

MEASURING VISUAL MIDLINE SHIFT SYNDROME & DISORDERS OF SPATIAL LOCALIZATION:

A LITERATURE REVIEW & REPORT OF A NEW CLINICAL PROTOCOL

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Abstract

Disorders of egocentric spatial localization are common in patients who have suffered brain injury. Symptoms of these conditions may include but are not limited to postural modifications, problems with eye hand coordination and difficulty navigating the environment. This group of symptoms in conjunction with a deviated visual straight ahead has been termed visual midline shift syndrome (VMSS). It is commonly treated with full-time wear, yoked prismatic lenses. A literature review of current methodology and diagnostic criteria includes the measurement of the egocentric reference in normal and neurologically impaired subjects. Important relationships between proprioception and vision were frequently investigated by administering the Subjective Straight Ahead test and the Visual Open-Loop Pointing (VOL) task. The relationship between these tasks has been extensively studied. The visual midline measurement, the proprioceptive midline task and the visual open loop pointing task offers insight for patients exhibiting symptoms of VMSS. A detailed methodology for using these tasks in the clinic is provided.

Key Words

brain injury, egocentric reference frame, hemianopia, prism adaptation, unilateral spatial inattention, visual midline shift syndrome, visual neglect, wedge prism, yoked prism

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Editor's note

Table 1 on page 89 lists the abbreviations for the many terms that are used in this article.

INTRODUCTION

To perform a well coordinated goal directed movement, a person must have information on the location of their body (egocentric localization) and the relative positions of objects to each other (allocentric localization). The brain creates a motor plan using multiple modes of sensory information including but not limited to the visual position of limbs, visual position of targets relative on one another, and proprioceptive sensation of felt position based on muscle spindle feedback.¹ Even in neurologically intact individuals, slight errors may occur while performing a visuo-motor task and can be adjusted. These adjustments are referred to as on-line corrections. Dysfunction in any part of this coordination loop may result in problems with eye hand coordination, postural control and/or locomotion. Researchers in rehabilitative optometry have observed these types of dysfunctions classifying them as the "Visual Midline Shift Syndrome" (VMSS) or more appropriately "abnormal egocentric localization" (AEL). Common practice for such diagnosis is to use a target as a pen or a fixation wand moved by either the patient or the examiner from the patient's right or left laterally across the visual field. The patient determines when it is centered on his midline. In addition to this visual midline test the examiner may also assess the patient's posture, balance, and ambulation for physical shifts that correspond to the direction of the visual shift.^{2,3} Yoked prisms may then be trialed

while observing gait to determine their immediate effect.^{3,4} The magnitude of the prism chosen is largely subjective. However, it appears from informal interviews with practitioners that most use less than 10 prism diopters. Full-time wear, yoked prism may be prescribed with the recommendation of a follow-up to assess for prolonged effects of the prism.

The purpose of this article is to critically examine these techniques while taking a close look at the more than 50 years of research on the measurement of egocentric perception and the eye hand coordination loop. This information may be useful to the practicing optometrist attempting to diagnose AEL or VMSS. These studies will serve as a basis for proposing a more comprehensive protocol for the diagnosis of AEL. I will also discuss how the clinical manifestations might be subcategorized into a separate visual-proprioceptive misalignment syndrome and/or spatial compression syndrome. These conditions are not always merely a skewed visual midline.

Methods

A literature review was conducted through Indiana University World Cat and Pub Med. Full text articles and books not available electronically were requested through interlibrary loan. Protocols were developed over the course of the past three years based on both the literature review¹⁻⁸ and by consultation of one of the researchers in the field, Gordon Redding, Ph.D.

