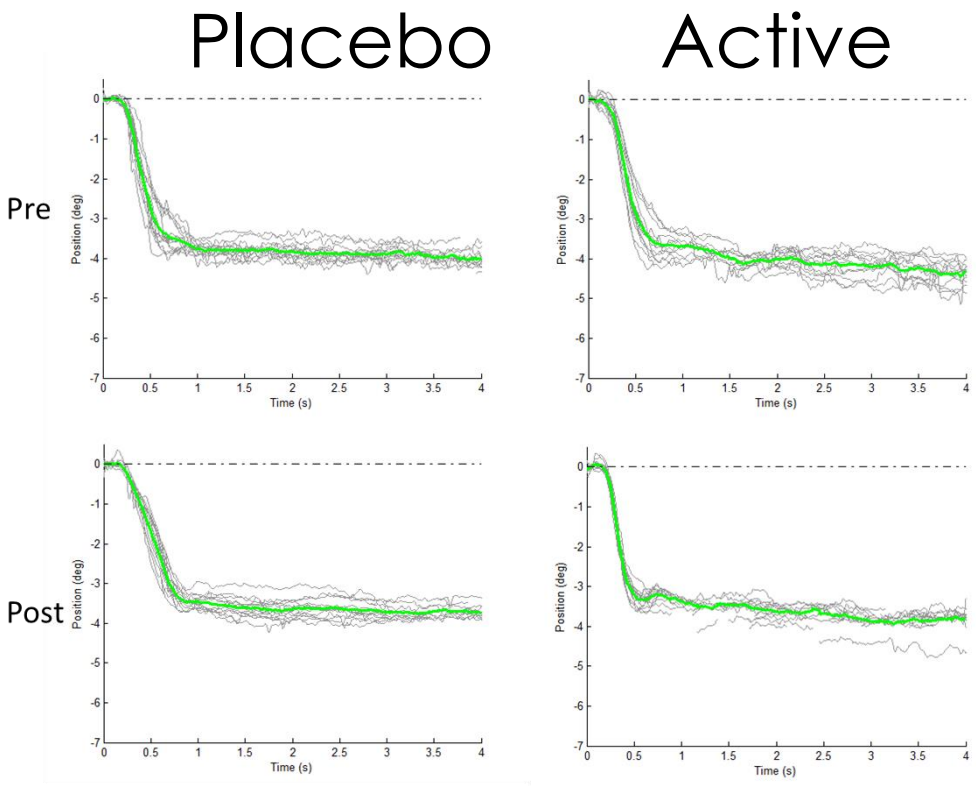

Figure B9 This figure shows ensemble plots of subject divergence movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

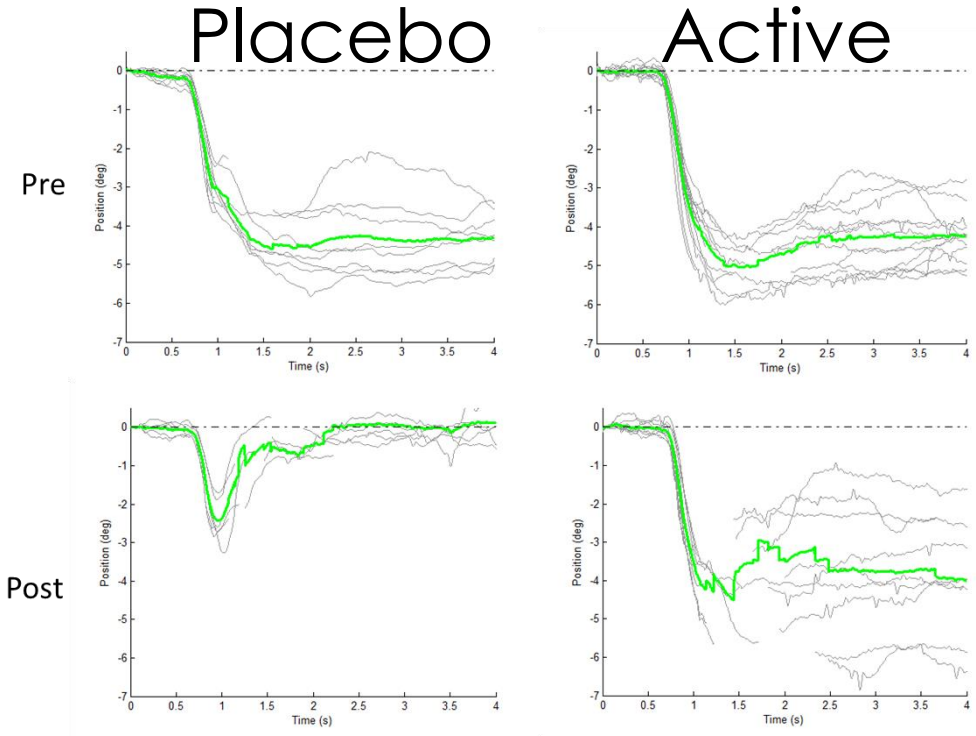

Figure B10 This figure shows ensemble plots of subject divergence disappearing step movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

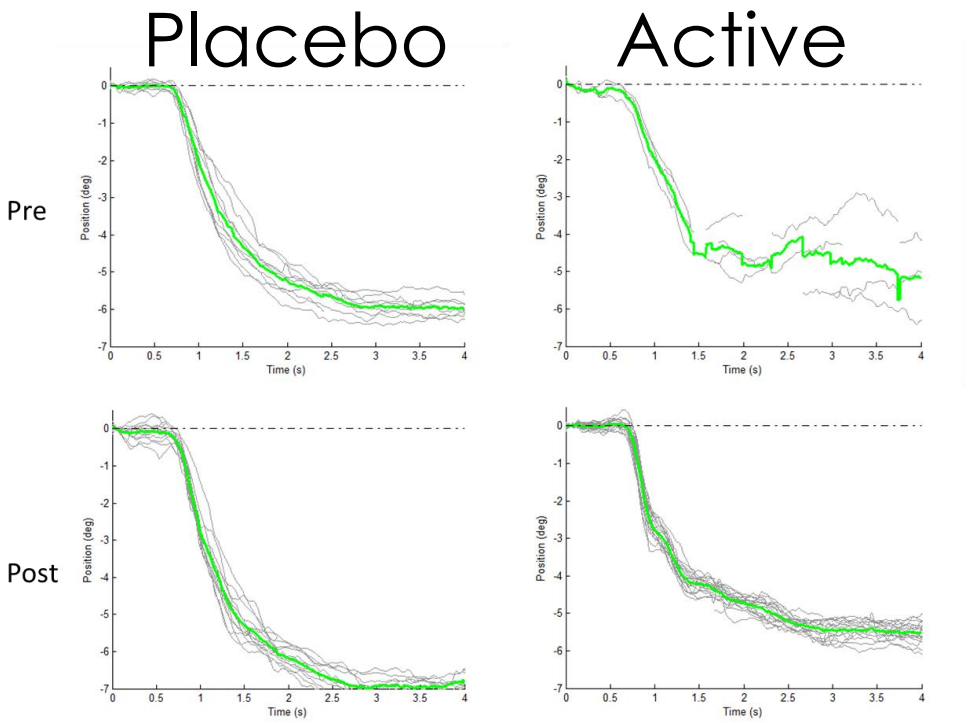

Figure B11 This figure shows ensemble plots of subject divergence stepramps movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

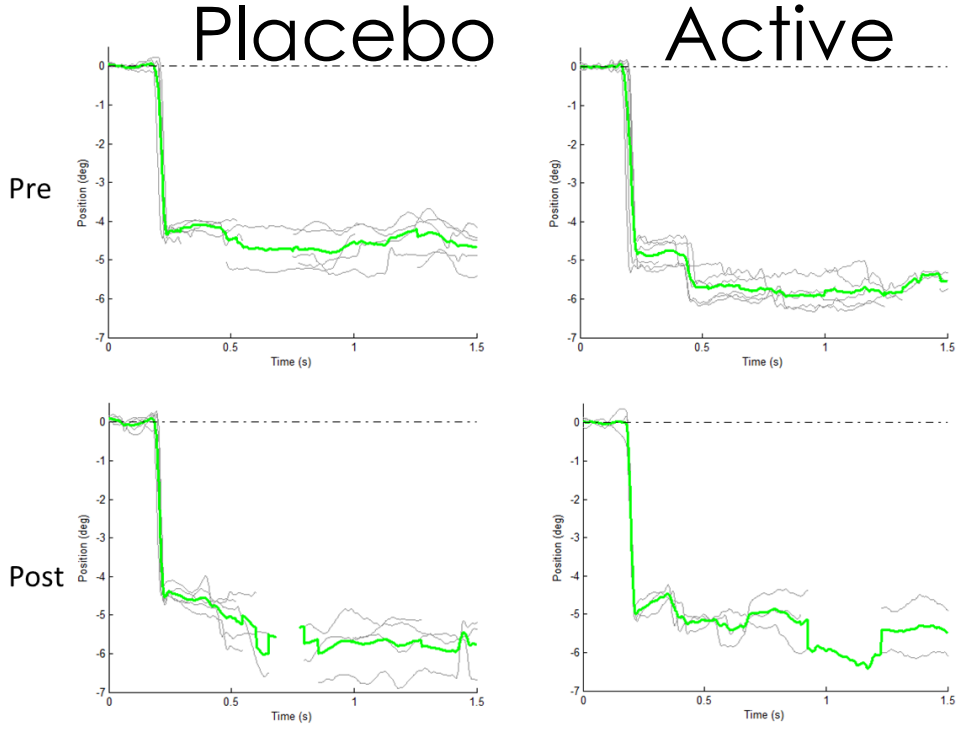

Figure B12 This figure shows ensemble plots of subject saccade movements before and after therapy for both active (right) and placebo (left) therapies. The green trace is the average of all individual movements.

