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A literature review of three common balance tests: Electronystagmography, Rotary Chair Testing, and Computerized Dynamic Posturography

Marie Schmitt

A Literature Review of Three Common Balance Tests: Electronystagmography, Rotary Chair Testing, and Computerized Dynamic Posturography

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INTRODUCTION

Balance in humans is achieved through three sensory systems: the visual system, vestibular system, and the somatosensory system. Two of these three systems are needed for an individual to maintain balance effectively. If they do not contribute equally, over time the body may learn to compensate. When problems occur with balance there is a range of symptoms from slight unsteadiness to vertigo which leaves the patient bedridden.

Dizzy patients may present with auditory symptoms, including hearing loss (often fluctuating), tinnitus, or auditory fullness in one or both ears. Audiologist are frequently involved in the evaluation of dizzy patients. They often see the patient first for a comprehensive hearing evaluation and later in the vestibular lab. Full evaluation of a dizzy patient includes a medical history, physical exam, audiologic evaluation, vestibular testing, laboratory tests and radiographic testing. There are many causes of dizziness and the results of the audiologic evaluation and vestibular testing aid the physician in differential diagnosis and treatment.

There are three common balance function tests: Electronystagmography (ENG), Rotational Chair Testing (RCT), and Computerized Dynamic Posturography (CDP). This paper will discuss rationale, clinical applications, advantages and disadvantages for each of the tests. Electronystagmography will be covered in more detail due to its prevalence.

ELECTRONYSTAGMOGRAPHY

A discussion on ENG presupposes a basic knowledge of electro-oculography and types of eye movements.

Electro-oculography (EOG) is a technique used to record eye movements. Through the use of electrodes placed around the eyes, the electrical potential between the cornea (+) and the retina (-) of the eye can be measured and recorded. This potential is called the Corneoretinal Potential (CRP). EOG allows eye movements to be measured behind closed eyes. In 1939 Jung modified this technique to meet the specific needs of evaluating nystagmus and other eye movements elicited from vestibular stimulation. This new noninvasive procedure led to ENG as it is currently performed (Cyr&Harker, 1993).

There are three types of eye movements: smooth pursuit, saccadic and vestibular. ENG tests these eye movements, or oculomotor function. Several subtests of the ENG assess oculomotility independent of vestibular stimulation or influence. This provides a base of knowledge about the pathways which in turn provides for more accurate interpretation of results relating to vestibular function. Oculomotor tests also have a diagnostic value of their own. After an acute peripheral lesion or congenital nystagmus is ruled out, abnormal oculomotor function is often indicative of central nervous system(CNS) involvement. In this way, oculomotor tests provide valuable site-of-lesion information.

Smooth pursuit allows the eyes to follow a moving target by stabilizing its image on the fovea. Often saccadic eye movements are needed to bring the target back to the center of the fovea. In other words, the eye "catches up" with the target. Carl states that saccades rapidly change the direction of the eye to acquire the image of the object of interest (Jacobson, 1993). Therefore, the purpose of saccadic eye

movements is to shift gaze.

Vestibular eye movements stabilize images when the head is in motion, while walking or running for example. The vestibulo-ocular reflex or VOR mediates this process. It consists of a three neuron arc from the semicircular canal to the extra-ocular eye muscles. The VOR produces compensatory eye movements opposite the direction of acceleration. This means that if you are turning to the right, the VOR will cause your eye to shift to the left, thus stabilizing gaze. Sustained rotation will produce nystagmus.

Nystagmus is an involuntary rapid jerk-like movement of the eye (Webster, 1988). There are two phases of nystagmus. The slow phase refers to the compensatory eye movement. The fast phase refers to the rapid return of the eye to the center of the visual field. Nystagmus is named by its fast phase, i.e. the direction it "beats". Nystagmus may also occur in response to certain types of visual stimulation, or may represent some underlying pathologic condition.

The ENG test measures and records the eye movements discussed to determine if oculomotor function is within normal limits, to assess the integrity of the vestibular system, and to detect any other pathologic nystagmus or eye movements.

BATTERY

Pretest preparation is essential for accurate test results and patient comfort. Pretest preparation begins with patient preparation and may be accomplished by a list of pretest instructions concerning food consumption, medications, and proper attire (See Appendix A). It is recommended that no food or liquid be consumed for four hours prior to testing due to possible nausea during the caloric portion of the test. Also no caffeine, aspirin, or alcohol should be consumed for 48 hours prior to testing. The patient should

consult with their physician regarding medications. The clinician should be aware of any medications taken, such as barbiturates and anticonvulsants, which may cause a variety of abnormal eye movements, or antihistamines and tranquilizers, which may suppress nystagmus (Barber & Stockwell, 1980). It is important that the patient not wear contact lens during ENG, as they may cause a false positive failure of fixation suppression. It is important to ensure that the patient has complied with these instructions on the day of testing.

Pretest preparation continues with otoscopy. Otoscopy must be performed to evaluate the state of the external auditory canal, i.e. whether it is clear of foreign objects and cerumen plugs. Whether the ear canal is tortuous or abnormally shaped due to previous surgeries, must be considered in order to ensure adequate stimulation. It is extremely important to obtain tympanograms before testing. If a tympanic membrane perforation exists, then an air irrigator must be used to deliver the caloric stimulation.

The next step in pretest preparation is skin preparation and electrode placement. This topic is addressed in the instructional video.

Finally, direct observation of the patient's eye movements should be performed before beginning the test. If nystagmus is present it may be too small in amplitude to be recorded during testing. Nystagmus may be horizontal, vertical, or torsional. Torsional nystagmus is a rotational movement of the eye and is not detectable through EOG. The clinician is also observing if the eyes move smoothly and conjugately.

Once all pretest preparation has been completed the clinician turns the lights off and begins testing.

CALIBRATION. The test battery begins with calibration. The patients eyes are calibrated to lights on a light bar or spots on the wall. Calibration measures the potential

(CRP) generated for a given degree of eye movement, usually ten degrees to the left and right. This relationship is then the basis for measuring all eye movements throughout the test. Calibration is conducted several times throughout the test to account for the adaptation of the patient's eyes to the dark.

Before discussing the ENG battery, it is important to note that findings fall in three categories:

1. Peripheral vestibular dysfunction: Peripheral is defined as labyrinth or VIII nerve. ENG cannot discriminate labyrinth from eighth nerve lesions.
2. Central vestibular dysfunction: Central nervous system involvement.
3. Non-localizing: findings which are not necessarily central or peripheral in nature.

GAZE. Both the horizontal and vertical planes of gaze are assessed. Any type of nystagmus observed during gaze testing is considered abnormal. Once again nystagmus may be horizontal, vertical, or torsional. Nystagmus from acute peripheral lesions, endpoint nystagmus, congenital nystagmus, and nystagmus caused by pharmaceutical agents must be ruled out.

SPONTANEOUS NYSTAGMUS. The definition of spontaneous nystagmus differs depending on the source cited. The definition that suits the purpose of ENG is that preferred by Cyr and Coats which defines spontaneous nystagmus as "nystagmus that is present when eyes are closed and the patient is in the sitting position." The patient must be kept alert with mental tasks while the eyes are closed, or nystagmus may be suppressed. See appendix B for examples of tasking. The presence of spontaneous nystagmus supports the diagnosis of an acute peripheral lesion.

SMOOTH PURSUIT. For smooth pursuit testing, the patient is asked to follow a target that moves smoothly back and forth across the screen. The clinician makes a qualitative judgment about the smoothness of the recorded results. The gain of the

patient's eye movements is also assessed. Gain is defined as the ratio of eye speed to target speed. Saccadic breakup of smooth pursuit or low gain may suggest possible CNS involvement. The patient's age must be considered when evaluating gain because gain often decreases with age.

OPTOKINETIC. The stimulus for optokinetic testing consists of a series of stripes that passes in front of the patient. The patient is asked to follow each stripe as it passes through the center. For effective stimulation of the optokinetic system, the patient's entire visual field must be filled with the stimulus. Otherwise, it is the smooth pursuit system which responds to the stimulation. Decreased or asymmetric gain is indicative of CNS involvement.

RANDOM SACCADE. There are two types of stimuli available to assess Saccadic eye movements: fixed and random saccades. The random saccade stimulus jumps across the screen at random distances and latencies. For fixed saccade the stimulus jumps between two fixed points on the screen at regular intervals. The fixed stimulus is chosen for patients who have difficulty following the random stimulus. A caveat of using fixed stimulus is that the patient can predict the movement of the stimulus. This may result in artificially improved patient performance. Reduced eye speed , asymmetric latencies, increased delay, and poor accuracy are all indicative of CNS involvement.

DIX HALLPIKE. A questionable part of the ENG battery is the Dix Hallpike. Positioning testing or the Dix Hallpike maneuver consists of rapid manipulation of the patient by the clinician from a sitting position to a supine position with the head off the table and to the left. The procedure is then repeated to the right. Some patients may not be physically able to complete this portion of the testing due to back injuries or other orthopedic conditions. It is a recommended practice to inquire about such conditions

before attempting the Dix Hallpike to avoid harming the patient. Positioning testing has become an effective tool in detecting Benign Paroxysmal Positional Vertigo (BPPV).

Jacobson, Newman and Kartush (1993) define BPPV as "brief attacks of vertigo and nystagmus precipitated by a rapid head tilt toward the affected ear or by head extension." Findings indicating BPPV, or a positive Dix Hallpike, include "typical rotary-nystagmus that beats toward the undermost ear, has a latency of 1-3 seconds, a duration less than 1 minute, a reversal on righting, and fatigues with repetitive provocation" (Jacobson, Newman, & Kartush, 1993). The term fatigable refers to a significant decrease in the intensity of the response by the third elicitation (Coats, 1975). Patients with BPPV demonstrate a positive Dix Hallpike on the side of the undermost ear. Other vestibular function test results are most often normal.

There are aspects of the Dix Hallpike Maneuver that persist to be a topic of discussion. As stated previously, a positive finding includes fatigability. Due to Positional testing, which is discussed next, and other patient movements prior to the procedure, it is believed that the response may already be fatigued. It is recommended that the Dix Hallpike be performed at the very beginning of or separately from ENG testing. More importantly nystagmus induced by the Dix Hallpike maneuver is often torsional. Torsional eye movements, as previously stated, cannot be detected through electro-oculography. Because ENG is performed in the dark, it is virtually impossible to observe the nystagmus directly. Therefore it is difficult to objectively evaluate a response. To avoid this dilemma the clinician may observe the patient's eyes while he/she wears Frenzel glasses. These are 20 diopter lenses which illuminate the patient's eyes while reducing the patient's ability to fixate.

POSITIONAL. Static Position testing consists of placing the patient in various positions, such as supine, head right , and head left. In each position, the patient's eyes

are open briefly, and then closed for 30 seconds. The patient must be tasked when eyes are closed. The primary finding of this test is nystagmus.

Normal subjects do not have nystagmus with eyes open but may have it with eyes closed (Barber & Stockwell, 1980). Nystagmus may present in several patterns. Direction-fixed nystagmus is nystagmus that beats in the same direction regardless of head position and may be indicative of a peripheral lesion. Direction changing is nystagmus which changes directions within a single position, or between positions. In the latter case, nystagmus may beat toward the ground (geotropic), or toward the ceiling (ageotropic). Such a finding is abnormal and may denote central or peripheral vestibular involvement. Interpretation of positional nystagmus is complicated by several factors. The reader is referred to The Handbook of Balance Function Testing by Jacobson, Newman, & Kartush for more extensive treatment of this topic.

CALORICS. The caloric portion of the ENG is the most important subtest for examining vestibular function. Vestibular stimulation is achieved by alternately running cool and warm water or air into the external ear canal. This cools (or warms) the endolymph in the portion of the horizontal semi-circular canal closest to the tympanic membrane. Subsequently, the temperature change causes a change in density of the endolymph. A convection current sets the endolymph in motion. The hair cells in the ampullated end of the horizontal semi-circular canal are bent by the endolymph movement, triggering a decrease or increase in the resting firing rate of the vestibular nerve. Due to the VOR, the eyes move in the direction of the endolymph flow.

Cool water causes the endolymph to flow toward the ear being stimulated and thus the nystagmus beats toward the opposite ear. For example a cool irrigation in the right ear induces left-beating nystagmus. Warm water causes the endolymph to flow opposite the ear being stimulated and thus the nystagmus beats toward the irrigated ear.

Therefore a warm irrigation of the right ear induces right-beating nystagmus.

There are several types of stimulus delivery systems available. The open loop water irrigator introduces water directly into the ear canal through a nozzle. A closed loop water irrigator has a rubber balloon on the tip through which the water is continuously recirculated. The water pressure causes the balloon to fill the external auditory canal. The thermal transmission is then conducted from the balloon to the temporal bone. According to Karlsen, Mikhail, Norris, and Hassanein (1992) "the closed loop system yielded responses that were approximately half those of the open-water loop." Air irrigators direct warm and cool air at the tympanic membrane. They have several advantages over the water irrigators. The air irrigators are less messy, safer, and can be used when water is contraindicated, as in cases of eardrum perforations. There are arguments for and against each type of irrigator.

