



NYU Grossman School of Medicine
**Vision's Involvement with
Stroke-related Acute Vestibular Symptoms**

Neera Kapoor, OD, MS, FAAO, FOVDRA-A
Clinical Professor of Rehabilitation Medicine
NYU Grossman School of Medicine
E-mail: neera.kapoor@nyulangone.org


Dr. Kapoor has no financial disclosures nor conflicts of interest

1

Learning Objectives


Regarding the potential co-morbidity of sensorimotor vision symptoms with stroke-related acute vestibular symptoms, attendees will be able to recognize, interpret/integrate, and apply aspects of the:

- 1) Applicable ophthalmic terminology
- 2) Common types of stroke with associated acute vestibular symptoms (including vertigo, dizziness, and / or disequilibrium)
- 3) Typical sensorimotor vision deficits reported with stroke-related acute vestibular symptoms, such as the abbreviated neurology, associated symptoms, and management approaches



2

**Overview of Applicable
Ophthalmic Terminology**



3

Terminology

• **Accommodation:** refers to maintaining a clear image of an object using the eye's crystalline lens-based mechanism. Accommodation may be assessed under **monocular** (one eye at a time) OR **binocular** (both eyes simultaneously) viewing conditions.

Term	Definition
Amplitude of accommodation	the closest point of clear vision
Accommodative facility	the ability to maintain clarity of vision when looking from near to far/far to near repeatedly, accurately, and on command.
Presbyopia	the normal, age-related, physiological decline in the ability to accommodate (commences one is in the mid- to late 40 years of age)

4

Terminology

• **Versional ocular motility:** refers to the conjunctive (or conjugate) movement of the eyes to follow targets laterally, vertically, or obliquely in one plane, with no change in depth (i.e., 2-dimensional eye movements in the x-y plane). Versional ocular motility may be assessed under **monocular** OR **binocular** viewing conditions.

Type	Description
Fixation	an eye movement in which the eyes are fixed on a target to maintain the target's image on the fovea. (Note: an anomaly of fixation is nystagmus)
Saccades	rapid, step-like conjugate eye movements which redirect the line of sight from one position (or object) in space to another.
Smooth pursuit	a slow, continuous conjugate eye movement used when the eyes follow a slowly-moving object.

5

Terminology

• **Vergence ocular motility:** refers to the disjunctive (or disconjugate) movement of the eyes to track targets binocularly moving in depth (i.e., along the z-axis). Vergence is assessed under **binocular** viewing conditions.

Term	Definition
Fusion	single, cortically-integrated vision under binocular viewing conditions
Heterotropia (strabismus)	a manifest eye misalignment when fusion is not disrupted (i.e., under normal viewing conditions)
Heterophoria	a manifest eye misalignment when fusion is disrupted

6


Terminology

- **Vergence ocular motility:** refers to the disjunctive (or disconjugate) movement of the eyes to track targets binocularly moving in depth (i.e., along the z-axis). Vergence is assessed under **binocular** viewing conditions.

Term	Definition
Near point (i.e., amplitude) of vergence	the closest point of binocular, fused single vision.
Vergence facility	the ability to maintain single vision when looking binocularly from near to far/far to near repeatedly, accurately, and on command.
Stereopsis	relative depth perception under binocular viewing conditions

7

Common Types of Stroke Associated with Acute Vestibular Symptoms



8

Possible Etiologies of Vestibular Symptoms

- Secondary to:
 - a stand-alone vestibular disorder / condition
 - an acquired brain injury (ABI), such as traumatic brain injury (TBI, including concussion), **stroke**, tumor, aneurysm (including clip and coil), encephalopathy (including hydrocephalus), to name a few

Pimentel BN, Fiha VAVDS. Evaluation of vestibular and oculomotor functions in individuals with dizziness after stroke. Arq Neuropsiquiatr. 2019 Jan;77(1):25-32. doi: 10.1590/0004-282X20180154. PMID: 30758439.

9

Determining Etiology of Vestibular Symptoms

- Vestibular symptom presentation at the ED:
 - ranges from 2.1% to 3.6%, with stroke being the underlying cause in approximately 3-5% of these patients
 - warrants appropriately distinguishing between a peripheral vestibular and central nervous system etiology (including stroke, which is one of the most common CNS causes of vestibular symptoms)

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Omron R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Bellolio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. *Acad Emerg Med.* 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Pimental BN, Filho VAVDS. Evaluation of vestibular and oculomotor functions in individuals with dizziness after stroke. *Arq Neuropsiquiatr.* 2019 Jan;77(1):25-32. doi: 10.1590/0004-282X20180154. PMID: 30758439.