APPENDIX C

BAR PLOTS OF PARAMETERS

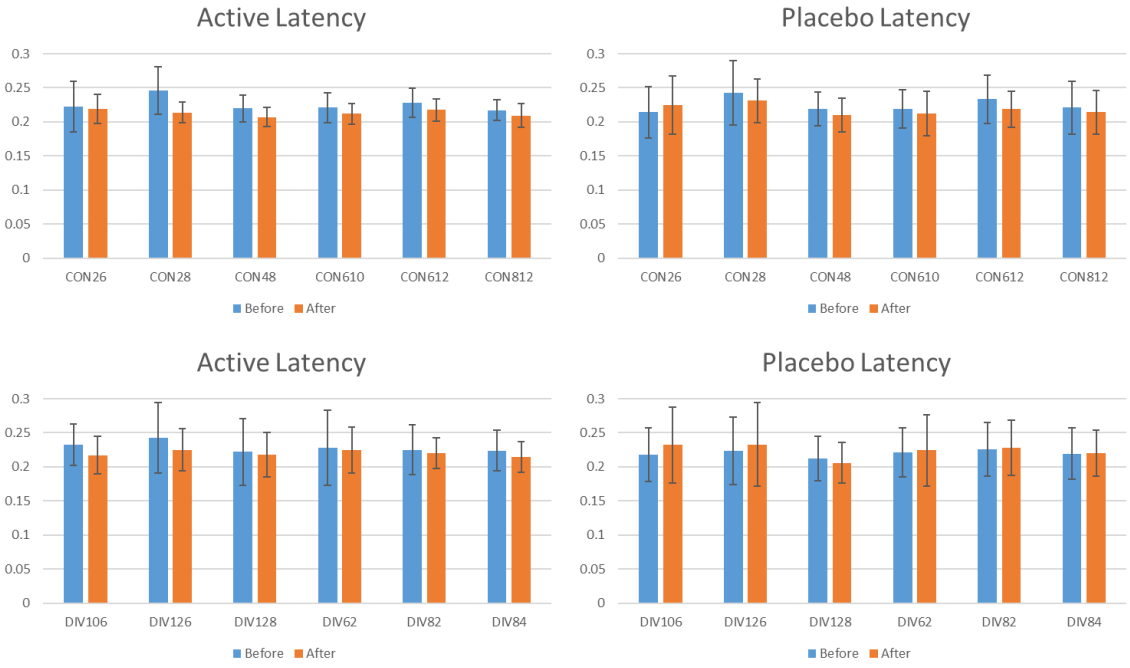

Figure C1 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

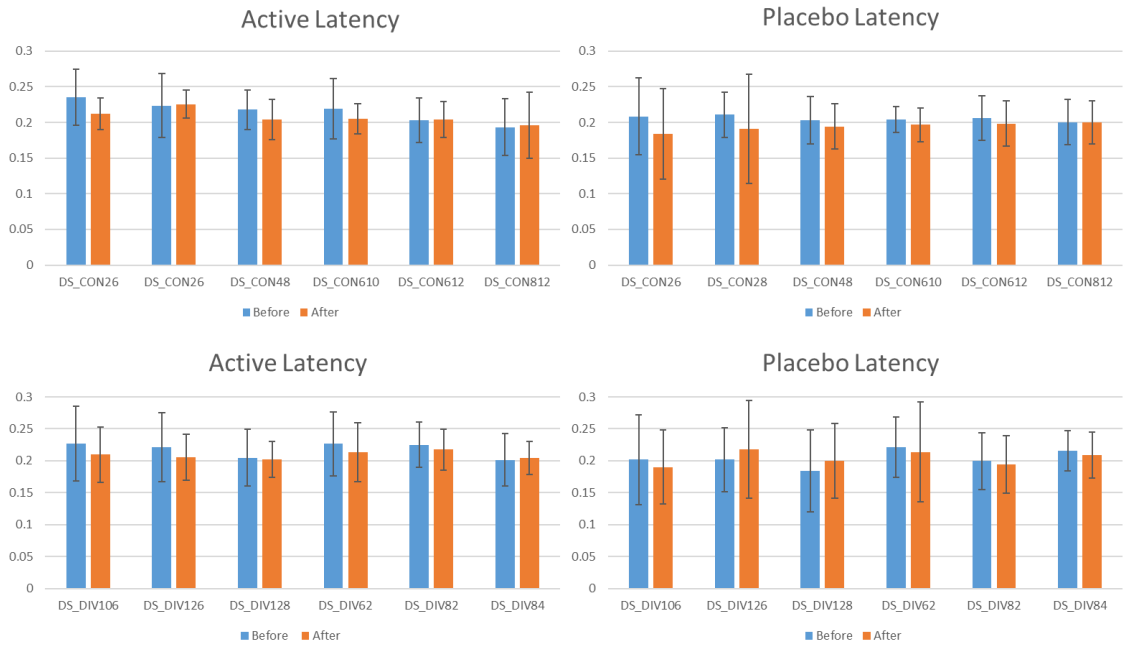

Figure C2 This figure shows the means and standard deviations for disappearing step convergence and disappearing step divergence movements for both the active and placebo therapies.