Literature Review on the Measurement of the Visual and Proprioceptive Midline

Techniques for measuring egocentric (where am I) and allocentric (where is it) perception have been established over decades of research. These were published

mostly in experimental psychology and neuroscience journals. In studying visuo-motor coordination, researchers have defined several functional egocentric reference frames. For example “where is a stimulus located in relation to my head” was termed a head centered reference frame. The reference frames believed to be important in the eye-hand coordination loop are the visual eye-head-centered reference frame and the proprioceptive hand-head reference frame. For simplicity, these may be referred to as “visual” for eye-head, and “proprioceptive” for hand-head, the predominant sense used for the task. Classically, researchers have used tests that isolate the reference frames allowing an independent analysis. It has been demonstrated that patients with brain injury, particularly right hemisphere brain damage (RBD), can have pathological shifts in either/or both reference frames, and may correspond to problems with visual or proprioceptive input and/or processing. Three different component measures have been used to measure egocentric reference position on both normal and neurologically impaired patients.

Proprioceptive Hand-Head Egocentric Midline (PS)

The literature review found that the proprioceptive hand-head egocentric midline is an important component task in assessing the eye hand coordination loop. Harris first documented the use of straight ahead pointing without vision as a measure of hand-head proprioceptive egocentric midline (PS) in 1963.^{9,10} Since then it has been widely used by multiple research labs for this purpose.^{11,12} It has most commonly been obtained by blindfolding the patient and having them point straight ahead, a task termed “subjective straight ahead pointing.”¹³

Visual Eye-Head Egocentric Midline (VS)

Visual eye-head egocentric midline (VS) was the second component test commonly emphasized in the literature for the assessment of the eye-hand coordination loop. It is the measurement most consistent with the test done by some optometrists for VMSS. The VS task is an isolated measurement of the head centered egocentric reference frame when sensory information is carefully controlled. This limits information from extraocular muscle proprioception and target position within the visual field. The test is predominantly visual, although proprioception may play

a role if the target is moved slowly. In research labs it has been measured in both neurologically intact and brain damaged patients by having the subject indicate when they perceive a target (black line, laser pointer, or LED light) to be centered as it moves slowly from the left or right towards the center.¹⁴⁻²⁰ One lab required the subject to hold the eyes stationary in what they perceived as the straight ahead position¹⁹ and indicate with a clicker button when the target was centered. The other labs required the subject to track the target as it moved and respond either verbally or with a clicker when it was perceived as straight ahead. All the research labs cited were careful to control for contamination of the VS measurement by eliminating exocentric visual landmarks either by darkening the room and using either a LED or laser pointer; or by using a black line on a very large white board. In this manner visual information is limited to retinal locus and proprioceptive position of the extra-ocular muscles and head.²¹⁻²³

Visual Open Loop Pointing (VOL)

A third component measure is visual open-loop pointing (VOL). This requires the subject to point towards the visual target when his arm is hidden under a shelf. This type of measurement is taken in some vision therapy practices using Dr. Streff’s spatial localization board.^a The spatial board procedure requires the patient to place his face into a notch at one end of the board and look down on the surface at a visual target. He then indicates the perceived location on the underside when his arm is hidden under the board.²⁴

The Van Orden Star test may also provide a measurement similar to the VOL. It requires the patient to look into a stereoscope (Keystone Correct-Eye-Scope),^a and draw a line with each hand simultaneously until the pencil points appear to touch.²⁵ Visual open loop pointing is believed to reveal the association between the VS and the PS, a relationship first suggested by Hay in 1970¹⁴ and defined by Wilkinson in 1971.¹² These researchers proposed a “theory of additivity.” It is based on the notion that a well-aligned and healthy visuo-motor system will have coordinated proprioceptive and visual integration with little to no deviation between the target and the unseen hand when performing the VOL. A experimentally induced shift in vision using yoked prism causes an eye-hand mismatch on VOL that should