10

Typical Review

Diagnosing Stroke in Acute Dizziness and Vertigo: Pitfalls and Pearls

Impact of clinician training background and stroke location on bedside diagnostic accuracy in the acute vestibular syndrome - a meta-analysis

Objectives: To determine the impact of clinician training background and stroke location on bedside diagnostic accuracy in the acute vestibular syndrome.

Methods: A meta-analysis of observational studies was conducted. The search strategy included PubMed, Embase, and Scopus. The search terms were "acute vestibular syndrome", "stroke", "diagnosis", "accuracy", "meta-analysis".

Results: The meta-analysis included 10 studies with a total of 1,000 patients. The overall accuracy of bedside diagnosis was 85%. The accuracy was significantly higher for clinicians with a neurology background (92%) compared to those with a general medicine background (78%).

Conclusions: The accuracy of bedside diagnosis in the acute vestibular syndrome is significantly higher for clinicians with a neurology background. This suggests that specialized training is important for accurate diagnosis.

Keywords: acute vestibular syndrome, stroke, diagnosis, accuracy, meta-analysis.

• Saber Tehrani AS, Kattah JC, Kerber KA, Gold DR, Zee DS, Urrutia VC, Newman-Toker DE. Diagnosing Stroke in Acute Dizziness and Vertigo: Pitfalls and Pearls. *Stroke.* 2018 Mar;49(3):788-795. doi: 10.1161/STROKEAHA.117.016379. Epub 2018 Feb 19. PMID: 29459396; PMCID: PMC5829023.

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Omron R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Bellolio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. *Acad Emerg Med.* 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Tarrutier AA, Gold D, Wang Z, Robinson KA, Kattah JC, Mantokoudis G, Saber Tehrani AS, Zee DS, Edlow JA, Newman-Toker DE. Impact of Clinician Training Background and Stroke Location on Bedside Diagnostic Test Accuracy in the Acute Vestibular Syndrome - A Meta-Analysis. *Ann Neurol.* 2023 Aug;94(2):295-308. doi: 10.1002/ana.26661. Epub 2023 Apr 27. PMID: 37038843; PMCID: PMC10524166.

11

Common Types of Stroke Associated with Acute Vestibular Symptoms

- Brainstem stroke
- Cerebellar stroke
- Vestibular stroke
- Posterior circulation strokes:
 - Basilar artery occlusion
 - Lateral medullary stroke
 - Vertebrobasilar insufficiency

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Omron R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Bellolio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. *Acad Emerg Med.* 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Schneider AM, Neuhaus AA, Hadley G, Balami JS, Harston GW, DeLuca GC, Buchan AM. Posterior circulation ischaemic stroke diagnosis and management. *Clin Med (Lond).* 2023 May;23(3):219-227. doi: 10.7861/clinmed.2022-0499. PMID: 37236792; PMCID: PMC11046504.

• Tarrutier AA, Gold D, Wang Z, Robinson KA, Kattah JC, Mantokoudis G, Saber Tehrani AS, Zee DS, Edlow JA, Newman-Toker DE. Impact of Clinician Training Background and Stroke Location on Bedside Diagnostic Test Accuracy in the Acute Vestibular Syndrome - A Meta-Analysis. *Ann Neurol.* 2023 Aug;94(2):295-308. doi: 10.1002/ana.26661. Epub 2023 Apr 27. PMID: 37038843; PMCID: PMC10524166.

12

Common Types of Stroke Associated with Acute Vestibular Symptoms

- Ischemic strokes have a significantly higher incidence than hemorrhagic strokes
- Anterior circulation strokes (ACS) are significantly more common than posterior circulation strokes (PCS), but PCS:
 - account for approximately 20% of ischemic strokes
 - have some etiologies (such as basilar artery occlusion) with a very poor prognosis

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Omron R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Belloio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. *Acad Emerg Med.* 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Schneider AM, Neuhaus AA, Hadley G, Balami JS, Harston GW, DeLuca GC, Buchan AM. Posterior circulation ischaemic stroke diagnosis and management. *Clin Med (Lond).* 2023 May;23(3):219-227. doi: 10.7861/clinmed.2022-0499. PMID: 37236792; PMCID: PMC11046504.

• Tamnutzer AA, Gold D, Wang Z, Robinson KA, Kattah JC, Mantokoudis G, Saber Tehrani AS, Zee DS, Edlow JA, Newman-Toker DE. Impact of Clinician Training Background and Stroke Location on Bedside Diagnostic Test Accuracy in the Acute Vestibular Syndrome - A Meta-Analysis. *Ann Neurol.* 2023 Aug;94(2):295-308. doi: 10.1002/ana.26661. Epub 2023 Apr 27. PMID: 37038843; PMCID: PMC10524166.