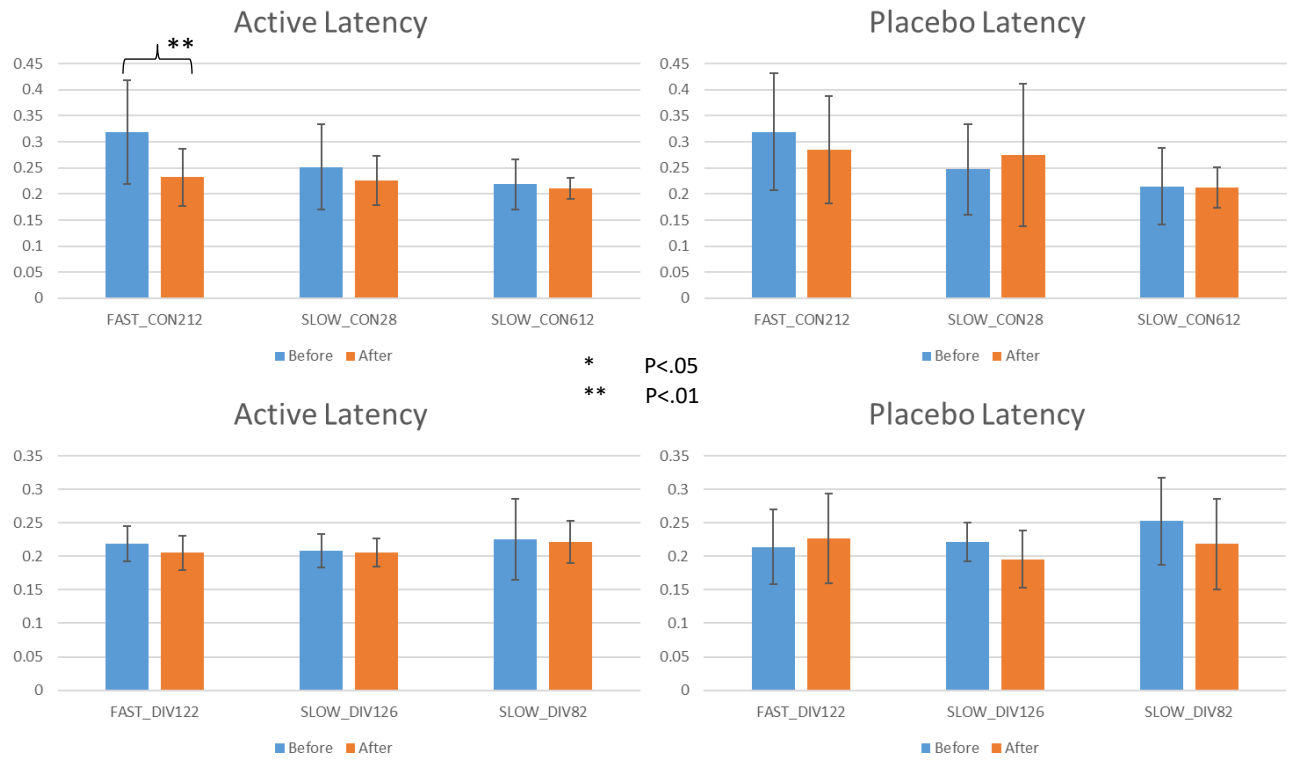

Figure C3 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

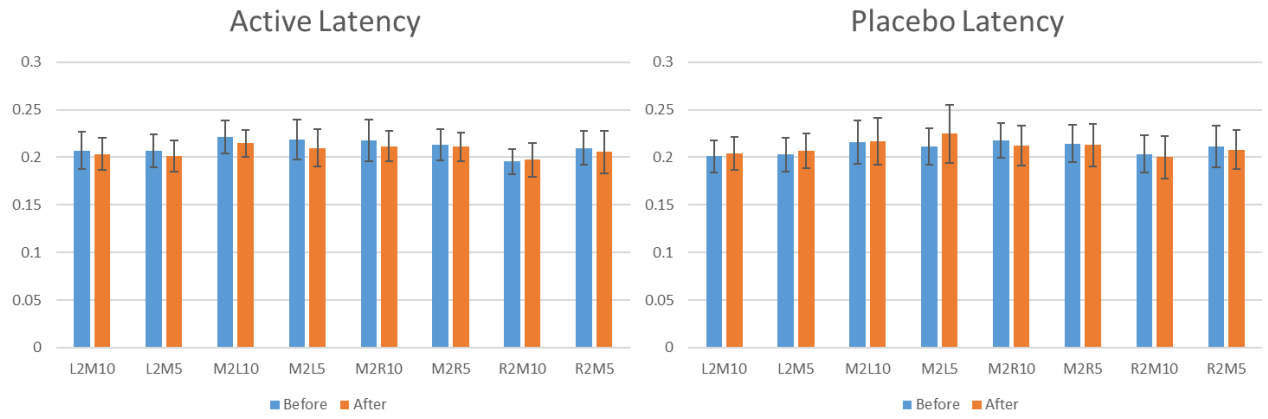

Figure C4 This figure shows the means and standard deviations for saccadic movements for both the active and placebo therapies.

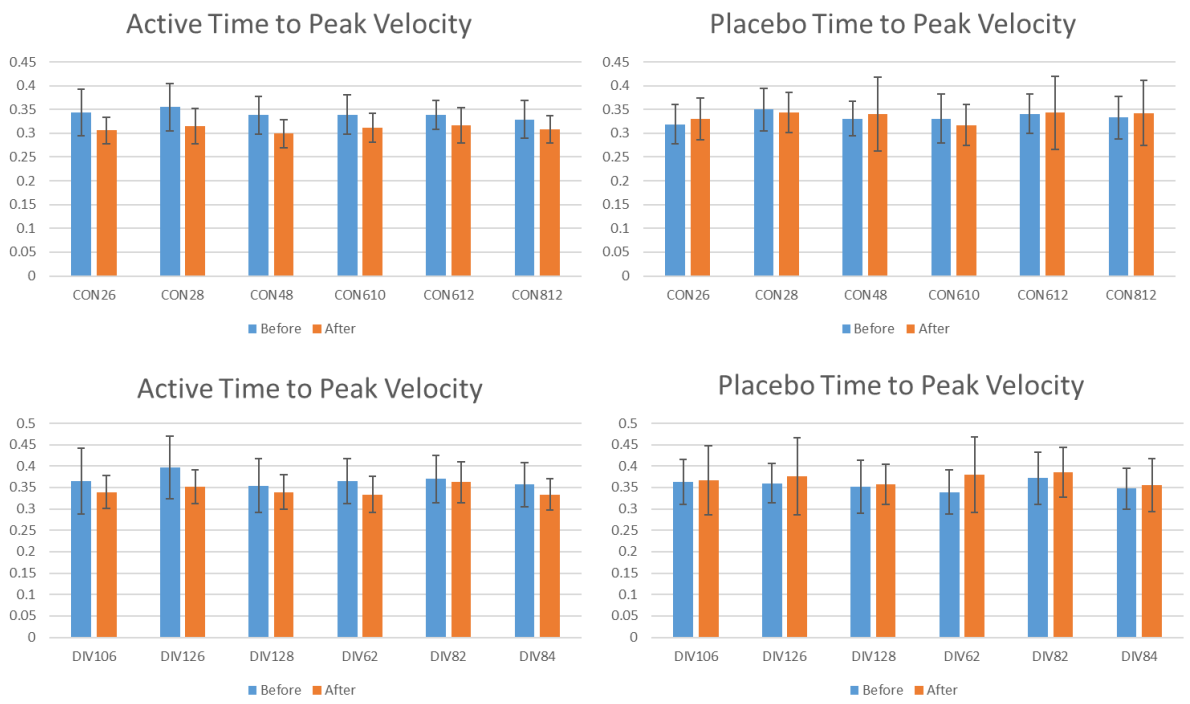

Figure C5 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

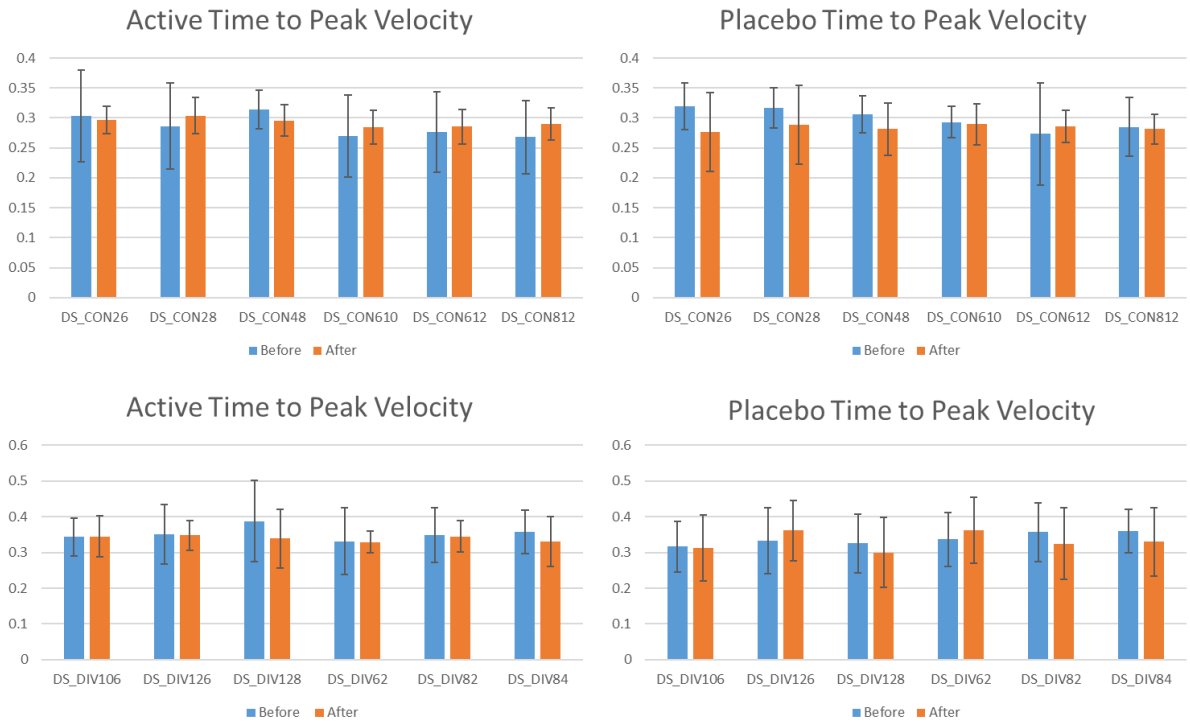

Figure C6 This figure shows the means and standard deviations for disappearing step convergence and disappearing step divergence movements for both the active and placebo therapies.