be equivalent to the sum of the absolute value of the visual shift and proprioceptive shift ($VOL = PS + VS$). To illustrate, imagine that vision were shifted 5 degrees right and proprioception 5 degrees left; the theory of additivity would predict VOL to be 10 degrees, representing the total misalignment between systems. One could also imagine, as a similar condition, a subject fitted with a 10 degree base right yoked prism and given an immediate VOL test without having time to adapt. In this scenario the subject would demonstrate a dissociation between vision and proprioception of approximately 10 degrees resulting in the unseen arm pointing 10 degrees to the left of the target at the virtual image created by the prism. Wilkinson’s additivity model¹² was confirmed by multiple labs using yoked prism lenses to induce misalignments.²⁶⁻³⁰ Opponents of the theory challenged it by demonstrating cases of over or under additivity.²⁶ Proponents of the additivity model were able to counter these arguments and reproduce the failures when strict methodology was not followed. The debate over this topic still exists. Recently, Hatada et al found that having the subject verbally indicate when the arm was pointing straight ahead while it was passively moved from the left or right by the examiner actually fit the additivity equation better than SSA pointing.¹⁰

Literature Review of Norms for Visual Midline and Proprioceptive Midline Testing

The prism adaptation technique used to investigate the additivity model required the subject to make multiple discreet pointing movements to a visual target while wearing 10-20 prism diopter yoked prisms. Initially they missed in the direction opposite the base but adapted over 60-100 trials. Upon removal of the prisms the subjects showed misreaching in the opposite direction for the next few minutes. This type of prism adaptation is distinctly different from that conventionally reported in ophthalmology literature as an undesirable response in the treatment of strabismus and phorias. Researchers referred to the lenses as “wedge prisms” or “laterally displacing prisms” with “yoked prism” being a term unique to the optical professions. The recent discovery in 1998 of the benefits of using prism adaptation therapy for patients with RBD exhibiting left neglect³¹ has led to an increase in publications on the measurement of egocentric perception

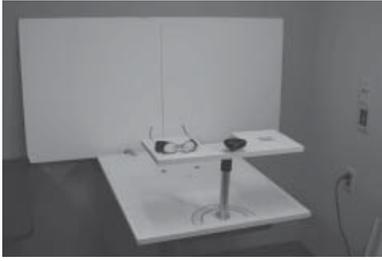


Figure 1a. Apparatus without the removable shelf

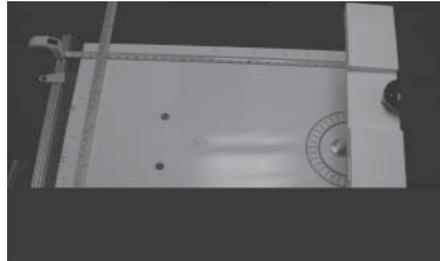


Figure 1b. Apparatus without the removable shelf. The track at the far end can accommodate a slider which has a bracket to clip the dowel rod bead assembly into for the VS and VOL tasks.

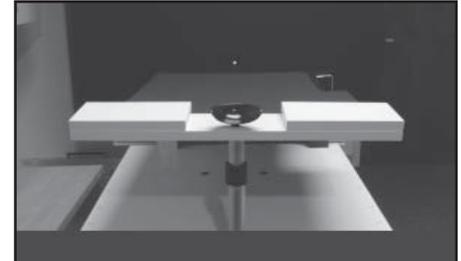


Figure 2. Apparatus with black removable shelf and black felt backdrop. Notice the 1cm white fixation bead and black dowel rod assembly visible over the black shelf which acts as a target for the VOL and VS task.

Table 1.
Glossary of Abbreviations

Abbreviation	Term
AEL	Abnormal Egocentric Localization
CVA	Cerebro-vascular Accident
LBD	Left Brain Damage
MCA	Middle Cerebral Artery
PCA	Posterior Cerebral Artery
PS	Proprioceptive Hand-Head Egocentric Midline
RBD	Right Brain Damage
SML	Sensory Motor Learning
VMSS	Visual Midline Shift Syndrome
VOL	Visual Open-Loop Pointing
VPM	Visual-Proprioceptive Misalignment
VS	Visual Eye-Head Egocentric Midline