The caloric portion of the ENG is the only vestibular test that stimulates each labyrinth separately. Normally, the vestibular systems have essentially equal responses. A unilateral weakness or significantly reduced vestibular response on one side compared to the other, indicates a peripheral vestibular lesion in the ear stimulated. Unfortunately, it is possible that a lesion may exist even though the ENG battery results are normal, as the calorics only stimulate the horizontal semi-circular canal. See Appendix C for normal ENG results.

CLINICAL APPLICATIONS

ENG is used to evaluate dizzy patients with a variety of underlying causes. As stated previously, there are existing relationships between specific ENG findings and certain medical conditions. This relationship is most clearly defined with acoustic tumors, BPPV, Meniere's disease, and vestibular neuronitis.

Acoustic tumors are also called Vestibular Schwannomas due to their origin in the

schwan cells of the vestibular portion of the VIII nerve. Therefore, the first indications of a tumor may be detected through vestibular testing. The ENG results of a patient with an acoustic tumor on the right, for example, would demonstrate no caloric responsiveness or a unilateral weakness for the right caloric irrigations (Jacobson, 1993). Bilateral acoustic tumors would be demonstrated by bilateral weakness. However, the best test for the differential diagnosis of acoustic tumors remains magnetic resonance imaging.

As indicated earlier (BPPV) is most often detected through the Dix Hallpike procedure. Other ENG results are usually normal for a patient with BPPV.

Meniere's disease is characterized by fluctuating sensorineural hearing loss, tinnitus, aural fullness, and vertigo. In a study of 610 patients with Meniere's disease, it was reported that a unilateral weakness occurred in 60-74% of the cases (Jacobson, Newman & Kartush, 1993). However, results vary depending on the stage of the disease.

According to Jacobson "vestibular neuronitis is a disease typified by a single attack of vertigo that may last for days or weeks" (Jacobson, Newman & Kartush, 1993). These patients do not report any hearing loss, tinnitus or other audiologic problems. Their caloric responses are similar to those of an acoustic neuroma. There is a total lack of response or a significant unilateral weakness on the involved side. An ipsilateral unilateral weakness has been reported in 97-100% of the cases (Jacobson, Newman & Kartush, 1993). An additional finding in these patient's would be spontaneous nystagmus that beats away from the involved side.

Unfortunately it is not possible to differentiate acoustic neuromas from vestibular neuronitis on the basis of ENG findings alone. A definitive diagnosis for the dizzy patient must be determined by a physician. Barber and Stockwell (1980) state "the results of

ENG tests are meaningful only after consideration by a physician in relation to the patient's history and other test results."

ADVANTAGES/DISADVANTAGES

The main advantage of the ENG battery is the ability to directly stimulate each labyrinth individually. This offers specific information concerning the function of the right versus the left side, which in turn provides valuable information for the physician in diagnosing the cause of dizziness and in determining surgical candidacy. Another advantage is the relatively low cost of the equipment.

Despite the popularity of ENG as a vestibular function test, there are several disadvantages :

1. The caloric stimulus is non-physiologic and is low in frequency; it is not representative of the normal operating frequencies of the vestibular system in every-day tasks.
2. Only a portion of the vestibular system is evaluated
3. The response may be effected by external factors such as ear canal size and shape
4. The patient must be alert throughout the test or the resultant data will be skewed. The task of maintaining alertness is difficult due to the dark and quiet room.
5. The response may be dependent on whether the patient is symptomatic at the time of testing.
6. ENG cannot be performed on a blind patient.
7. Patient discomfort due to dizziness during the caloric test, although unpredictable may be intense.
8. ENG is insensitive to subtle changes in the vestibular system.
9. ENG procedures are not standardized.
10. There is highly variable training of examiners.

Due to these factors, test/retest reliability of ENG testing is poor (Cyr & Harker, 1992). The advent of computers in ENG testing has improved this situation somewhat with computer regulation of stimuli and data collection. However, there is no way to account for differences in test interpretation by clinicians of varying levels of training and experience.

ROTARY CHAIR TESTING

Rotational Chair Testing (RCT) has existed since the turn of the century. It has gained recent popularity due to computer control of chair rotation. RCT tests the VOR by rotating a seated patient in the dark. As the patient is rotated to the left the eyes will reflexively move to the right and then saccade to the left. With sustained rotation, left-beating nystagmus results. There are three primary aspects of eye movement assessed during RCT:

1. **Gain** is the ratio of maximum eye velocity to maximum head velocity. Head velocity essentially equals chair velocity except for slippage. The theoretical gain value equals one. That is, the compensatory eye movement velocity is equal and opposite to the head/chair movement velocity (Cyr, 1993). In actuality the gain is less due to the fact that at "lower head velocities, the compensatory eye movement gain is generally less." Gain appears to be most affected by the patient's state of mental alertness. Abnormally low gain may be indicative of a pathologic condition. Additionally, gain decreases with age.

2. **Phase** is the temporal relationship between changes in eye velocity and changes in head velocity. A phase lead is considered abnormal. Phase lead is defined as changes in slow phase eye velocity which occur in advance of head velocity (Stockwell & Bojrab, 1993).

3. **Symmetry** is the peak slow phase eye velocity of the eye movements to the right versus the left. Symmetry does not indicate side of lesion (Cyr, 1993).

BATTERY

Sinusoidal Harmonic Acceleration (SHA) is currently the most frequently used type of rotation. The patient is rotated sinusoidally at frequencies ranging from 0.01Hz to 1.28Hz. The interaction of visual and vestibular systems or the visual-vestibulo-ocular reflex (VVOR) can be tested by supplementing the vestibular stimulation with visual information from stripes projected on the wall surrounding the patient. The patient is once again rotated sinusoidally. VVOR may be accidentally tested during VOR testing

if the door to the test booth is not completely shut, allowing light into the booth. The light will give the patient a reference while being rotated, therefore testing the VVOR as opposed to the VOR. See Appendix D for an example of normal RCT results.

CLINICAL APPLICATIONS

RCT examines the vestibular system over several frequencies in a short period of time, with little patient discomfort, and requiring minimal patient cooperation. For these reasons, it is effective in testing a wider range of patients, including children. Due to its sensitivity to subtle vestibular changes RCT is ideal for monitoring the effects of vestibulotoxic drug therapy. As the damaging effects of the drugs increase, gain decreases. Finally, while it is tempting to believe that a patient with absent vestibular responses upon caloric testing has no vestibular function, this is not necessarily the case. ENG only tests the response of the vestibular system to very low frequency stimulation. These patients may have normal gain in the higher frequencies of Sinusoidal Harmonic Acceleration, indicating that the VOR is intact.

ADVANTAGES/DISADVANTAGES

In addition to the above advantages, there is better control of stimulus and test protocol with RCT as compared to ENG. Unfortunately equipment costs for rotary chair are high. The frequencies assessed through RCT though higher than those assessed during ENG are not indicative of frequencies encountered by the vestibular system in normal activities such as walking and running (about 5-6Hz). RCT also stimulates both vestibular systems simultaneously, making it impossible to lateralize a lesion to the left or right side.

COMPUTERIZED DYNAMIC POSTUROGRAPHY

Computerized Dynamic Posturography (CDP) is a "global" balance test as opposed to a true vestibular test. It is a test of balance function rather than a site-of-lesion test. Although CDP can never be used alone for diagnostic purposes it provides additional information regarding the nature and extent of a patient's disequilibrium and possible avenues of rehabilitation.

BATTERY

There is little patient preparation for posturography. The medication instructions for ENG apply to CDP.

Sensory Organization Test (SOT)

The SOT consists of six conditions which challenge the visual, vestibular, and somatosensory systems and evaluate their individual contributions to imbalance. Results of this sensory analysis are plotted for each condition as they compare to norms for the patient's age and height. The patient's center of gravity (COG) is also reported to determine the patient's alignment and their internal perception of "vertical". Strategy analysis assesses the patient's use of hip and ankle movements to restore the COG to its resting position during anterior and posterior sway.

Motor Coordination Test (MCT)

MCT evaluates the patient's compensation strategies for sudden forward and backward translations of the platform. Specifically, MCT measures the latencies of the patient's initial compensatory movement. Abnormalities may indicate motor system abnormalities due to CNS deficits or early demylinating diseases (Nasher, 1994).

Adaptation (ADT)

The adaptation test tilts the patient's toes up five times in a row and down five times. ADT evaluates the patient's adaptation skills. A normal patient demonstrates improvement or consistency with each trial. See Appendix E for normal CDP results.

CLINICAL APPLICATIONS

CDP along with vestibular tests, such as ENG and RCT, can aid in differential diagnosis. CDP can verify whether a peripheral lesion is compensated. If other vestibular tests indicate a peripheral lesion, CDP results will be normal for a compensated lesion or indicate a vestibular pattern for an uncompensated lesion. A vestibular pattern of CDP may indicate CNS involvement if results of other vestibular tests are either normal or indicative of CNS involvement.

ADVANTAGES/DISADVANTAGES

CDP offers an expanded view of balance dysfunction. The conditions of the SOT represent challenges faced daily by patients, such as uneven surfaces and confusing visual cues. By identifying detrimental balance strategies, rehabilitation goals for better stability can be set and monitored through CDP.

CDP is a an excellent test for indicating non-organicity. For a discussion of this application of CDP, the reader is referred to the EquiTest System Version 4.0 Data Interpretation Manual.

There are several disadvantages of CDP:

1. There are machinery limits, such as weight(300lbs.).
2. CDP does not lateralize findings.
3. CDP cannot be used alone.
4. CDP is a test of functioning level, not physiologic status.
5. Test results are dependent on patient cooperation.

6. Compensated lesions are not detectable.
7. The patient's balance problems must be active at the time of testing for data to indicate a dysfunction.
8. The patient must be able to stand unassisted for at least three minutes at a time.

CONCLUSION

There are three primary goals of the balance system : to maintain a center of gravity, provide accurate proprioception, and to control eye movements in order to maintain a clear visual image while in motion. Through the use of ENG, RCT, and CDP the ability of the balance system to achieve these goals can be evaluated.

APPENDIX A

Balance Assessment Instructions

To achieve the best test results, please follow these instructions:

1. Remove contact lenses before exam.
2. Face should be washed thoroughly. Creams, lotions, and makeup should NOT be used.
3. No foods or liquids for 4 hours before the test.
4. Meals between 5 and 8 hours before the test should be minimal.
5. No coffee, tea, or cola after midnight of the evening before the test.
6. No aspirin or medication containing aspirin for 2 days before the test.
7. Avoid alcoholic beverages and medications containing alcohol for 48 hours prior to the test.
8. The following medications should be avoided for 48 hours prior to the test: allergy pills, diet pills, sleeping pills, tranquilizers, decongestants, and dizziness medication. If you have any questions about stopping these medicines, please consult your physician.
9. Continue to take medication for your heart, blood pressure, diabetes, or any other medical condition.
10. Do not wear high heels, skirts, or dresses to the test.
11. If you have any questions regarding medications, contact your physician immediately.

CAUTION: It may be unsafe to drive a motor vehicle immediately following the test and we do recommend that you arrange transportation with another driver for that day.

YOUR COOPERATION IN FOLLOWING THESE INSTRUCTIONS WILL ENSURE RELIABLE TEST RESULTS AND REDUCE THE LIKELIHOOD OF REPEAT TESTING.

I have read the above, understand it, and my questions (if any) have been answered. I elect to have the test performed.

_____ _____

Date Patient's Signature

Excerpt from St. Louis University Medical Center Balance Assessment Instruction and consent form. (1994)

APPENDIX B

Tasking

Count by 2s
Count by 3s

Tell me a man's name that begins with the letter A....Z
Tell Me a woman's name that begins with he letter A...Z

Tell me three...