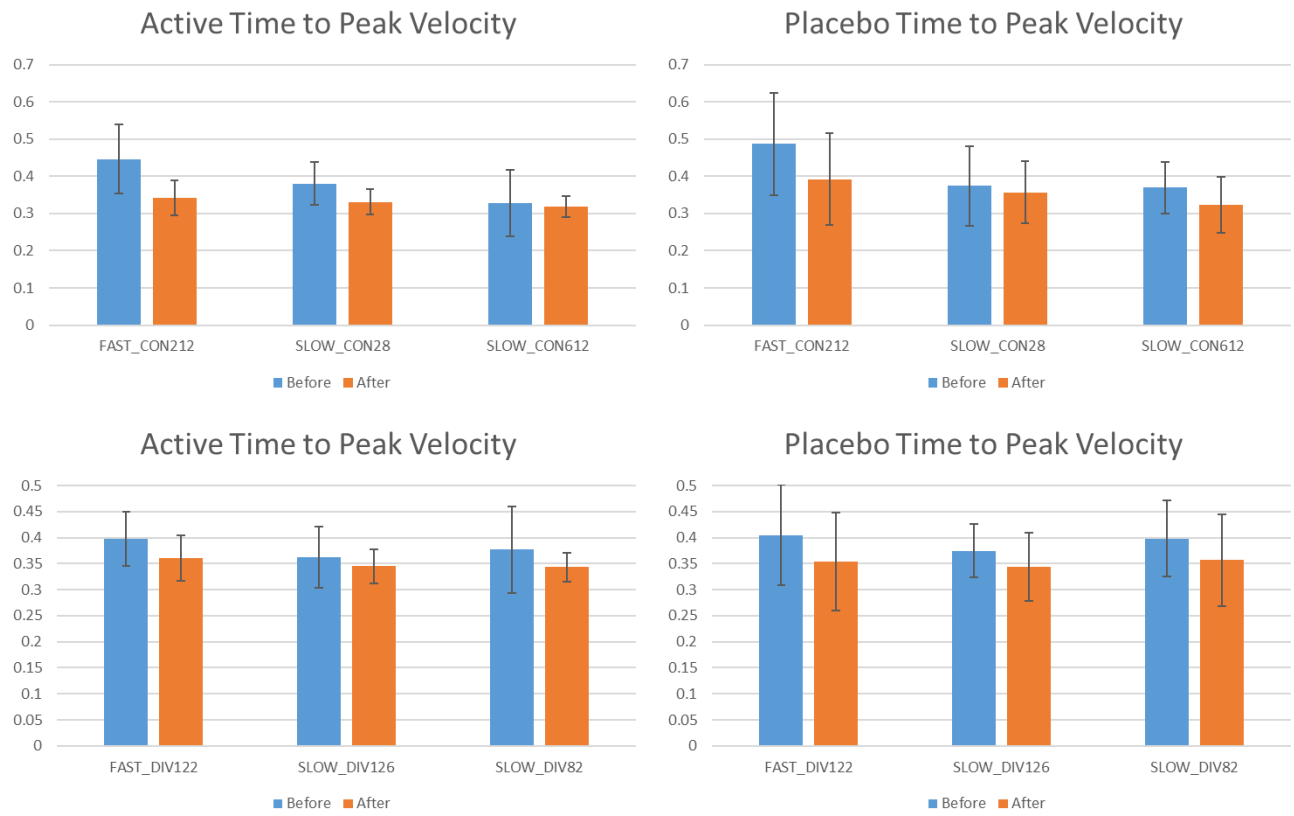

Figure C7 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

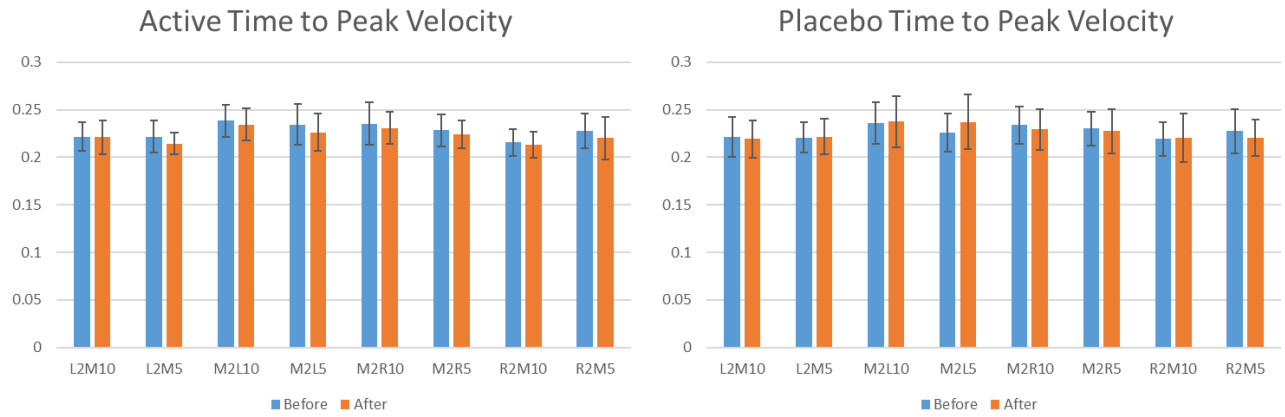

Figure C8 This figure shows the means and standard deviations for saccadic movements for both the active and placebo therapies.

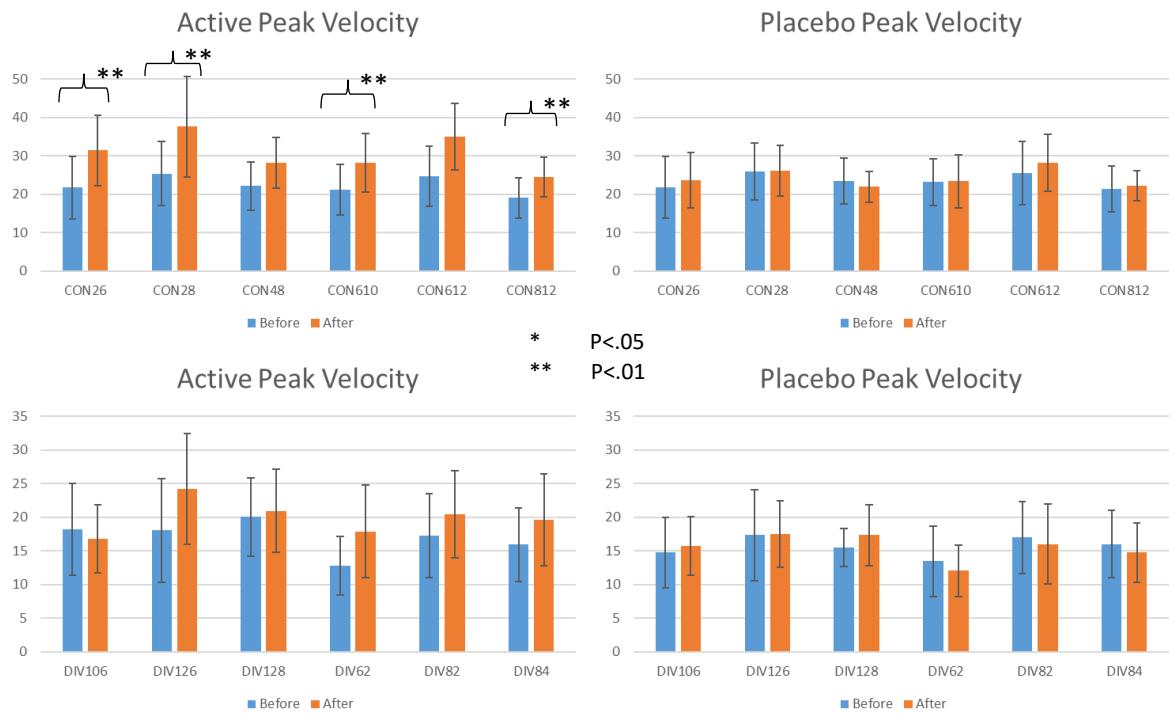

Figure C9 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

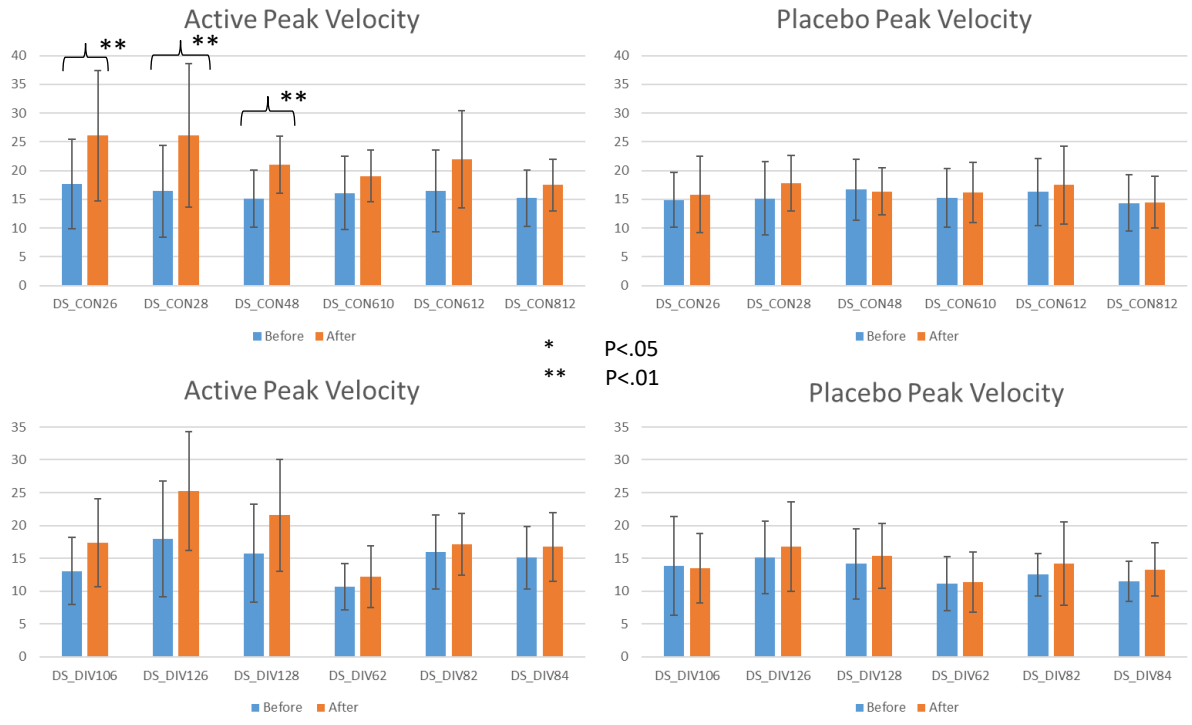

Figure C10 This figure shows the means and standard deviations for disappearing step convergence and disappearing step divergence movements for both the active and placebo therapies.