in this population. Two recent studies examined the performance of RBD patients vs. controls on the VS, PS, and VOL tasks. On the PS task, normal subjects tend to point slightly to the left of the center and patients with right parietal lesions often point right of center.³² Conversely, VOL in RBD patients was found to be relatively normal.³² Padula, using a technique similar to the VS test, found a high correlation between RBD with left hemiparesis and a rightward shift in VS.⁴ Farne et al, in 1998, found RBD patients with left inattention perform differently depending on whether the target is coming from the left or right.²⁰ Right to left scanning direction yielded a rightward shift of the VS, however if the target was moved from left to right VS was not significantly deviated compared to controls. Data has been published about pathological egocentric midline shifts occurring due to damage in other parts of the brain, but is not as comprehensive. Frassinetti et al's case report was on a person with a left PCA territory CVA. The person had optic ataxia without neglect, who complained of not being able to accurately reach for things. The researcher also demonstrated a rightward

deviation of the pointing hand on the VOL task.³³ Chorkin showed a leftward deviation in the PS task in 30 left-brain-damaged (LBD) patients with or without right neglect.³⁴ Padula et al studied post-acute stroke patients and found a rightward shift on the VS task in 77% of 17 patients with LBD and a leftward shift in 79% of 13 patients with RBD.⁴

Use of Yoked Prism for Visuo-spatial dysfunctions

Yoked prism has been described in the optometric literature since the 1950s for various perceptual and postural applications. Kaplan and Kraskin were the first to suggest methodology where the practicing optometrist could apply these tools for the benefit of their patients. Kaplan took into account the phoria, AC/A ratio, performance on the Van Orden Star and other visuo-motor tasks to determine the direction of the base.²⁵ He recommended that prism magnitude be 5 diopters or less to prevent disruption of the visual system. Kraskin advocated the use of stereoscopic tasks to determine the amount and direction of yoked prism. He suggested prescribing the amount that would decrease stereopsis causing the patient to make a

change in their posture or function.³⁵ Padula used 12 diopters of yoked prism base opposite the direction of visual midline shift on the VS task in patients with neurological injury.⁴

New Clinical Protocol to Measure Egocentric Localization

Apparatus

The apparatus is comprised of a 30" x 25" x 1/2" plywood board (Figures 1a and 1b). A chinrest is affixed to the board with a 10" to 15" telescoping arm. There is a removable 25" x 25" black foam core shelf to occlude the subject's view of their arm during VOL (Figure 2). This shelf serves also to conceal a protractor divided into 1 degree increments. A dowel rod with a 1cm white bead is clipped onto a sliding track at the far end of the board (Figure 2).

Technique

The patient sits with his head in the chinrest and is manually adjusted by the examiner to align the chin to zero on the protractor. The shoulders should be brought square with the apparatus. The patient's posture should be monitored to ensure accuracy. The VS, PS and VOL are then measured.

Visual Eye-Head Egocentric Midline (VS)

The patient's view of his arms and body is occluded by the black removable shelf (Figure 2). External visual cues are minimized by placing the black felt against the wall as a back drop. The examiner positions himself below the shelf, completely out of the patient's view as he slides the white bead along the track (Figure. 2) from the patient's far right (40° eccentricity) at approximately 3 degrees/second along the front edge of the apparatus. The target is 30" from the patient. The subject indicates verbally when the bead is perceived to be directly centered in front of

himself. The subject is allowed to move his eyes to follow but is required to keep the head stationary on the chinrest. This eliminates any influence hemianopsia may have on performance and is consistent with methodology described in the literature. Patients who are slow to respond require an extra step to ensure accurate and consistent measurements. For these patients, the examiner asks the subject if the bead looks perfectly centered or if it should go a little left or right. Scores are recorded in degrees with 90 being the objective midline. This is repeated five times from the left and right for a total of 10 measurements. The measurements are then averaged to obtain the VS measure.