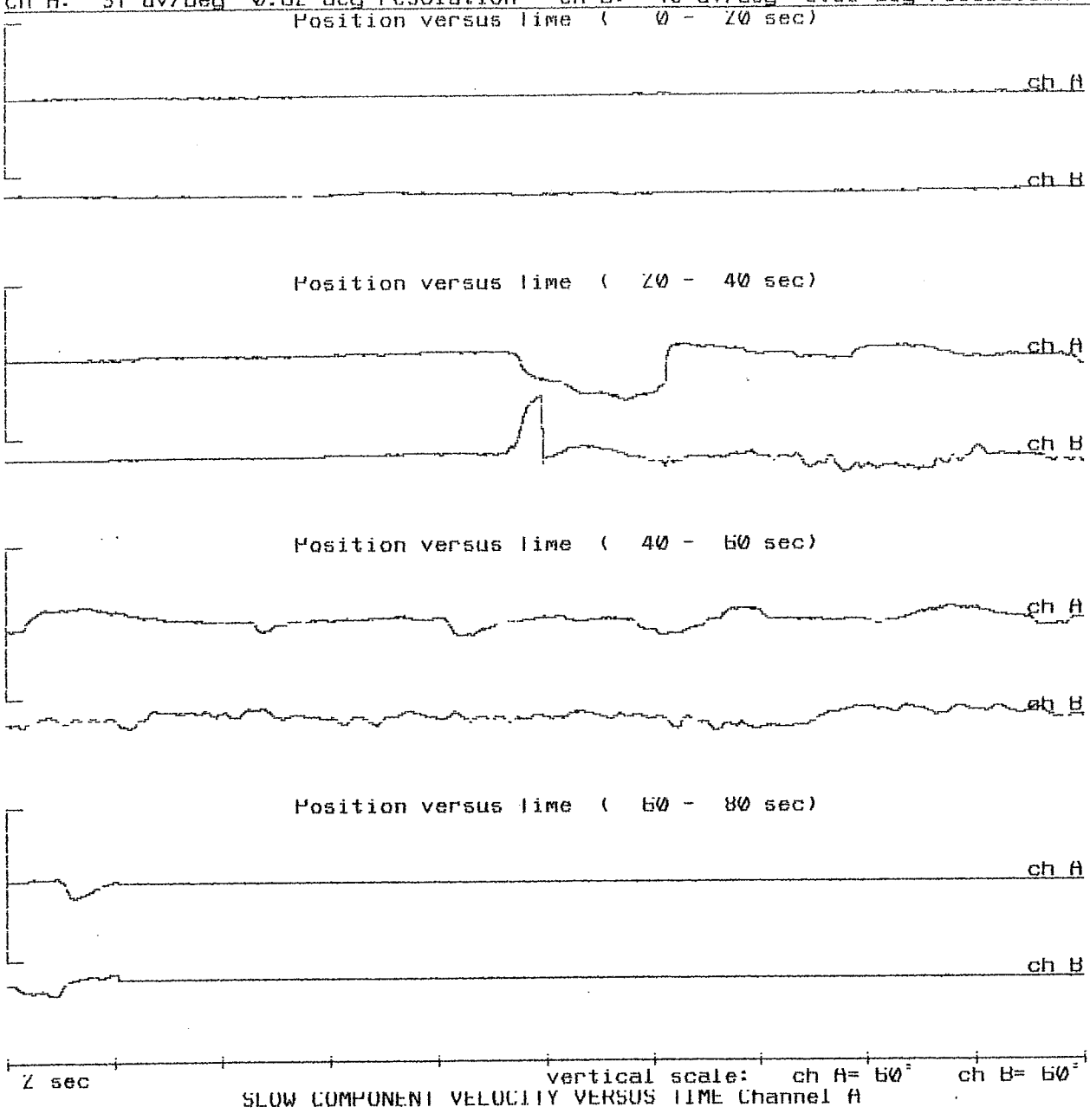
- -flavors of ice cream
- -toppings for ice cream
- -toppings on a pizza
- -basketball teams
- -baseball teams
- -football teams
- -hockey teams
- -makes of cars
- -states that begin with m, w, n...
- -of your favorite magazines
- -books you have read
- -vacation spots
- -cities in California
- -cities in Florida
- -types of flowers
- -types of trees
- -of your hobbies
- -types of birds
- -of your favorite holidays

APPENDIX C

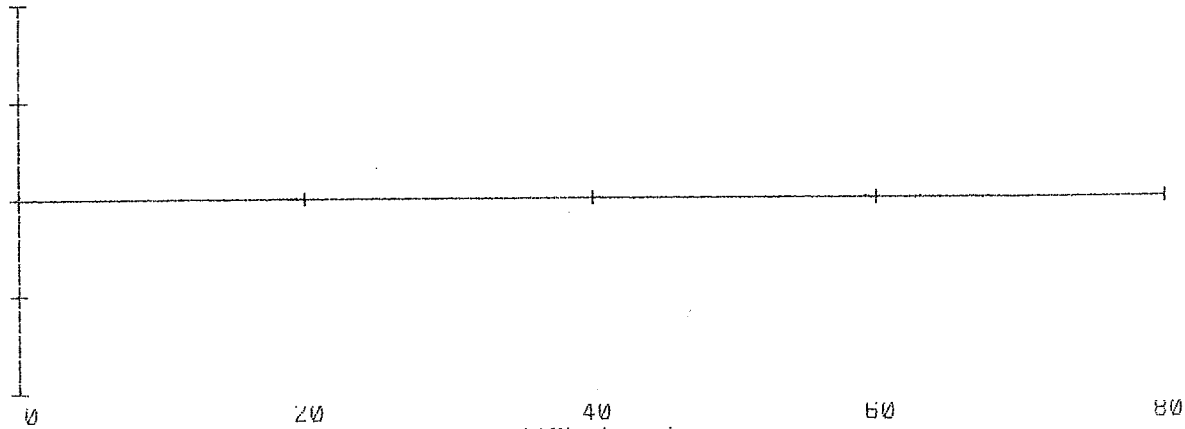
Name: APPENDIX
Age : 23
Sex : f
ID :

Date: 18 March 1995 10:16:21
Test: GAZE EVOKED NYSTAGMUS
Stim: Horizontal, 30 degrees

Ch A: 31 uV/deg 0.62 deg resolution Ch B: 40 uV/deg 9.99 deg resolution



SLOW COMPONENT VELOCITY VERSUS TIME Channel A



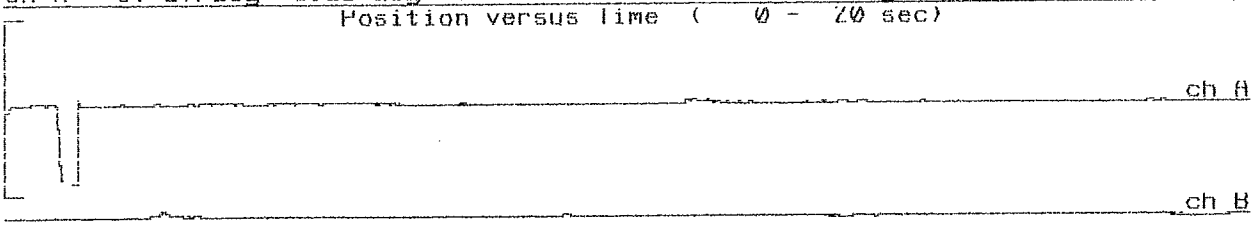
ArtRej= 18 MinAmp= 1

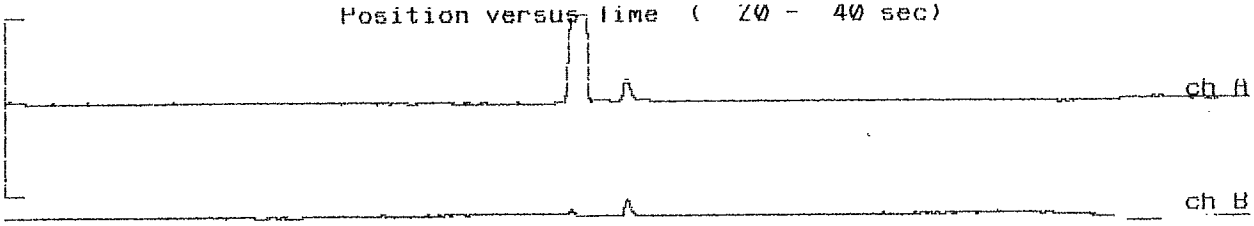
Lft/Dn Beat: Vmax= 0°/s @ 0 s Vmean= 0°/s F= 0.0 beats/s N= 0
Rht/Up Beat: Vmax= 0°/s @ 0 s Vmean= 0°/s F= 0.0 beats/s N= 0

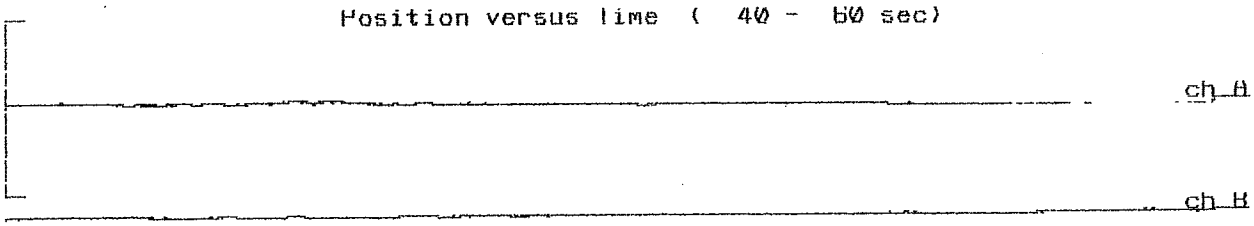
Name: APPENDIX
Age : 23
Sex : F
ID :

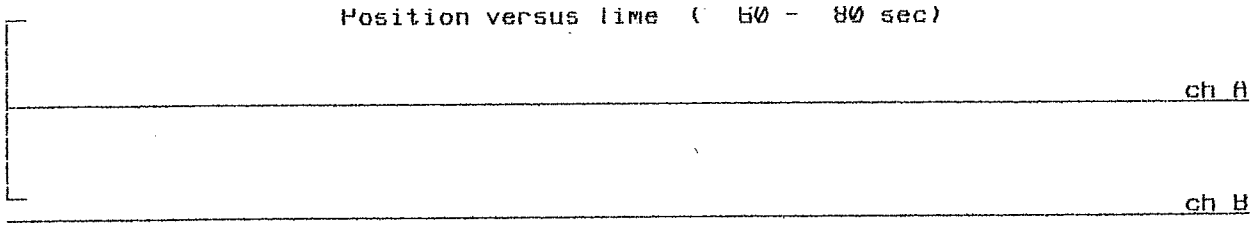
Date: 18 March 1995 10:18:05
Test: GAZE EVOKED NYSTAGMUS
Stim: Horizontal, 30 degrees

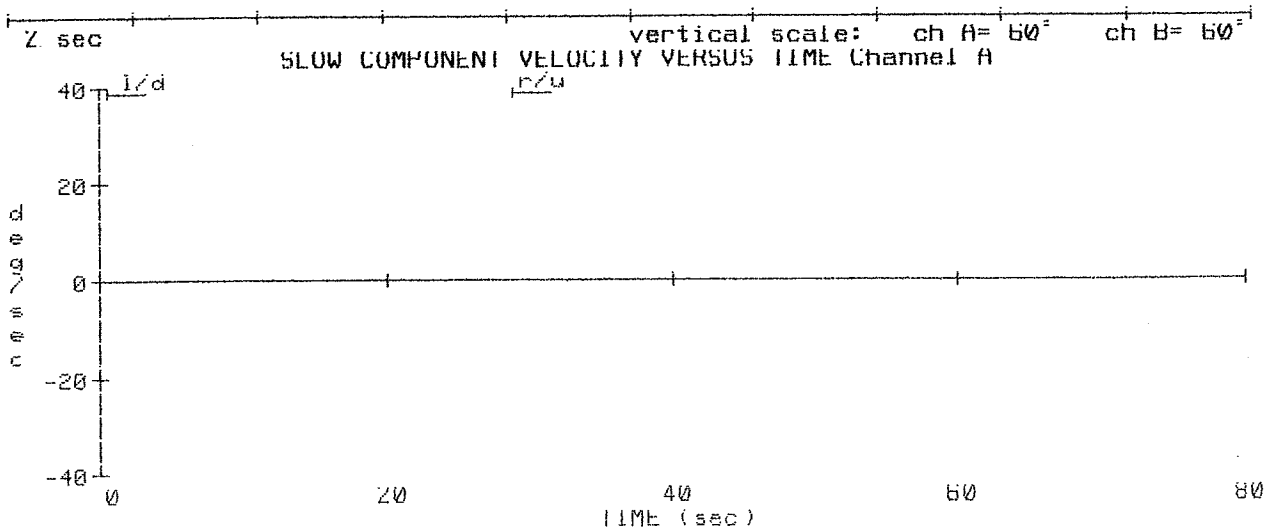
Ch A: 31 uV/deg 0.62 deg resolution Ch B: 40 uV/deg 9.99 deg resolution