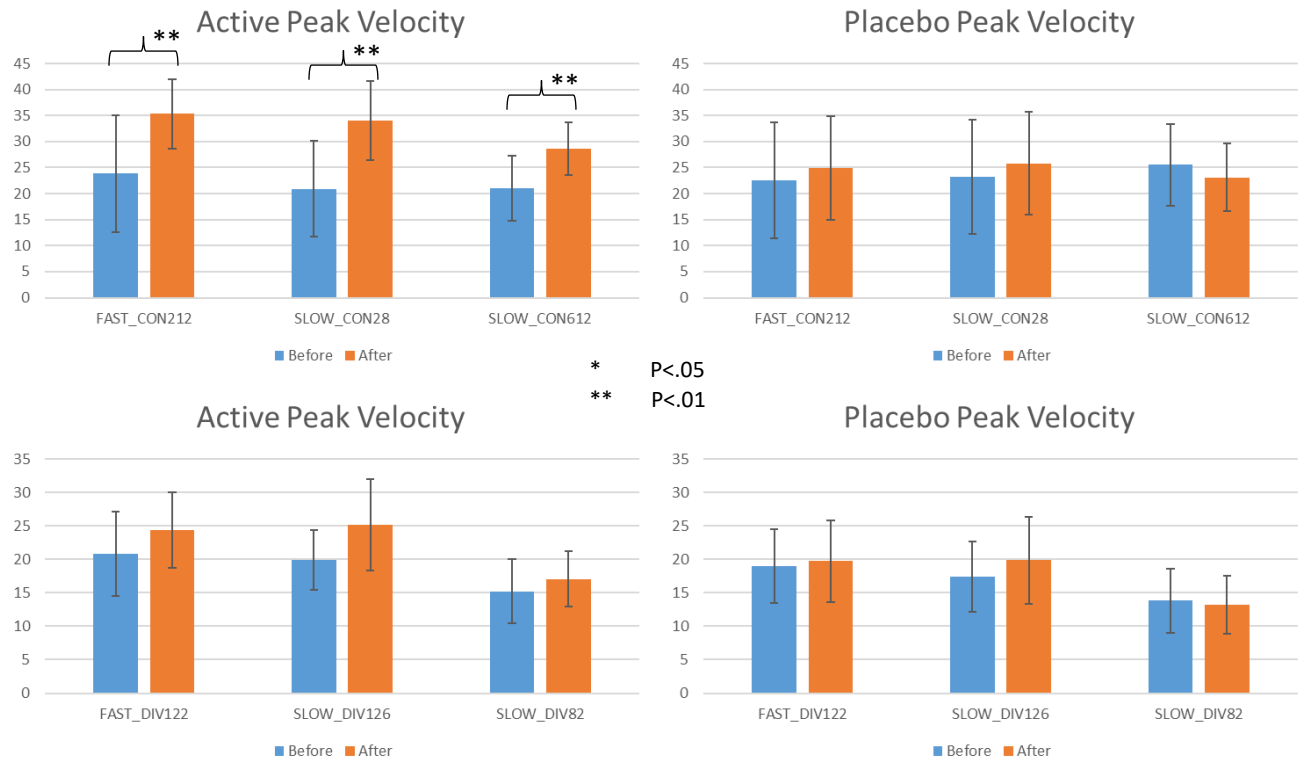

Figure C11 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

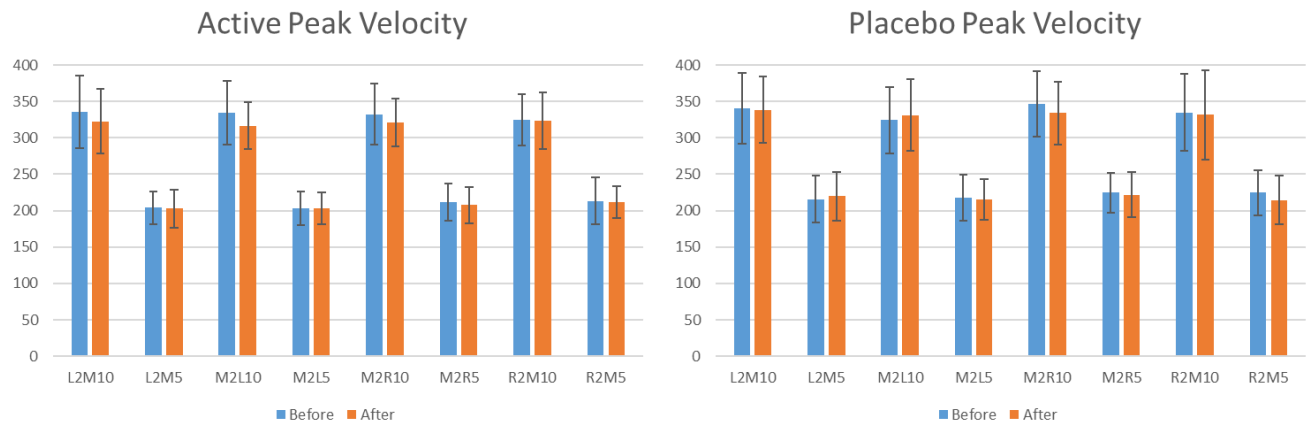

Figure C12 This figure shows the means and standard deviations for saccadic movements for both the active and placebo therapies.