Proprioceptive Hand-Head Egocentric Midline (PS)

The subject is placed into the apparatus in exactly the same manner as described for the VS task and the shelf is removed. Vision is completely occluded with two black eye patches and he is given these specific instructions: "Take your forefinger and point straight, to where your finger is aligned with your nose." If the patient attempts to touch his nose, this should be discouraged and that trial discarded. Once pointing straight ahead the patient is asked to hold that position while the examiner drops a measuring string from the patient's finger to the table to quantify any misalignment. Scores are recorded in degrees with 90 being objective midline.

Visual Open Loop Test (VOL)

The subject is placed into the apparatus exactly as described previously. The shelf is reinserted. The patient's right hand is placed on the table under the shelf. The examiner ensures that the patient has no view of any part of his body below his head. The dowel rod with a white bead is inserted into a clamp at the objective midline (90 degree mark), 30" in from the subject and perpendicular to the table so that the subject can see it over the shelf (Figure 2). The examiner positions himself as with the VS task. The subject is given the instructions, "Point directly at the bead with your right forefinger like you are trying to touch it. You will not see your hand." Once pointing straight ahead the patient is asked to hold that position while the examiner drops a measuring string from the patient's finger to the table to quantify any misalignment. VOL scores are recorded in degrees with 90 being objective midline.

Discussion

The Appendix summarizes the discussed methods of testing. The goal of this paper is to improve the clinical testing protocol for disorders of spatial localization such as VMSS. This information should then lead to better therapies, particularly for prescribing yoked prism. The protocol presented here has predominantly been used with RBD patients exhibiting neglect. It is reasonable to presume that it could be applied to other neurological conditions causing disorders of egocentric localization such as right or left hemisphere stroke,³⁶ damage secondary to tumor resection,³⁷ bilateral damage resulting in optic ataxia,³⁸ multiple sclerosis,³⁹ and cerebral palsy.³⁹ I will discuss the rationale for these tests, the methodology chosen and how prismatic lenses might be prescribed using this information.

Visual Eye-Head Egocentric Midline (VS)

Based on the literature review, the proposed testing protocol is an important and valid measure to assess egocentric perception. However, the current practice of using a wand either moved by the examiner or the patient needs modification. Firstly, allowing the patient to move the target is not advisable because it provides too much feedback to the patient and does not isolate visual eye-head from proprioceptive arm or shoulder reference frames. The examiner should, therefore, move the target.

A second concern is the failure to minimize exocentric cues. Using a large white piece of matte board or a laser pointer in a dark room is probably the easiest way for a clinician to minimize cues.¹⁹ Moving the target at constant speed of about 3 deg/sec is recommended, being careful not to vary the speed from trial to trial as this may increase variability. Experimenters did not allow the patient to make any minor adjustments in position after the initial response, however I typically permit this since the neurological impairment is often accompanied by increased response times. The patient should be allowed to visually track the target, a technique used by Wilkinson to derive the Additivity equation.¹² This methodology might be challenged by the argument that the VS is contaminated by extraocular muscle proprioception. This is countered by stating that obtaining a purely visual egocentric midline is not possible since proprioceptive cues are present regardless of whether

the eyes are tracking or stationary. Additionally, a stationary gaze would be influenced more by homonymous field defects skewing the midline away from the defective side. In personal conversation with a veteran motor research psychologist, the common opinion appears to be that tracking or not tracking the target has little effect on the measurement.

Proprioceptive Hand-Head Egocentric Midline (PS)

As illustrated in the literature review, the PS task is the most well studied task used to compare alignment of hand versus head proprioceptive maps as it relates to the eye-hand coordination loop and additivity. Without this information the optometrist is not able to quantify an eye-hand misalignment. Also since the PS test is entirely proprioceptive, the optometrist can gauge the system affected. For example, the VS task cannot discriminate since it is both a visual and proprioceptive task. There are a few keys to obtaining a valid PS measurement. First, it has been useful to give the specific instruction: "Point straight ahead so that your finger is in line with your nose." When allowed to decide the reference point to use, patients often do not intuitively choose the center of their head. Most commonly they point straight ahead of their shoulder, or may even use a remembered point seen prior to the application of the occluders. Second, positioning within the apparatus has been a common source of error. Any amount of head turning will skew the measurement in the direction of the turn.