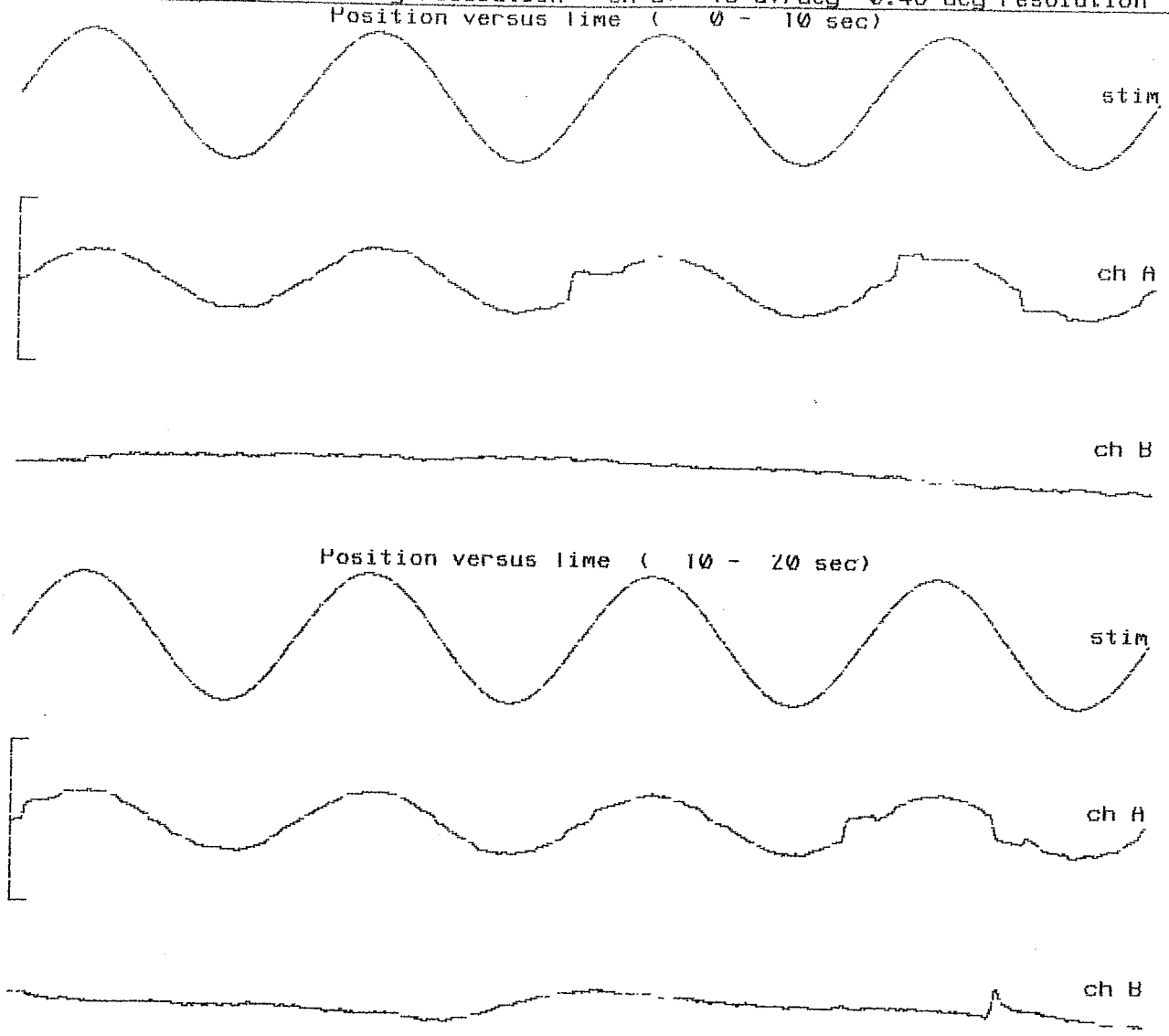
ArtRej= 18 MinAmp= 1

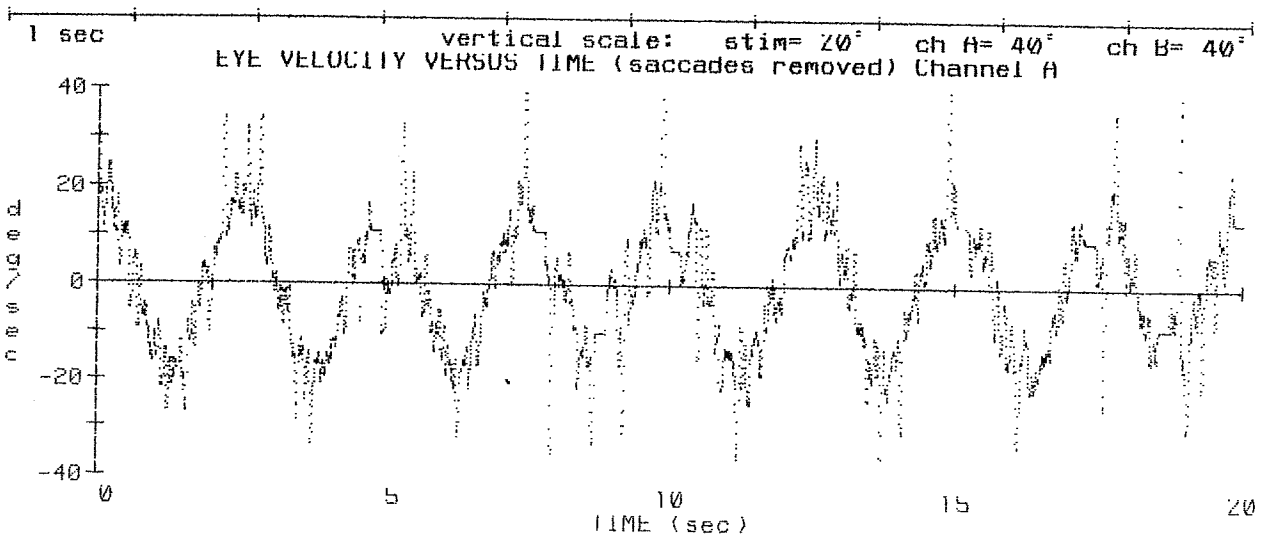
Lft/Dn Beat: Vmax= 0°/s @ 0 s Vmean= 0°/s F= 0.0 beats/s N= 0
Rht/Up Beat: Vmax= 0°/s @ 0 s Vmean= 0°/s F= 0.0 beats/s N= 0

Name: APPENDIX
Age : 23
Sex : f
ID :

Date: 18 March 1995 10:21:05
Test: HORIZONTAL SMOOTH PURSUIT
Stim: 0.4 Hz (sine) Amp= 8 deg
Peak velocity=20 deg/sec

Ch A: 31 uV/deg 0.62 deg resolution Ch B: 16 uV/deg 0.48 deg resolution

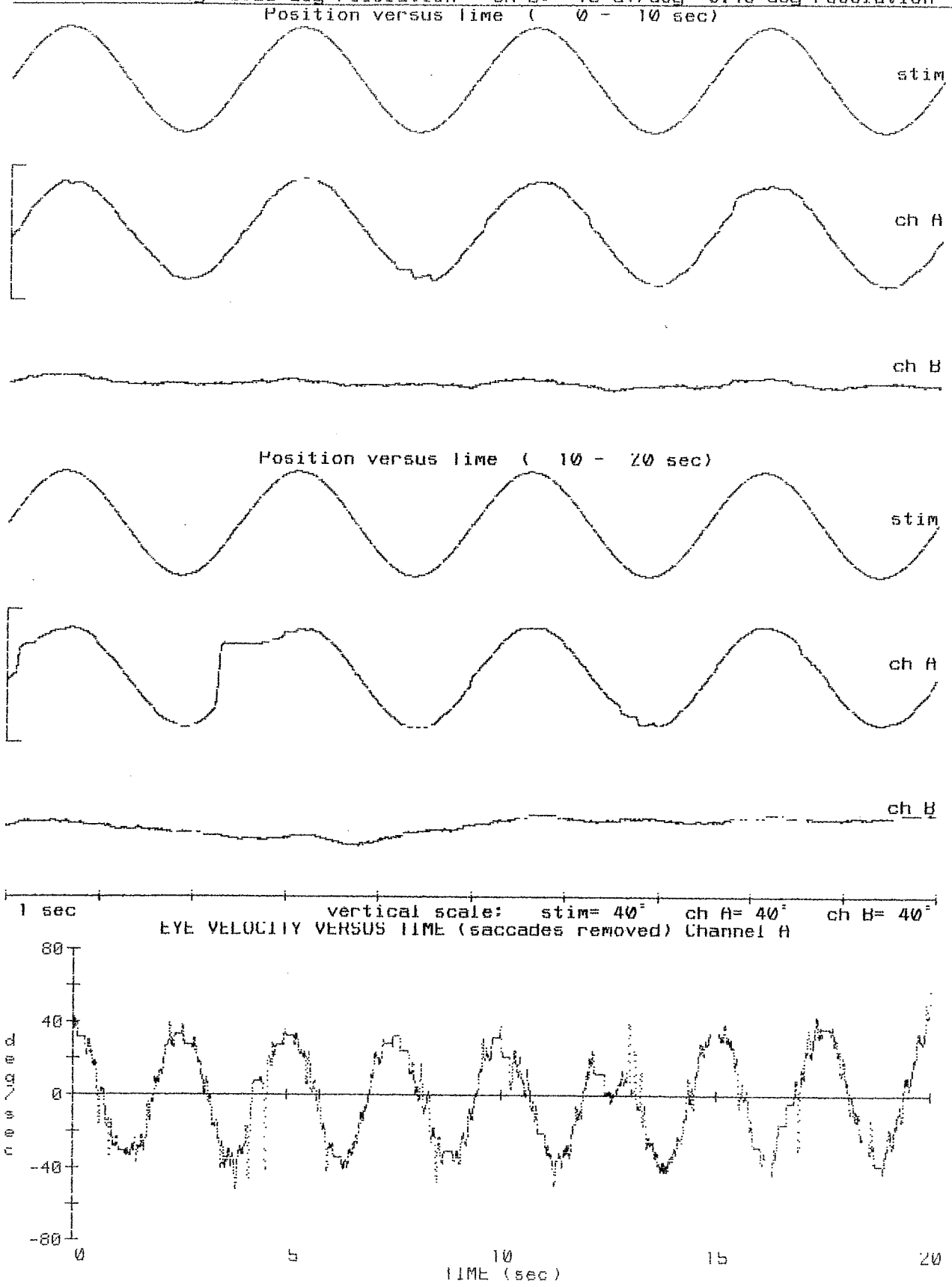




MAGNITUDE= 16.19°/s DC OFFSET= -0.48°/s RHT/UP SACCADES: N= 6
GAIN = 0.80 THD = 18% LFT/DN SACCADES: N= 2

Name: APPENDIX
Age : 23
Sex : f
ID :
Ch A: 31 uV/deg 0.62 deg resolution

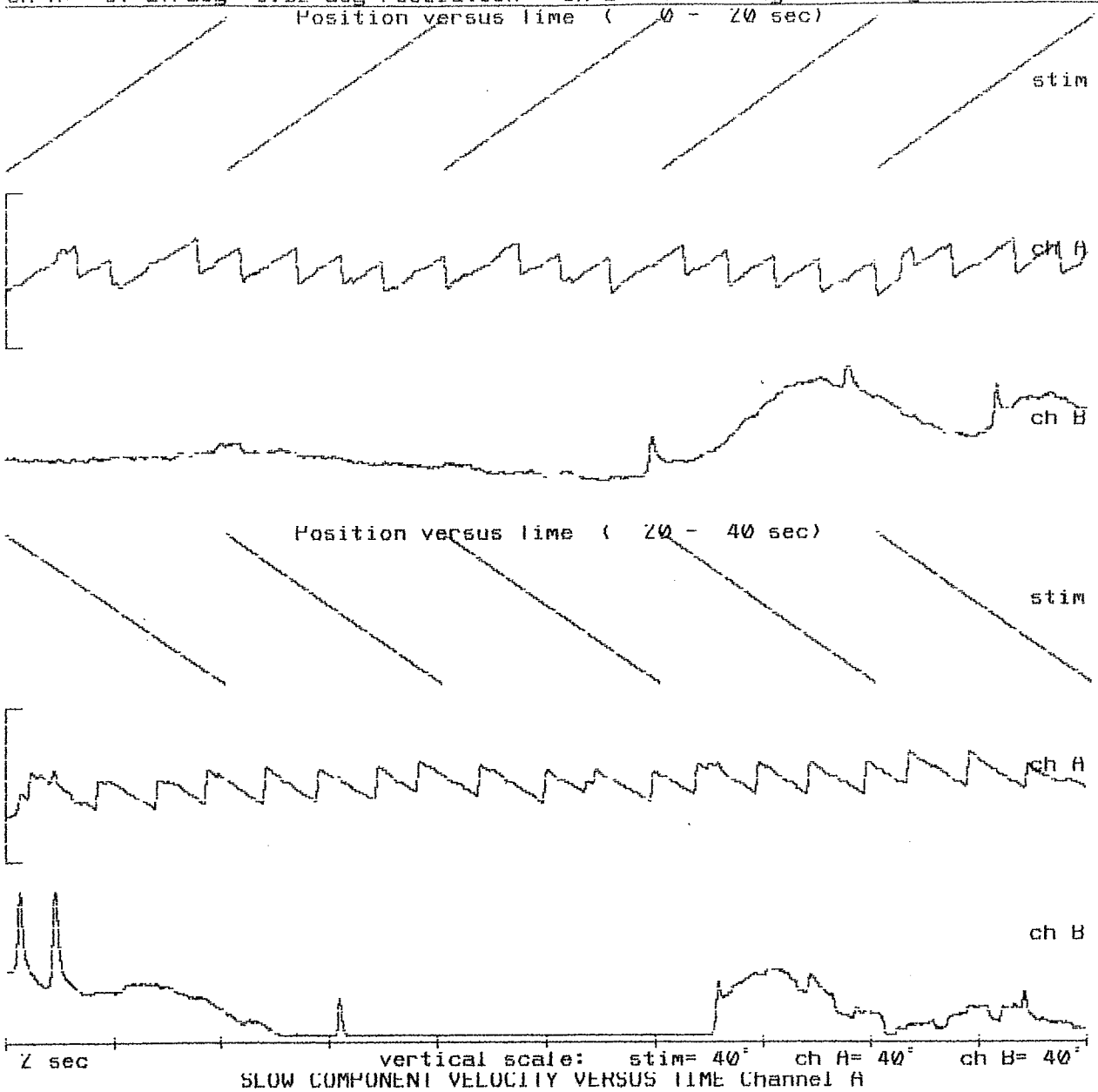
Date: 18 March 1995 10:22:25
Test: HORIZONTAL SMOOTH PURSUIT
Stim: 0.4 Hz (sine) Amp=16 deg
Peak velocity=40 deg/sec
Ch B: 16 uV/deg 0.48 deg resolution