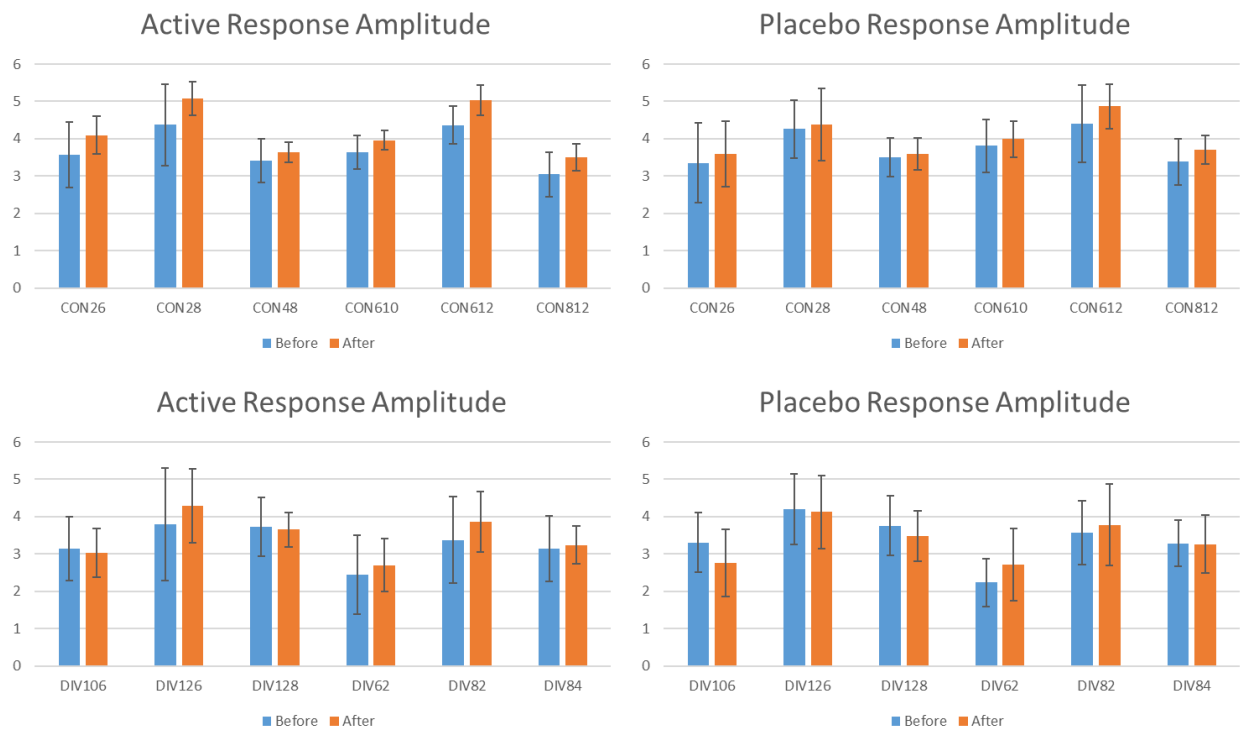

Figure C13 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

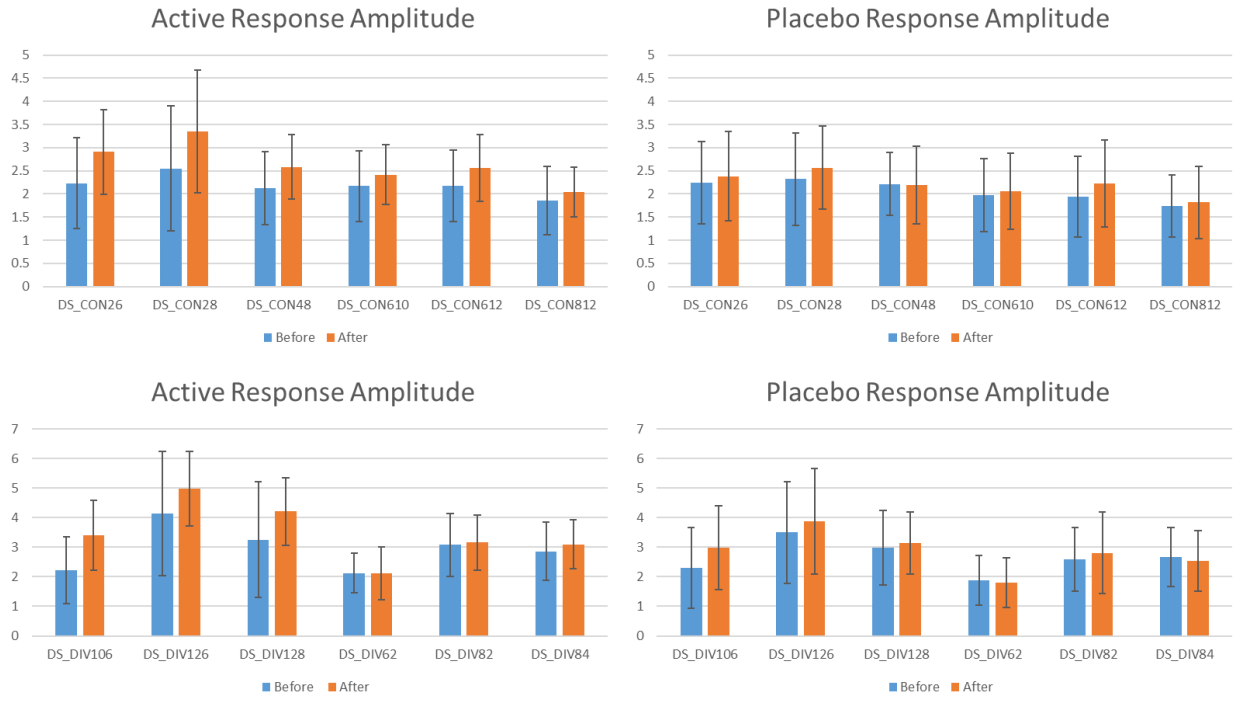

Figure C14 This figure shows the means and standard deviations for disappearing step convergence and disappearing step divergence movements for both the active and placebo therapies.

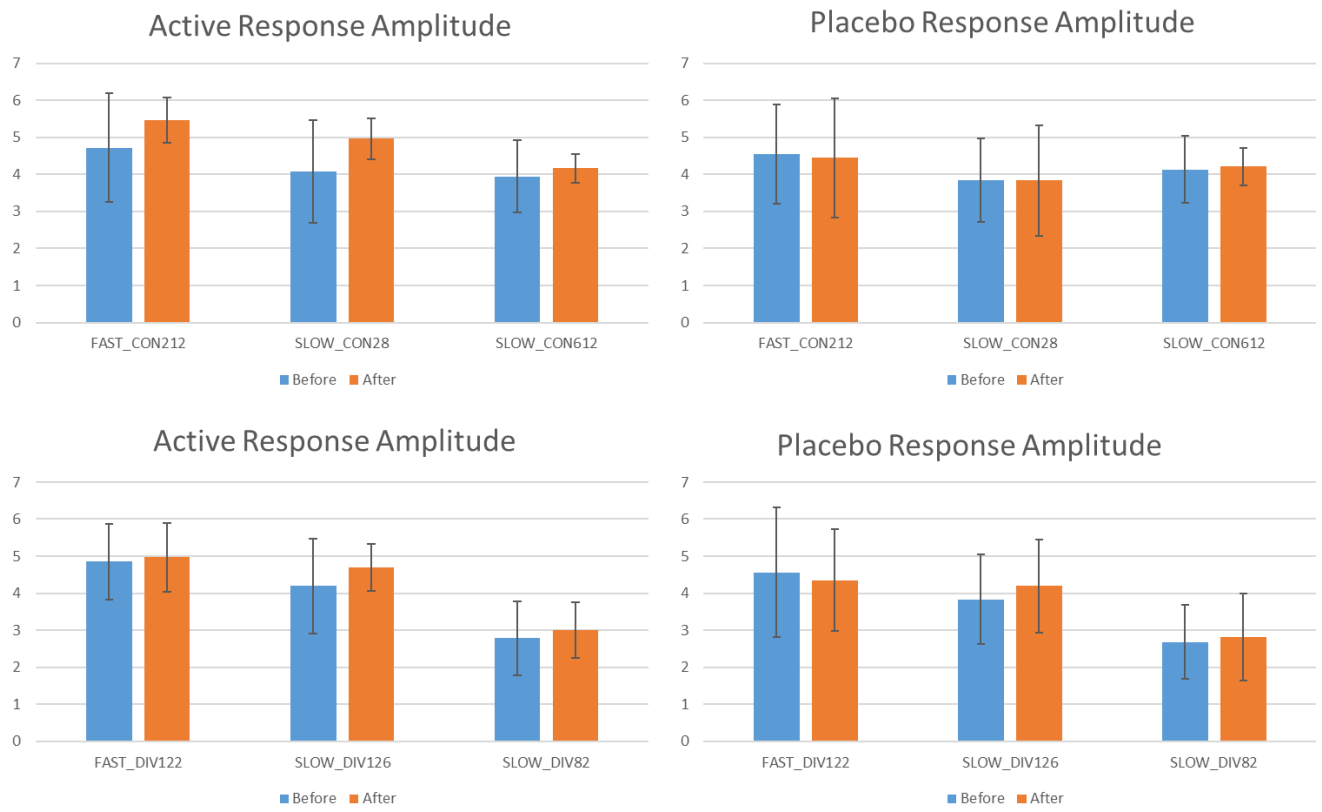

Figure C15 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

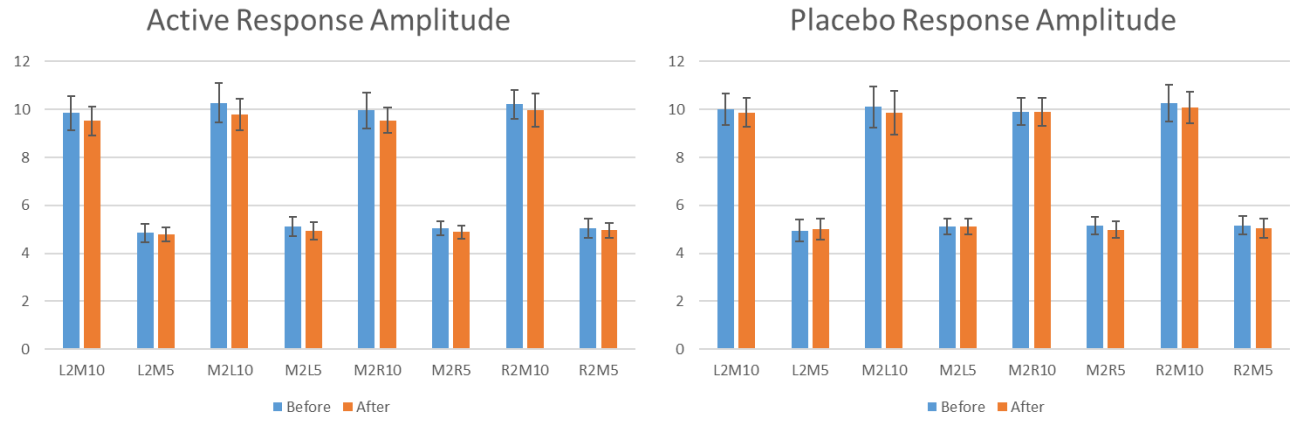

Figure C16 This figure shows the means and standard deviations for saccadic movements for both the active and placebo therapies.