Visual Open Loop Test (VOL)

The literature review revealed many clinical studies where VOL was the only parameter measured, omitting VS and PS.^{31,40,41} So why not continue to use this test in isolation? This is not advised since the VOL, as demonstrated by Redding and Wallace 1993,⁴² can be contaminated by sensorimotor learning strategies (SML). This can cause it to either be greater or less than the sum of VS and PS. This may mislead the optometrist into prescribing more or less prism than needed. SML could create similar problems if using the spatial localization board or Van Orden star in isolation to prescribe yoked prisms. It may also be possible to have vision and proprioception skewed an equal amount in the same direction, resulting in a seemingly normal VOL despite significant spatial dysfunction. It may be possible to use the spatial board as a substitute for the VOL

test. A word of caution is that the target on the spatial board is in peripersonal space (touchable by the patient), whereas the target in laboratory VOL measurements is in extrapersonal space (untouchable by the patient). Whether this difference is significant enough to affect additivity is unknown and a study probably should be performed to validate the spatial board for this use.

Additivity

Use of the additivity equation in combination with the component tests has been a useful clinical tool to help confirm the diagnosis when one of the tests was unreliable. For example, a patient gives an average VOL of 10° left and a variable VS of 0-20° rightward. If the patient performs consistently on the PS task the clinician can extrapolate the VS using the additivity model such that $VOL = PS - VS$, or $10 = 6 - VS$, then VS equals 4° rightward.

Interpretation of Test Results and Application of Prisms

It is evident from the literature review that there is insufficient data to confidently provide one single method for prescribing full-time wear prism for AEL and VMSS. Clearly, more research is needed in this area. Padula suggested providing yoked prism with the base oriented opposite the direction of the visual midline shift.³⁸ He used 12 diopters in one study,³ however, the method of determining the amount of prism was not specified. One theory is that the distortion effect of the prism creates the therapeutic effect for patients with VMSS, making the diopter value somewhat arbitrary. This has yet to be supported. Indeed it has been my observation that some patients demonstrate behaviors when performing figure copying tasks that would suggest this theory is accurate, drawing the compressed side of space larger (Figure 3). However, through the use of the protocol in our lab on acute RBD patients, we have observed some cases with a misalignment on VOL that was predictably corrected by providing the appropriate prism power when converting degrees to prism diopters.

$$PD = 100 \tan \delta$$

where $\delta = PS - VS$

For example, a 10 degree leftward VOL composed of a 10 degree rightward deviated VS and a normal PS is corrected with a 17.6 diopter base left yoked prism.

$$PS - VS = 10 \text{ degrees}$$

$$100(\tan 10) = 17.6PD$$

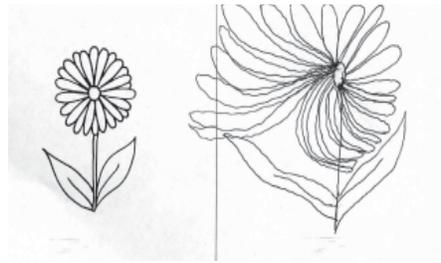


Figure 3. Figure Copy Task of a RBD patient showing compression of left space. Note that a perceived compression would result in the patient drawing that side larger.

Upon retesting the VOL with 17.6 diopters, no deviation is present (VOL=90). I interpret this as a positional dissociation between visual eye-head and proprioceptive hand-head spatial maps rather than a merely a perceptual compression. I further suggest that this particular presentation be subcategorized under the terminology visual-proprioceptive misalignment (VPM). The correction of VPM by converting degrees of deviation on the VOL to prism diopters will need to be confirmed and studied for short and long term effects on VOL, VS, PS, and related functional tasks. Clearly there will be limitations to the magnitude of prism that can be tolerated for full-time wear.