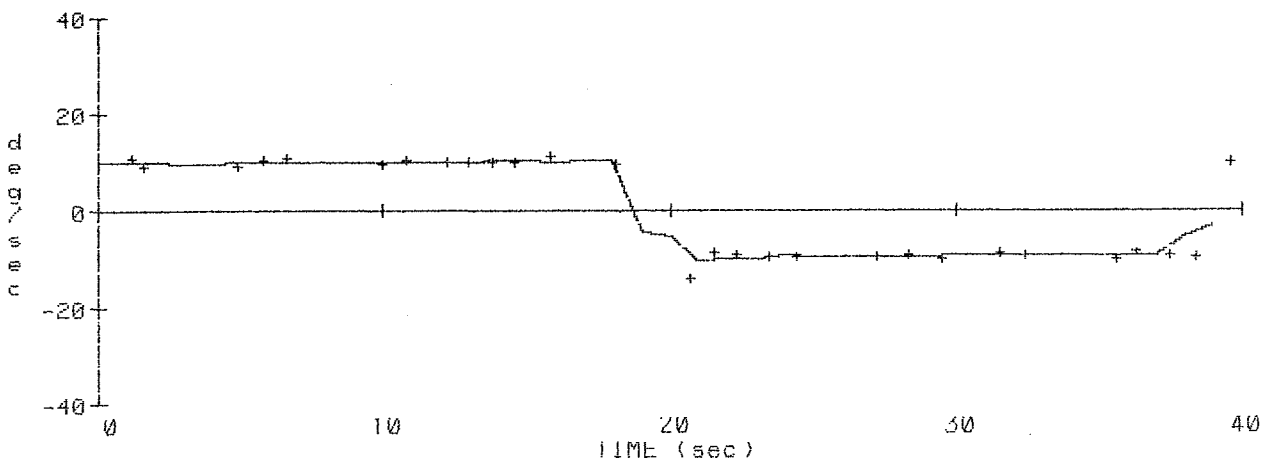


MAGNITUDE= 33.09°/s DC OFFSET= -1.32°/s RHT/UP SACCADES: N= 13
GAIN = 0.82 THD = 13% LFT/DN SACCADES: N= 11

Name: APPENDIX
Age : 23
Sex : F
ID :
Ch A: 31 uV/deg 0.6Z deg resolution

Date: 18 March 1995 10:23:56
Test: OPTOKINETIC NYSTAGMUS
Stim: Horiz bi-dir 10 deg/sec
10.24 deg target spacing
Ch B: 16 uV/deg 0.48 deg resolution



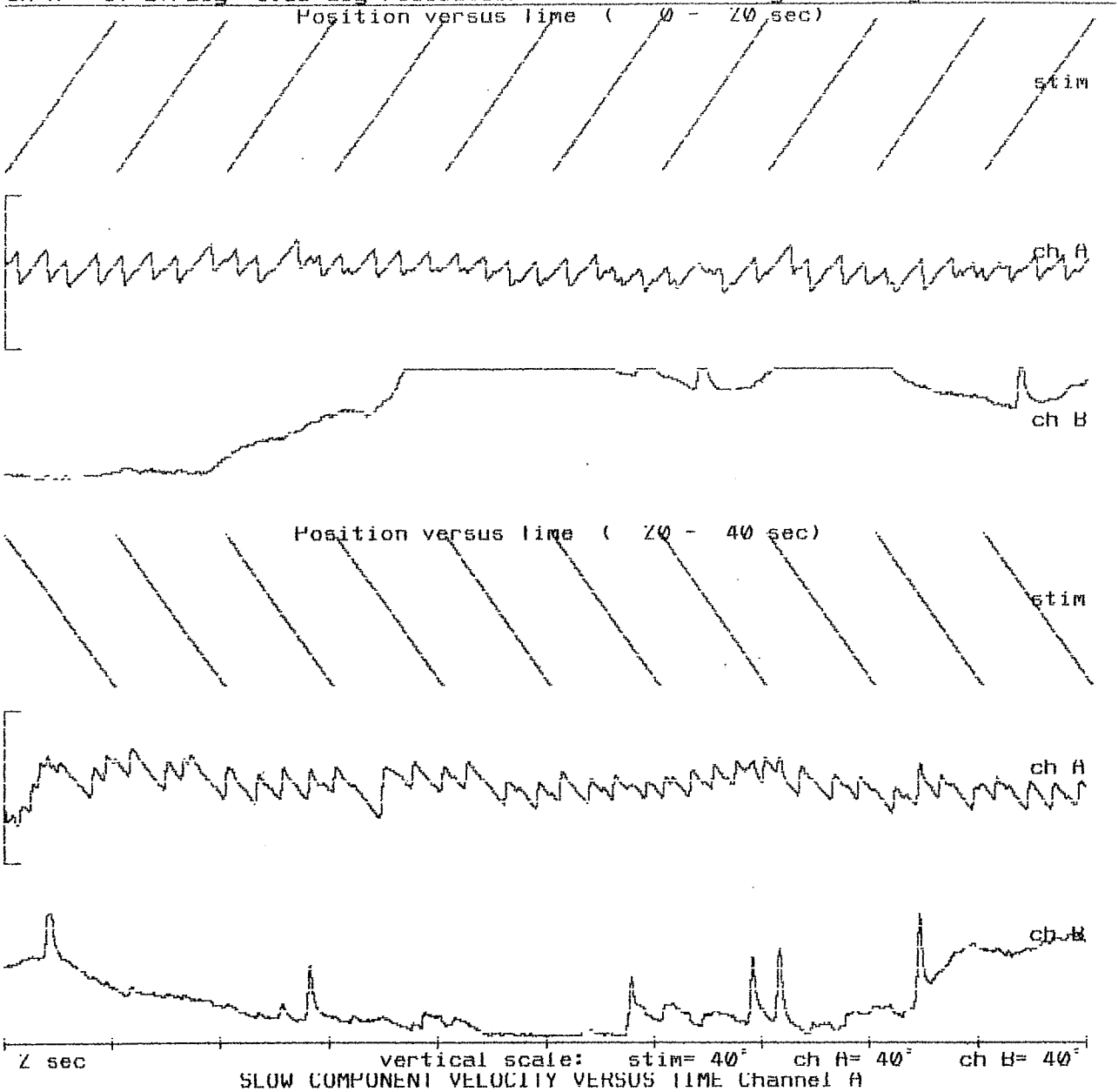


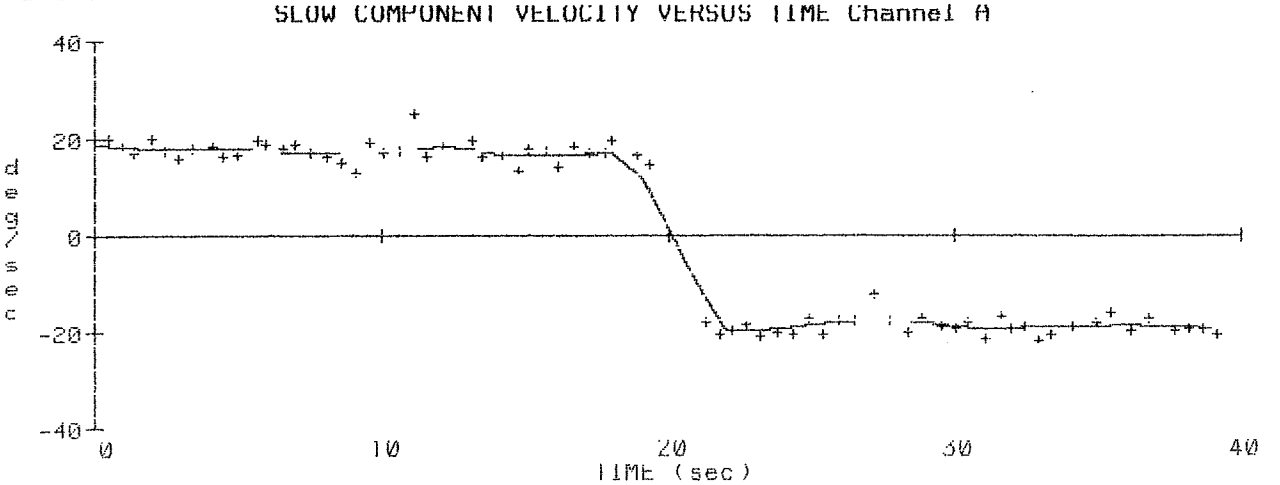
ArtRej= 18 MinAmp= 1

Lft/Dn Beat: Vmax= 11°/s @ 18 s Vmean= 10°/s F= 1.0 beats/s N= 14
Rht/Up Beat: Vmax= 10°/s @ 21 s Vmean= 9°/s F= 1.0 beats/s N= 14

Name: APPENDIX
Age : 23
Sex : f
ID :
Ch A: 31 uV/deg 0.62 deg resolution

Date: 18 March 1995 10:25:29
Test: OPTOKINETIC NYSTAGMUS
Stim: Horiz bi-dir 20 deg/sec
10.24 deg target spacing
Ch B: 16 uV/deg 0.48 deg resolution