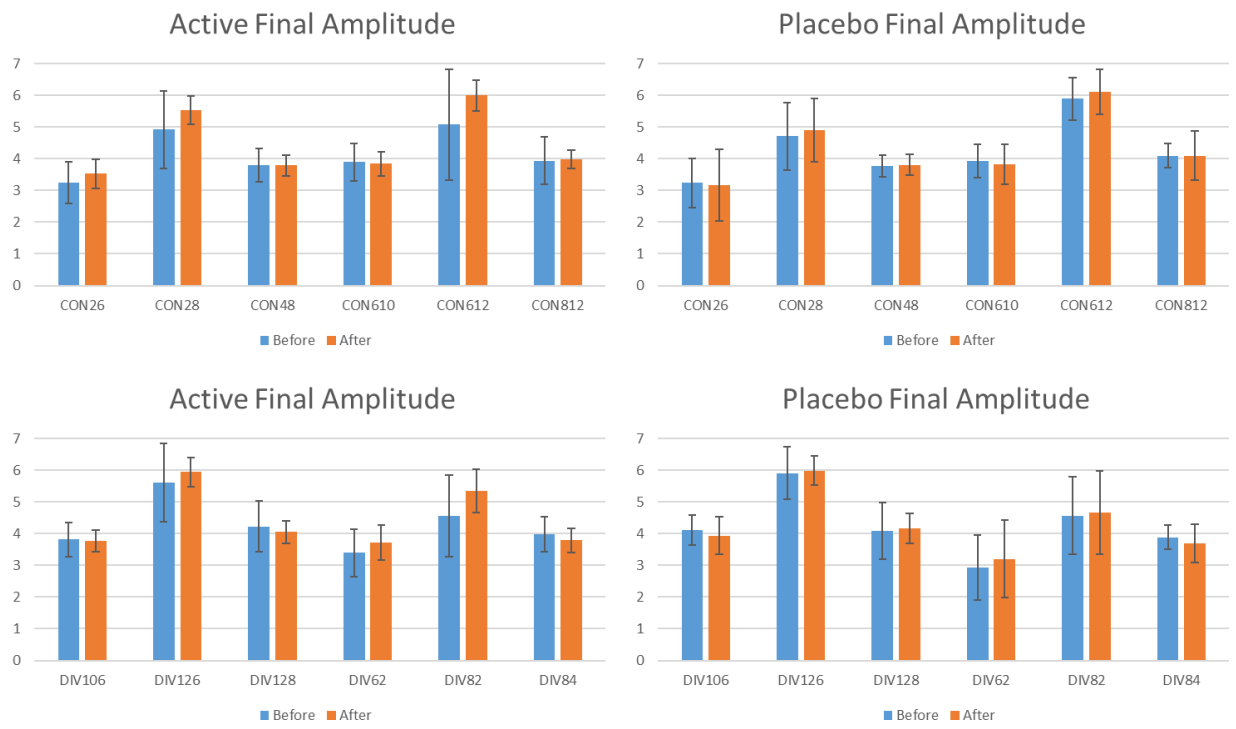

Figure C17 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

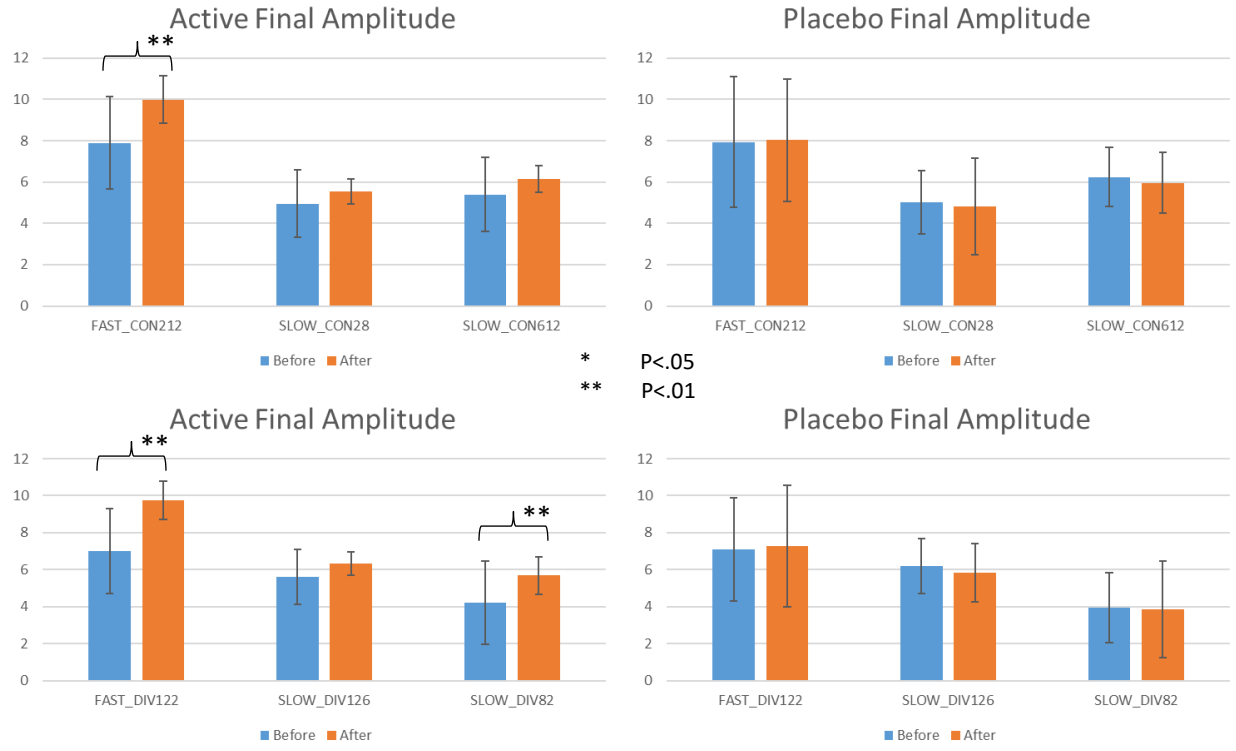

Figure C18 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

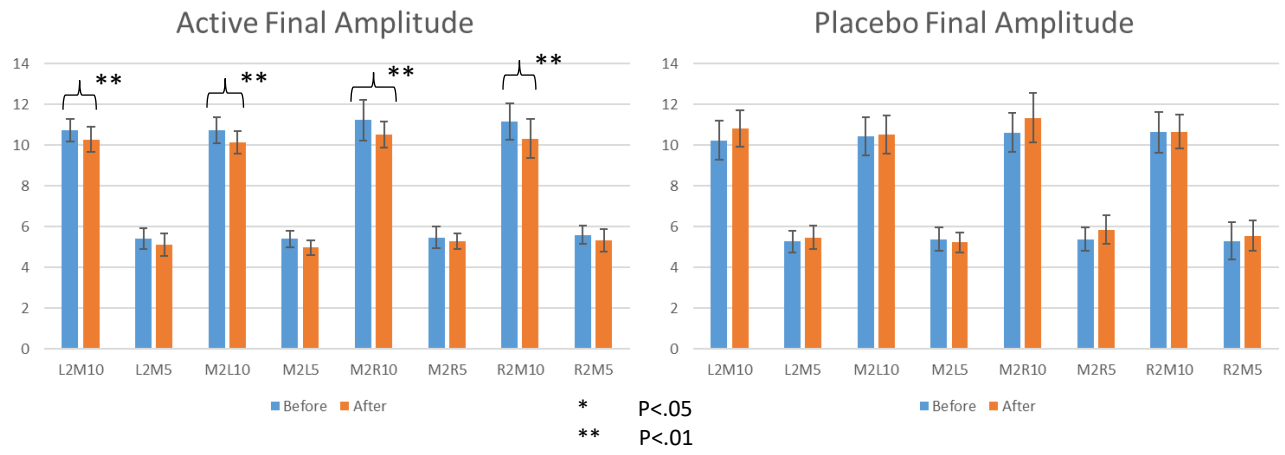

Figure C19 This figure shows the means and standard deviations for saccadic movements for both the active and placebo therapies.

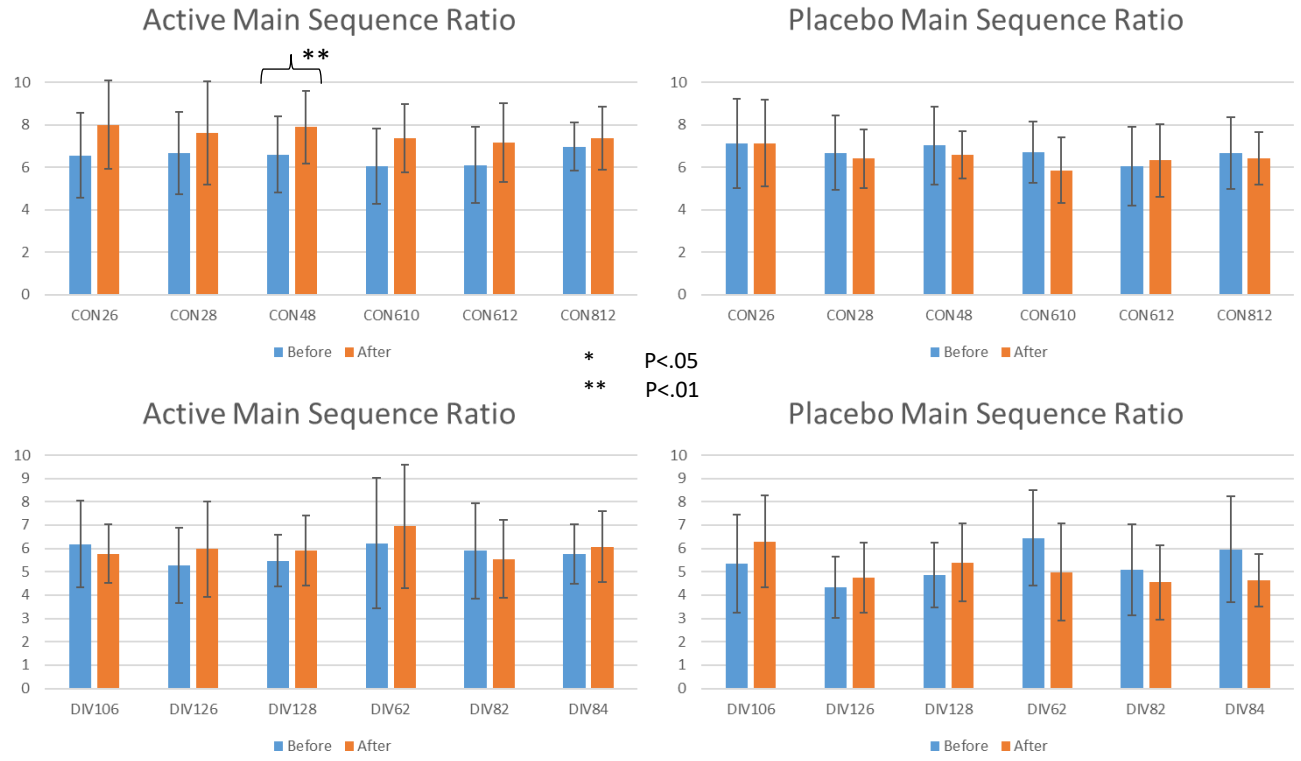

Figure C20 This figure shows the means and standard deviations for convergence and divergence movements for both the active and placebo therapies.