Other Considerations

One study reported that the VS task was commonly abnormal with the RBD patient pointing right of center.³² We have also observed a portion of RBD patients pointing left of center and may be equivalent to what is known as Pusher's Syndrome or Pusher's Behavior. These patients present slumped over in their wheel chair and frequently will also have neglect and hemianopsia.⁴³ What the relationship is between this, VPM and VMSS is unknown. It is possible that these conditions are different entities that can occur together or in isolation, or that they are of the same mechanism with variability in presentation owed to severity. A recent study published in 2009 suggested that Pusher's Behavior helps decrease problems with spatial orientation caused by left neglect.⁴⁴ Indeed the prism adaptation therapy for neglect results in a leftward proprioceptive misalignment, similar to the situation seen in Pusher's Syndrome.³¹ It must then be considered that correcting these misalignments, at least in the early recovery period, may not be in the patient's best interest. Using a base right prism to correct the condition could potentially contribute to an increased and eventually persistent left neglect.

Conclusion

This manuscript has proposed a modification and addition to the standard clinical protocol for the diagnosis of egocentric spatial localization disorders including VMSS.

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Note

The author has no proprietary interest in any of the equipment used in this study.

Source

a. Bernell Corporation, 4016 N Home St., Mishawaka, IN 46545

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Appendix

Egocentric Midline Testing Methods Quick Reference Guide

Equipment Needed

- Apparatus (chin rest and arm occluder), with protractor in 1 degree increments and vertical rod.
- Arm occluding shelf. The Spatial Localization Board (Bernell Corp) may also be used.
- 5ft x 2ft white matte board that has a dowel rod with 1cm white fixation bead in front of a black felt backdrop.
- Adjust the chinrest and support the patient's back with a pillow. The head cannot move or turn in order to obtain an acceptable measurement.
- The shoulders should be square with the table or apparatus.

Visual Eye-Head Egocentric Midline (VS)

- Move the visual target from the far right at 3 degrees/second along the front edge of the apparatus.
- Instruct the patient to report when the target is directly in front of them. They can move their eyes to follow, but should keep their head stationary on the chinrest.
- When the patient says stop, ask them if the target is perfectly centered or should it go a little left or a little to the right to get the most accurate reading.
- Repeat this step 5 times from the left and 5 times from the right and take the mean.

Proprioceptive Hand-Head Egocentric Midline (PS)

- Completely block the patient's vision with 2 occluders or a blindfold.
- Give these specific instructions: "Take your forefinger and point straight, to where your finger is aligned with your nose."
- Repeat 10 times and take the mean.

Visual Open Loop Pointing (VOL)

- Insert the arm occluding shelf and rod.
- Have the patient look at the rod and point to it with the arm out of their view under the shelf.
- Note any deviation in degrees on the protractor from the actual target.
- Repeat 10 times and take the mean.

Additivity Equation

- Add together, in degrees, the total deviation between VS and PS.
- This number should be within 3-4 degrees of the VOL.

Application of Prisms

- Convert the subsequent VOL degrees from the Additivity equation to prism diopters to determine starting lens. The formula for calculating the prism diopters is: $PD=100 \tan \delta$ where $\delta=PS-VS$. An example would be: $PS-VS=10$ degrees. $100 (\tan 10)= 17.6PD$.
- Allow the patient to adapt to the prism over 10 minutes while doing any eye hand coordination task.
- Remeasure VS, PS, VOL to determine effect of prism.
- Trial frame prism and refine as needed.

Note: Redding and Wallace showed significant differences between eye-hand coordination tasks and what they called hallway exposure, with overadditivity being common in the latter. Measurements taken while seated likely will over estimate the prism amount needed for walking/locomotion tasks.

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