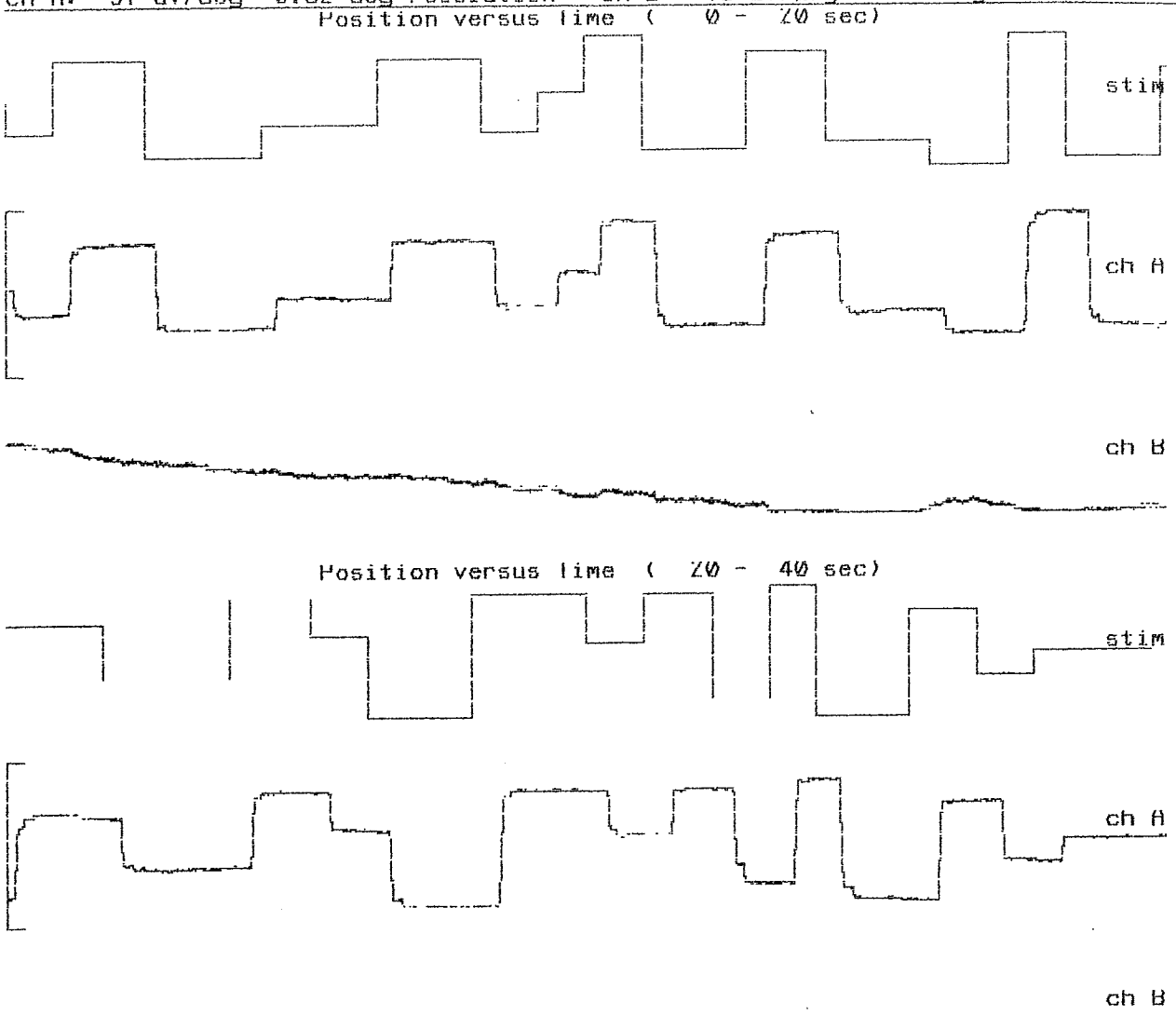


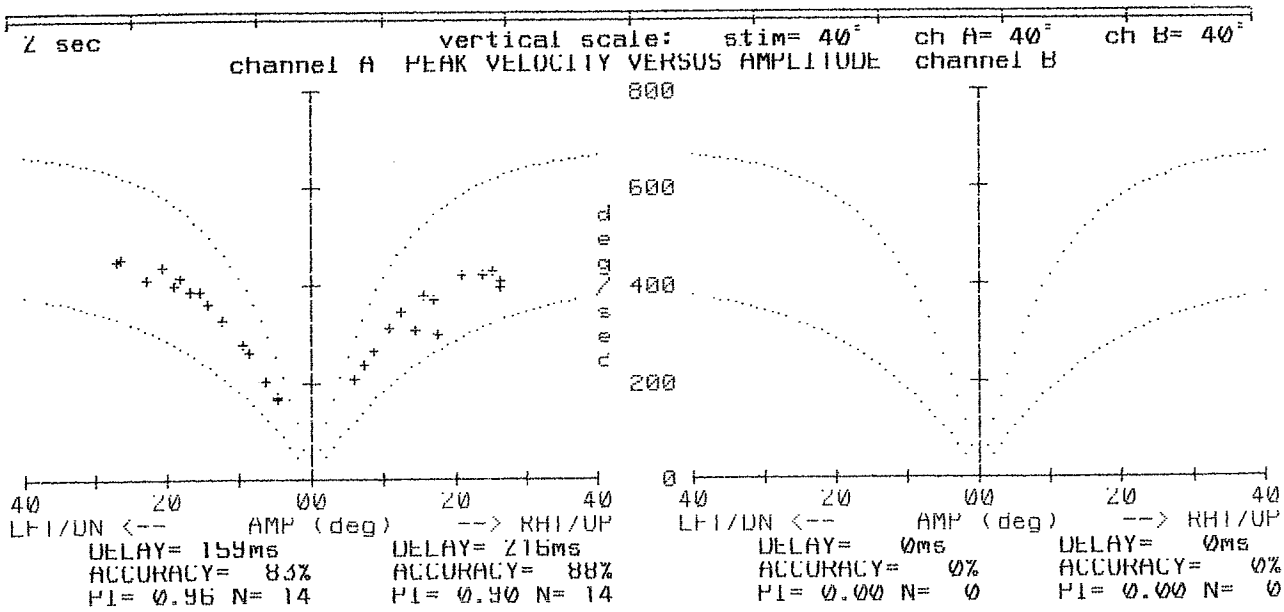
ArtRej= 18 MinAmp= 1

Lft/Dn Beat: Vmax= 19°/s @ 0 s Vmean= 17°/s F= 2.2 beats/s N= 37
Rht/Up Beat: Vmax= 20°/s @ 22 s Vmean= 18°/s F= 2.0 beats/s N= 33

Name: APPENDIX
Age : 23
Sex : f
ID :
Ch A: 31 uV/deg 0.6Z deg resolution

Date: 18 March 1995 10:27:29
Test: HORIZONTAL RANDOM SACCADE
Stim: 6-3Z deg jumps,
center visual field
Ch B: 16 uV/deg 0.48 deg resolution

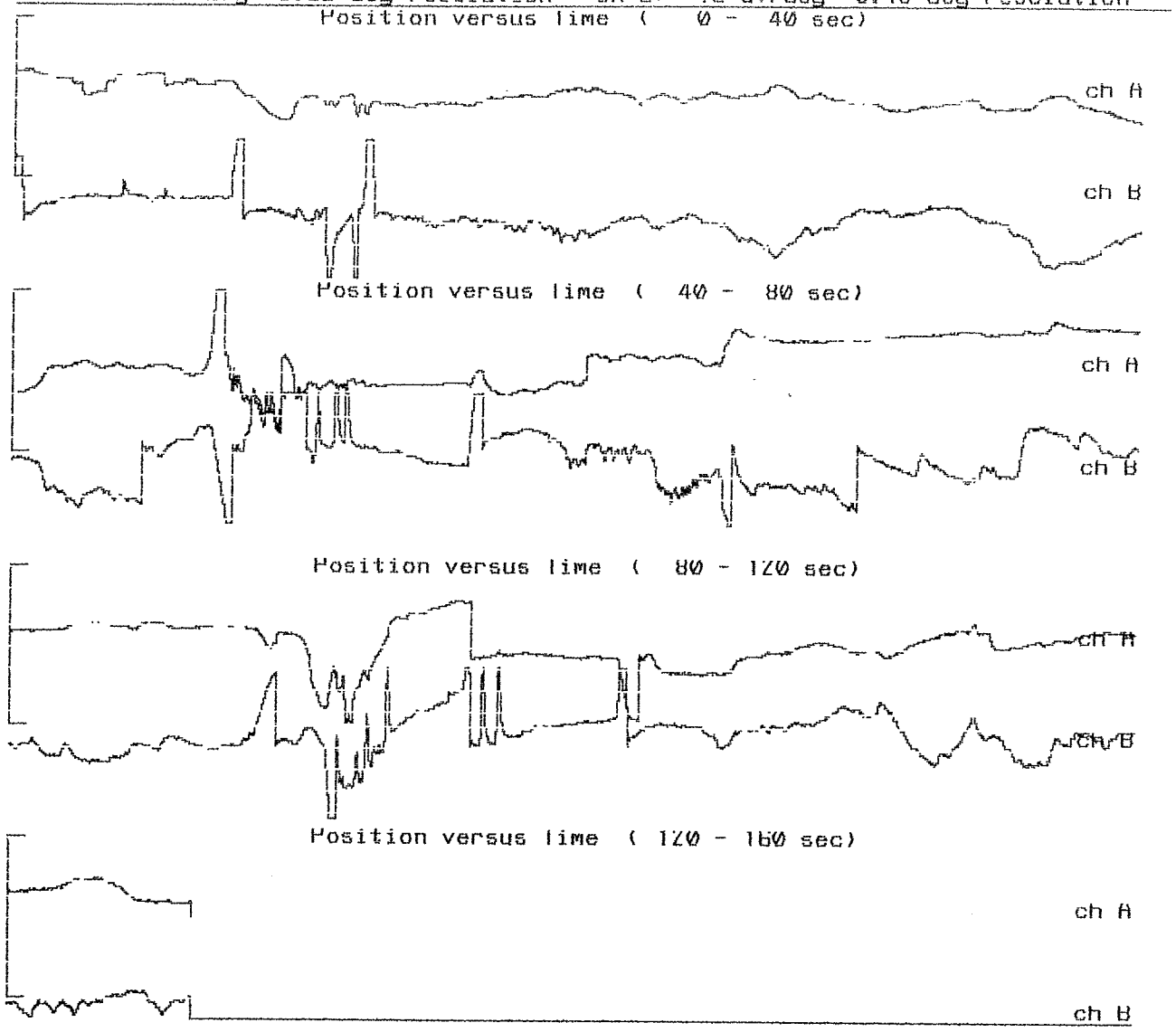


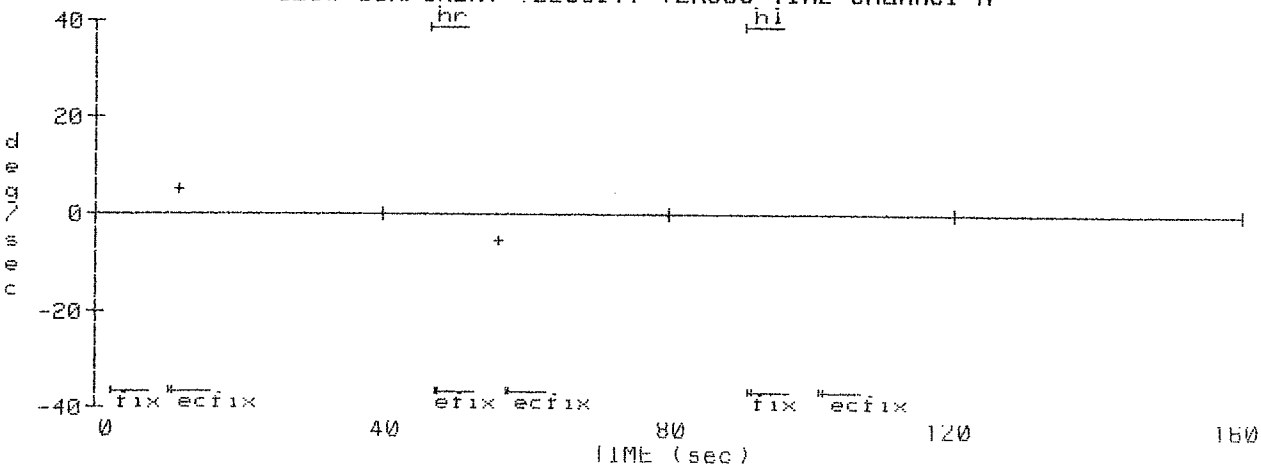


Name: APPENDIX
Age : 23
Sex : f
ID :

Date: 18 March 1995 10:31:54
Test: POSITIONAL NYSTAGMUS
Stim: Stationary, supine

Ch A: 31 uV/deg 0.67 deg resolution Ch B: 16 uV/deg 0.48 deg resolution



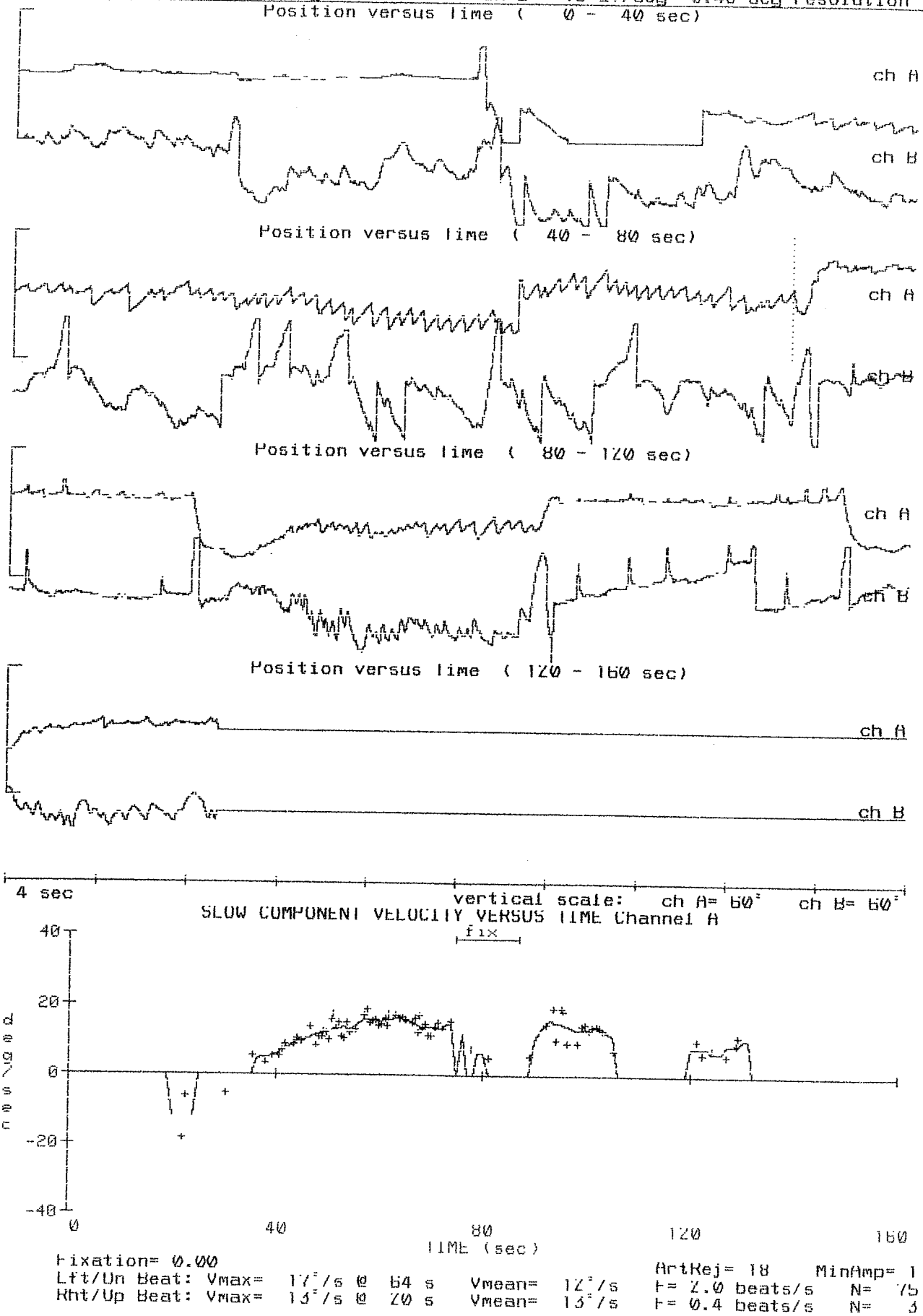


ArtRej= 18 MinAmp= 1

Lft/Dn Beat: Vmax= 0°/s @ 0 s Vmean= 0°/s F= 0.0 beats/s N= 1
Rht/Up Beat: Vmax= 0°/s @ 0 s Vmean= 0°/s F= 0.0 beats/s N= 1

Name: APPENDIX
Age : 23
Sex : F
ID :
Ch A: 31 uV/deg 0.62 deg resolution

Date: 18 March 1995 10:39:33
Test: BITHERMAL WATER CALORIC
Stim: Right ear, cool water
Ch B: 16 uV/deg 0.48 deg resolution