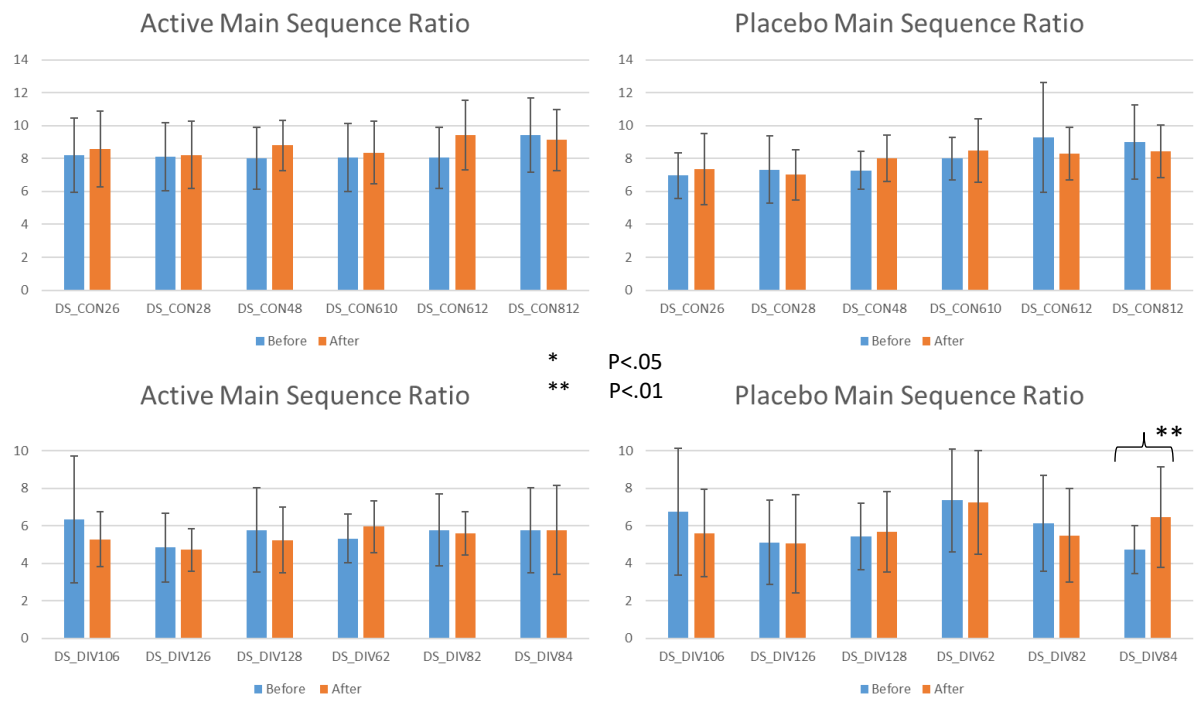

Figure C21 This figure shows the means and standard deviations for disappearing step convergence and disappearing step divergence movements for both the active and placebo therapies.

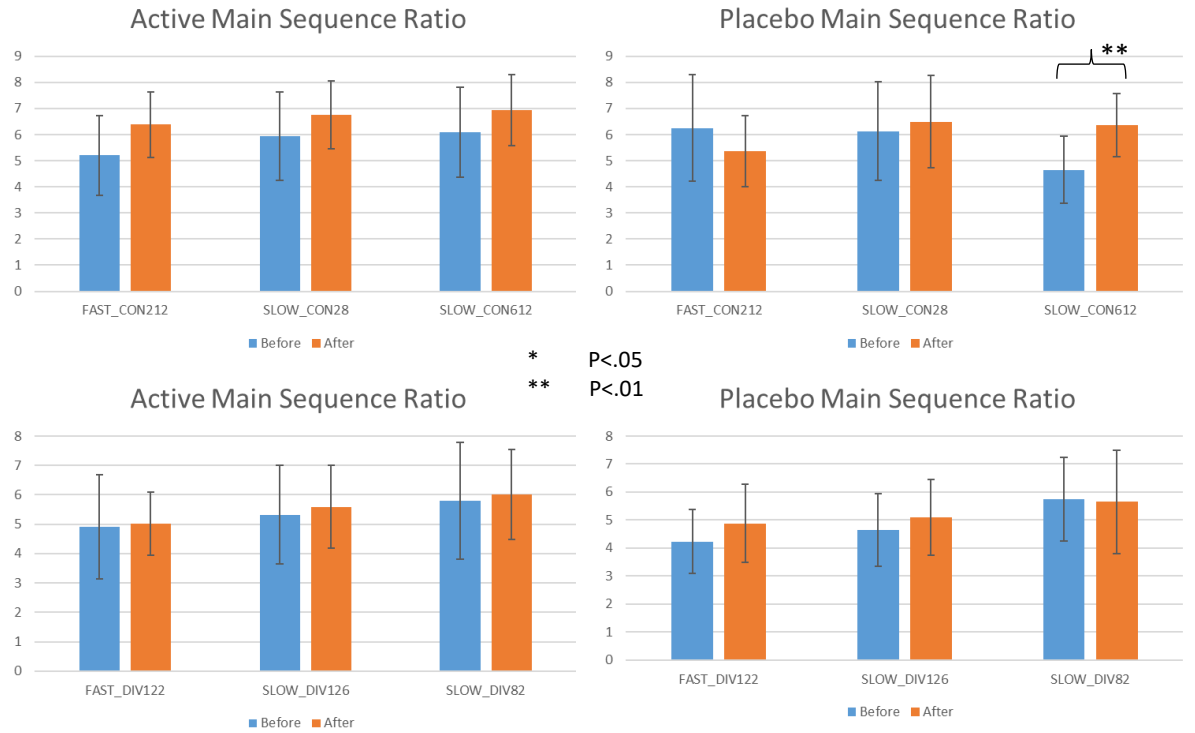

Figure C22 This figure shows the means and standard deviations for stepramp convergence and stepramp divergence movements for both the active and placebo therapies.

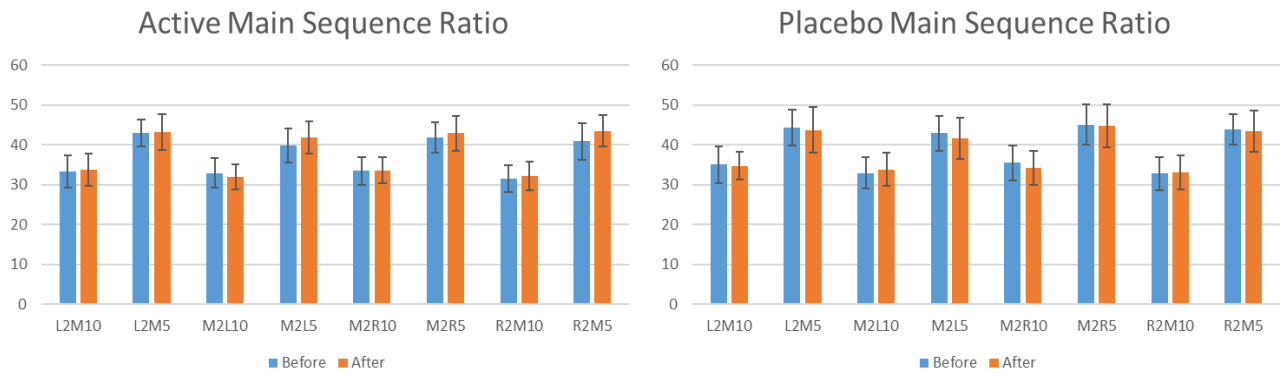

Figure C23 This figure shows the means and standard deviations for saccadic movements for both the active and placebo therapies.

APPENDIX D

CONVERGENCE INSUFFICIENCY SYMPTOM SURVEY

Convergence Insufficiency - Symptom Questionnaire V-15

Name _____ DATE __/__/__

Subject instructions: Please answer the following questions about how your eyes feel when reading or doing close work. Choose your response from the card that I have just handed you.

		Never	Infrequently	Sometimes	Fairly often	Always
1.	Do your eyes feel tired when reading or doing close work?					
2.	Do your eyes feel uncomfortable when reading or doing close work?					
3.	Do you have headaches when reading or doing close work?					
4.	Do you feel sleepy when reading or doing close work?					
5.	Do you lose concentration when reading or doing close work?					
6.	Do you have trouble remembering what you have read?					
7.	Do you have double vision when reading or doing close work?					
8.	Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?					
9.	Do you feel like you read slowly?					
10.	Do your eyes ever hurt when reading or doing close work?					
11.	Do your eyes ever feel sore when reading or doing close work?					
12.	Do you feel a "pulling" feeling around your eyes when reading or doing close work?					
13.	Do you notice the words blurring or coming in and out of focus when reading or doing close work?					
14.	Do you lose your place while reading or doing close work?					
15.	Do you have to re-read the same line of words when reading?					
	TOTAL Xs in each column	x 0	x 1	x 2	x 3	x 4

Score _____

Figure D1 Convergence Insufficiency Symptom Survey (CISS) used to determine subject use in study. The survey detects CI via the subject's symptoms. Scores below 10 indicate a binocularly normal subject.

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