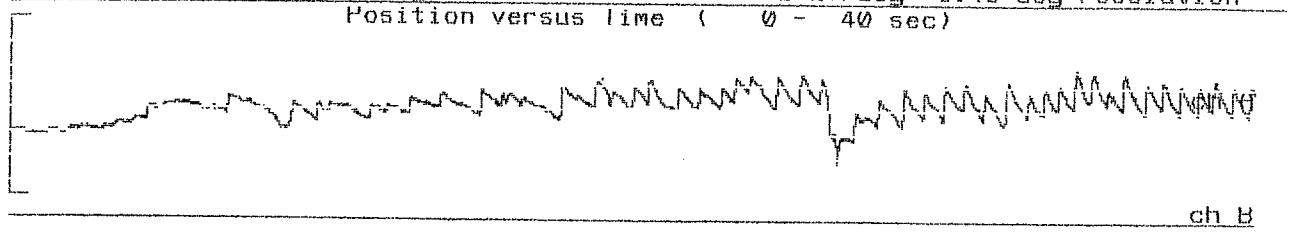
Fixation= 0.00

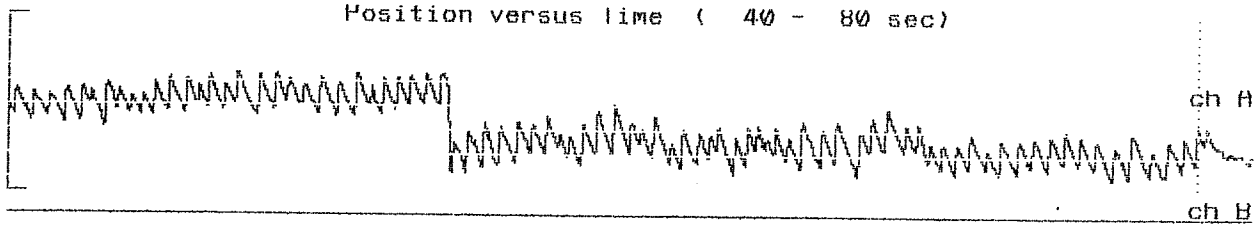
Lft/Un Beat:	Vmax=	17°/s	@ 64 s	Vmean=	12°/s	F= 2.0 beats/s	N= 75
Rht/Up Beat:	Vmax=	13°/s	@ 20 s	Vmean=	13°/s	F= 0.4 beats/s	N= 3

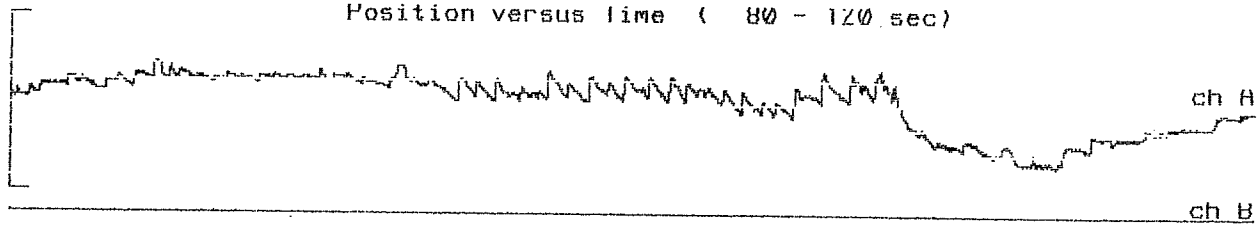
ArtRej= 18 MinAmp= 1

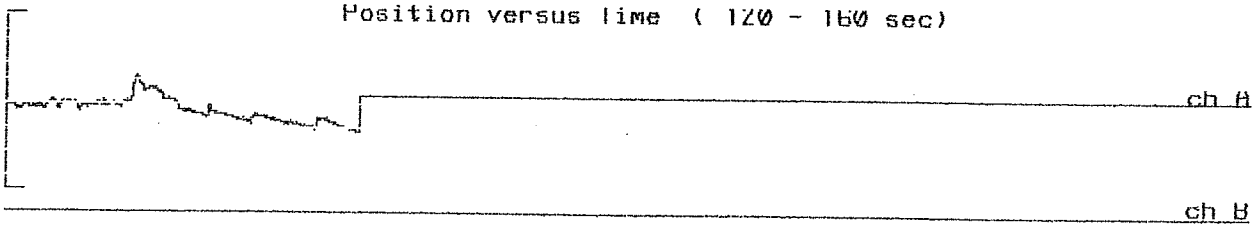
Name: APPENDIX
Age : 23
Sex : f
ID :
Ch A: 31 uV/deg 0.67 deg resolution

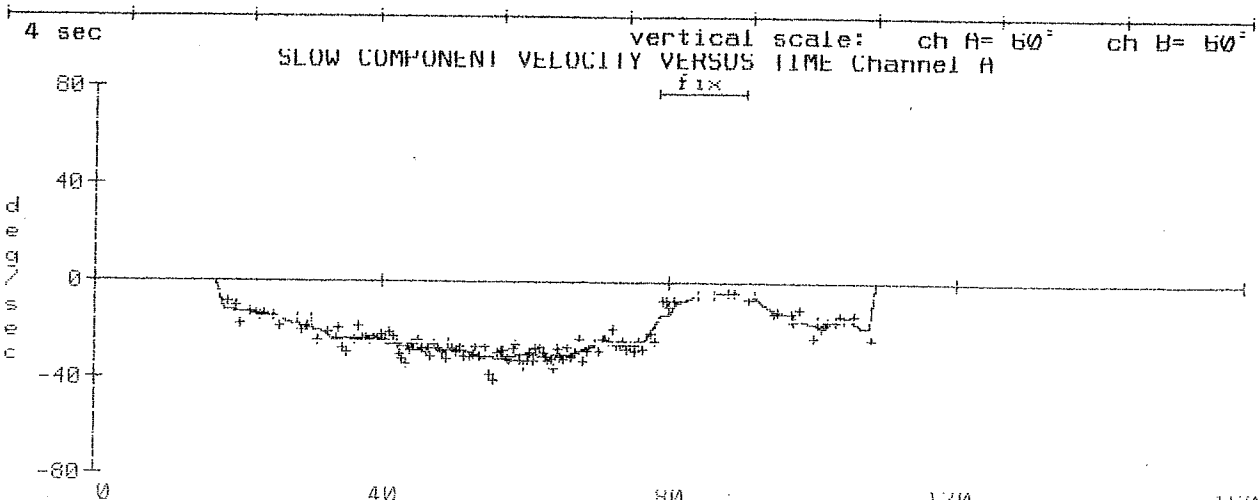
Date: 18 March 1995 10:49:09
Test: BITHERMAL WATER CALORIC
Stim: Left ear,
cool water
Ch B: 16 uV/deg 0.48 deg resolution











Fixation= 0.17

Lft/Dn Beat:	Vmax=	0°/s	@ 0 s	Vmean=	0°/s	f= 0.0 beats/s	N= 0
Rht/Up Beat:	Vmax=	32°/s	@ 54 s	Vmean=	20°/s	f= 2.4 beats/s	N= 128

ArtRej= 18 MinAmp= 1

APPENDIX D

Micromedical Technologies, Inc.
Rotational Vestibular Chair

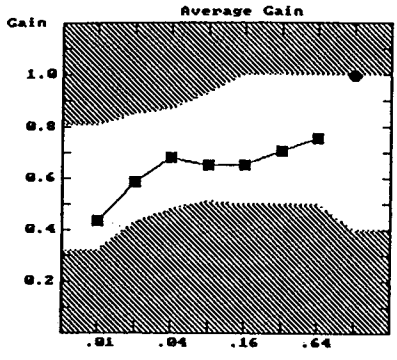
Saint Louis University Med. Center
3660 Vista Ave.
St. Louis, MO 63110
(314) 577-6110

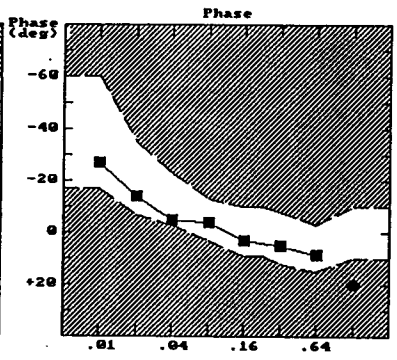
student
Exam Date: 03-25-1995 Age: 24

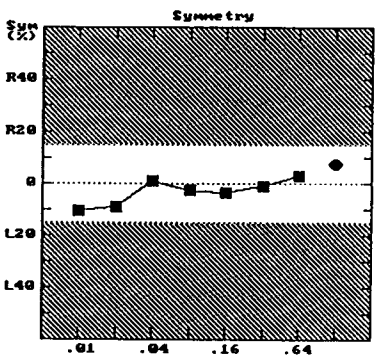
ID #:

ROTATIONAL CHAIR SUMMARY

VESTIBULO OCULAR REFLEX (VOR)

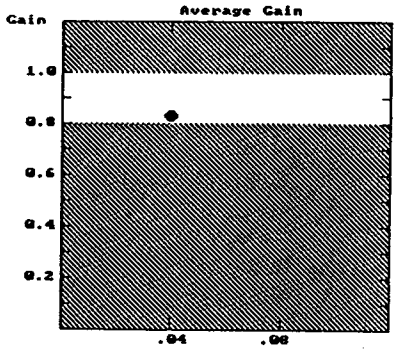


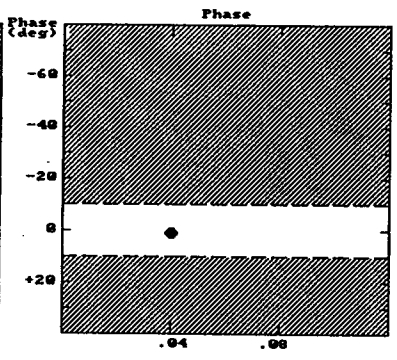


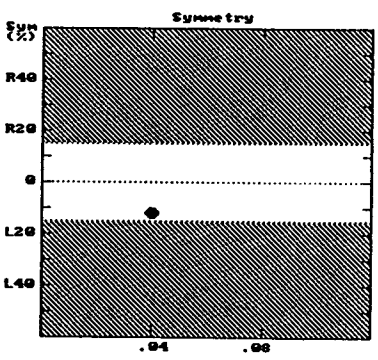


Freq. Hz	Vel. d/s	Gain	Phase deg	Symmet. %
■0.010	60	0.44	-27	L10.5
■0.020	60	0.58	-14	L 9.1
■0.040	60	0.68	-5	R 1.1
■0.080	60	0.65	-4	L 2.5
■0.160	60	0.65	3	L 3.6
■0.320	60	0.70	5	L 0.8
■0.640	60	0.76	9	R 2.9
●1.280	40	1.00	20	R 7.3

VISUAL VESTIBULO OCULAR REFLEX (VVOR)







Freq. Hz	Vel. d/s	Gain	Phase deg	Symmet. %
●0.040	60	0.83	1	L12.2

APPENDIX E

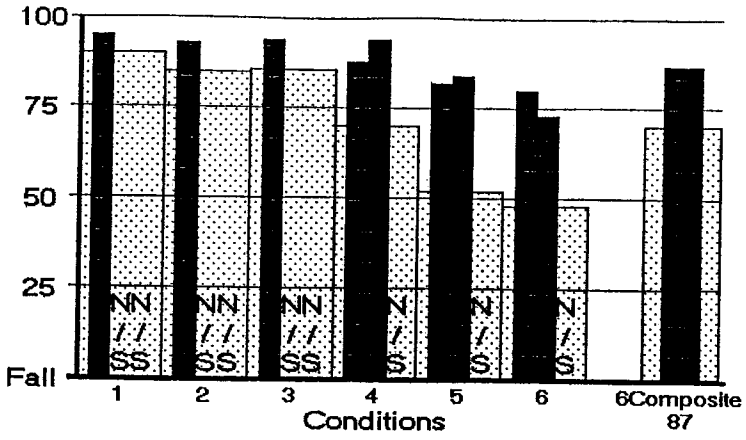
EQUITEST SUMMARY

Patient: schmitt, marie
Age: 23
ID:

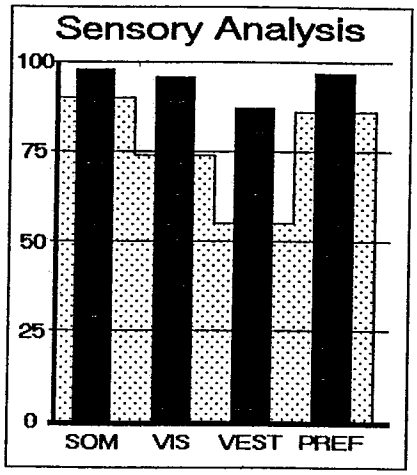
Referred By:
Sway-Referenced Gain: 1.00 Operator ID:

File: 000188A.RAW
Date: Mar 18 1995
Time: 09:03

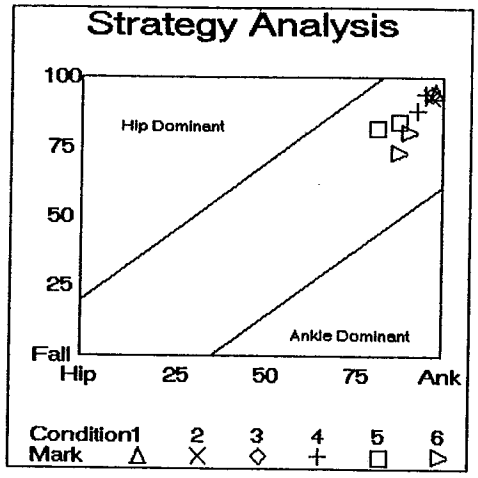
Equilibrium Score



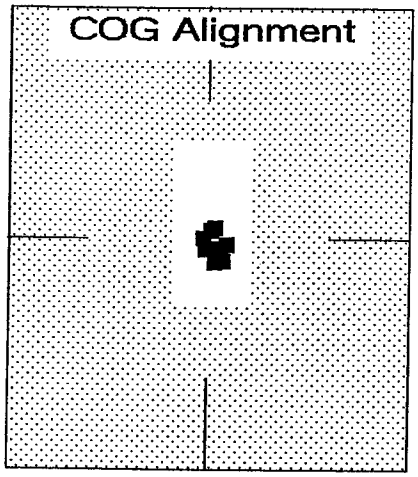
Sensory Analysis



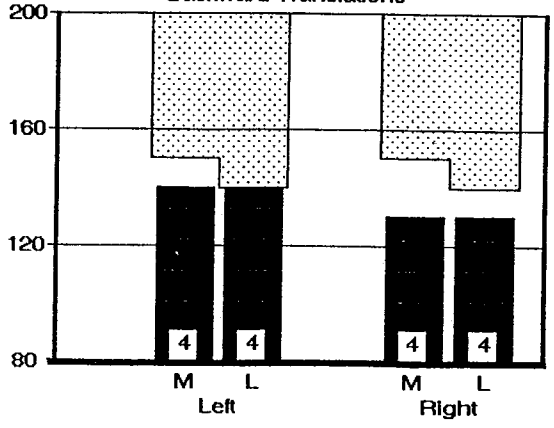
Strategy Analysis

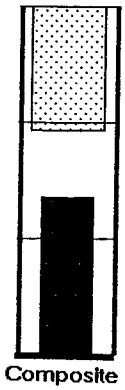


COG Alignment

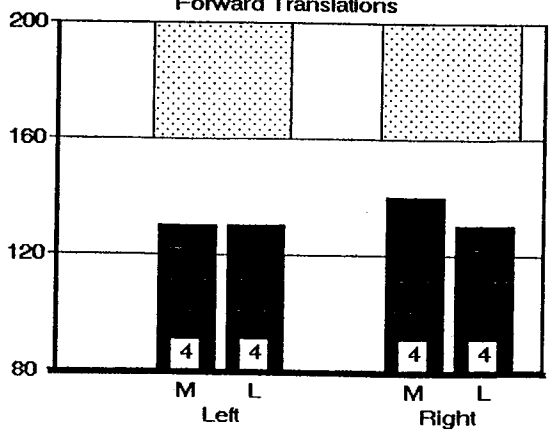


Latency (msec)
Backward Translations





Latency (msec)
Forward Translations



TEST NOTES: NeuroCom Data Range: 20 - 59; Data from EquiTest Version 5.03

SENSORY ORGANIZATION TEST ANALYSIS

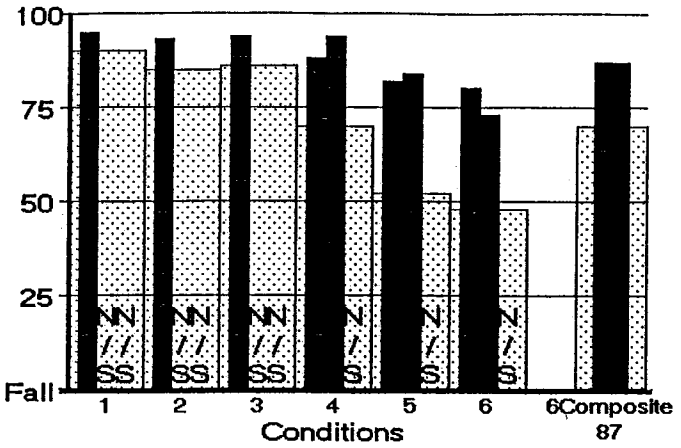
Patient: schmitt, marie
Age: 23
ID:

Referred By:
Sway-Referenced Gain: 1.00

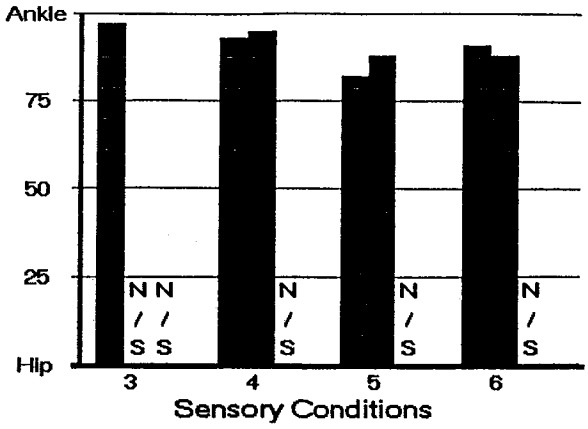
Operator ID:

File: 000188A.RAW
Date: Mar 18 1995
Time: 09:03

Equilibrium Score



Strategy



Sway, Shear, and Alignment Data

	Trial 1	Trial 2	Trial 3
1		No Data	No Data
2		No Data	No Data
3		No Data	No Data
4			No Data
5			No Data
6			No Data

TEST NOTES: NeuroCom Data Range: 20 - 59; Data from EquiTest Version 5.03

MOTOR CONTROL TEST

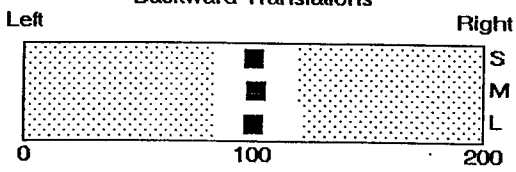
Patient: schmitt, marie
Age: 23
ID:

Referred By:
Sway-Referenced Gain: 1.00

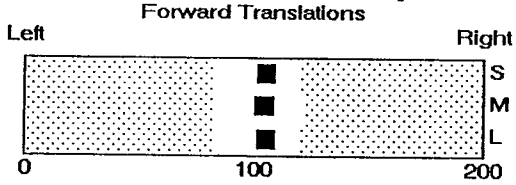
Operator ID:

File: 000188A.RAW
Date: Mar 18 1995
Time: 09:03

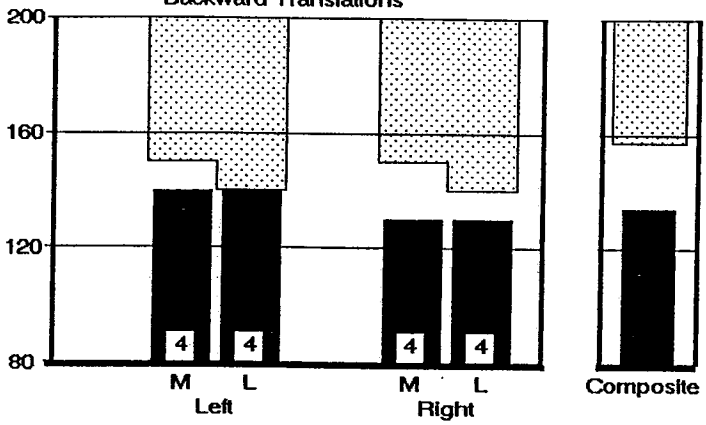
Weight Symmetry
Backward Translations



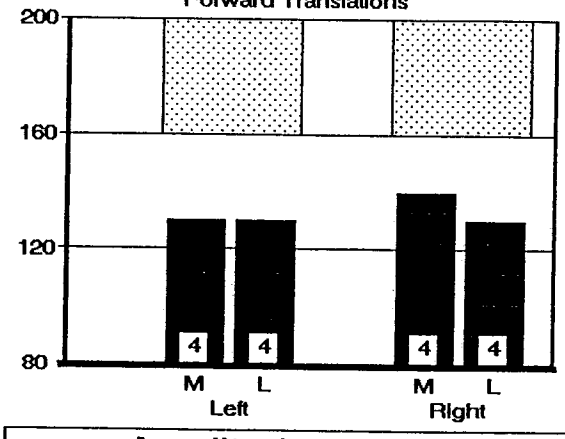
Weight Symmetry
Forward Translations



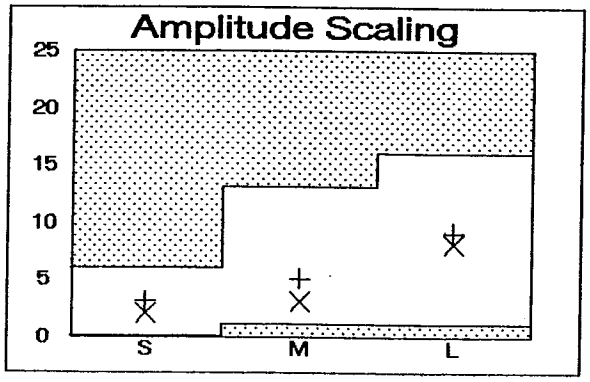
Latency (msec)
Backward Translations



Latency (msec)
Forward Translations



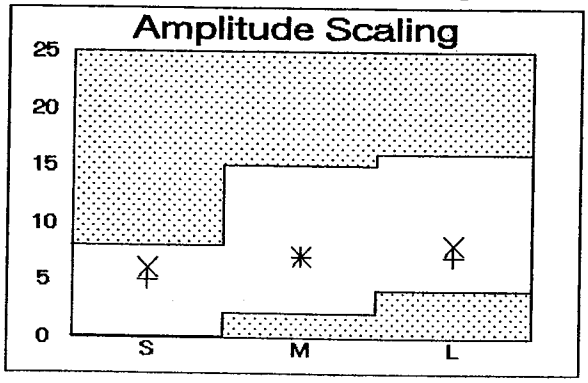
Amplitude Scaling



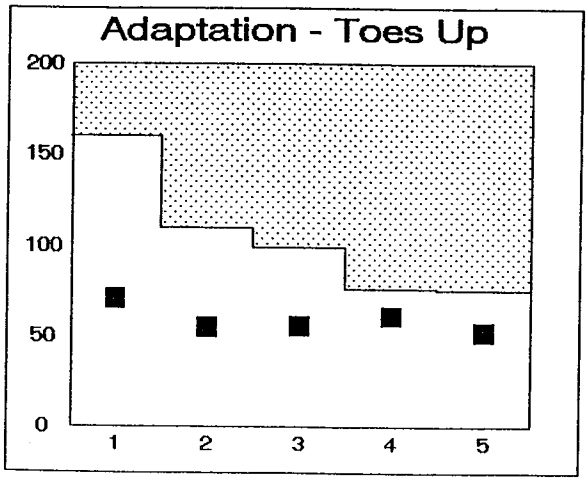
X = Left

\+ = Right

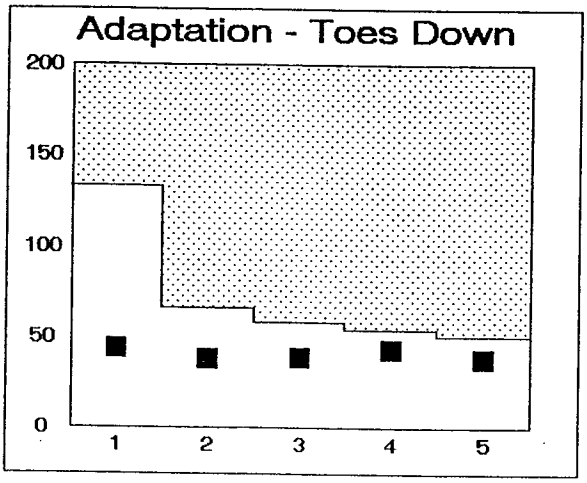
Amplitude Scaling



Adaptation - Toes Up



Adaptation - Toes Down



TEST NOTES: NeuroCom Data Range: 20 - 59; Data from EquiTest Version 5.03

EQUITEST TESTS NUMERIC SUMMARY

Patient: schmitt, marie
Age: 23
ID:

Height: 64 In

Referred By:
Sway-Referenced Gain: 1.00

Operator ID:

File: 000188A.RAW
Date: Mar 18 1995
Time: 09:03

Sensory Organization Test Results

	Equilibrium			Strategy			COG Alignment		
Condition	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	95	N/S	N/S	98	N/S	N/S	0.3, -0.2	N/S	N/S
2	93	N/S	N/S	97	N/S	N/S	0.5, -0.2	N/S	N/S
3	94	N/S	N/S	97	N/S	N/S	0.4, -0.5	N/S	N/S
4	88	94	N/S	93	95	N/S	0.2, -0.5	0.1, 0.2	N/S
5	82	84	N/S	82	88	N/S	0.1, -0.2	-0.0, -0.2	N/S
6	80	73	N/S	91	88	N/S	-0.1, 0.0	0.2, 0.2	N/S

6Composite = 87

Motor Control Test Results

	Weight	Latency		Response Strength		Strength
Translation	Symmetry	Left	Right	Left	Right	Symmetry
Small B	101	140 (4)	140 (4)	2	3	120
Medium B	102	140 (4)	130 (4)	3	5	125
Large B	101	140 (4)	130 (4)	8	9	105
Small F	106	130 (3)	130 (3)	6	5	90
Medium F	105	130 (4)	140 (4)	7	7	100
Large F	106	130 (4)	130 (4)	8	7	93

Composite = 134

Adaptation

Trial	Toes Up	Toes Down
1	71	44
2	55	38
3	56	39
4	61	43
5	52	38

Test Notes:

TEST NOTES: NeuroCom Data Range: 20 - 59; Data from EquiTest Version 5.03

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