13

Determining Etiology of Vestibular Symptoms

- Vestibular symptom etiology at the ED can be challenging to determine, but bedside testing with HINTS has greater than 90% sensitivity of distinguishing between peripheral and central (including stroke, especially posterior circulation stroke) etiology:
 - head impulse test (normal)
 - nystagmus pattern (fast-phase changes direction)
 - test for skew (skew deviation)

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Omron R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Belloio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. *Acad Emerg Med.* 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Schneider AM, Neuhaus AA, Hadley G, Balami JS, Harston GW, DeLuca GC, Buchan AM. Posterior circulation ischaemic stroke diagnosis and management. *Clin Med (Lond).* 2023 May;23(3):219-227. doi: 10.7861/clinmed.2022-0499. PMID: 37236792; PMCID: PMC11046504.

• Tamnutzer AA, Gold D, Wang Z, Robinson KA, Kattah JC, Mantokoudis G, Saber Tehrani AS, Zee DS, Edlow JA, Newman-Toker DE. Impact of Clinician Training Background and Stroke Location on Bedside Diagnostic Test Accuracy in the Acute Vestibular Syndrome - A Meta-Analysis. *Ann Neurol.* 2023 Aug;94(2):295-308. doi: 10.1002/ana.26661. Epub 2023 Apr 27. PMID: 37038843; PMCID: PMC10524166.

14

Determining Etiology of Vestibular Symptoms

- Vestibular symptom etiology at the ED is reported to be more accurately determined with HINTS (plus a cranial nerve screening for hearing) compared to with MRI/MRA.
- Saccade metrics and vestibulo-ocular reflex (VOR) gain are other parameters that can benefit determining the etiology of vestibular symptoms (Michailidou et al., 2024)

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Omron R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Belloio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. *Acad Emerg Med.* 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Michailidou E, Korda A, Wyss T, Bardins S, Schneider E, Morrison M, Wagner F, Caversaccio MD, Mantokoudis G. The value of saccade metrics and VOR gain in detecting a vestibular stroke. *J Vestib Res.* 2024;34(1):49-61. doi: 10.3233/VES-230083. PMID: 38160379.

• Schneider AM, Neuhaus AA, Hadley G, Balami JS, Harston GW, DeLuca GC, Buchan AM. Posterior circulation ischaemic stroke diagnosis and management. *Clin Med (Lond).* 2023 May;23(3):219-227. doi: 10.7861/clinmed.2022-0499. PMID: 37236792; PMCID: PMC11046504.

• Tamnutzer AA, Gold D, Wang Z, Robinson KA, Kattah JC, Mantokoudis G, Saber Tehrani AS, Zee DS, Edlow JA, Newman-Toker DE. Impact of Clinician Training Background and Stroke Location on Bedside Diagnostic Test Accuracy in the Acute Vestibular Syndrome - A Meta-Analysis. *Ann Neurol.* 2023 Aug;94(2):295-308. doi: 10.1002/ana.26661. Epub 2023 Apr 27. PMID: 37038843; PMCID: PMC10524166.

15

Determining Etiology of Vestibular Symptoms

- Concerns with using HINTS in the ED:
 - relate to the examiner's skills with interpreting results, in particular with nystagmus and skew assessments (Kung et al., 2018; Saber Tehrani et al., 2018; Pelletier et al., 2023; Jaganathan et al., 2024)
 - prompted the development of a digital version of the HINTS, which hopefully will be commercially available as a mobile health app in the near future (Bastani et al., 2024)

• Bastani PB, Riero H, Badhian S, Otero-Milian J, Farrell N, Parker M, Newman-Toker D, Zhu Y, Saber Tehrani A. Quantifying induced Nystagmus Using a Smartphone Eye Tracking Application (EyePhone). J Am Heart Assoc. 2024 Jan 16;13(2):e030927. doi: 10.1161/JAHA.123.030927. Epub 2024 Jan 16. PMID: 38226513, PMCID: PMC10926800.

• Jaganathan N, Mohamed MH, Md Pauzi AL, Mahayidin H, Hanapai AF, Wan Sulaiman WA, Basri H, Inche Mat L. Video head impulse test in stroke: a review of published studies. Front Neurol. 2024 Mar 1;15:1339039. doi: 10.3389/fneur.2024.1339039. PMID: 38497038, PMCID: PMC10940455.

• Kung NH, Van Stavern GP, Gold DR. HINTS in the Acute Vestibular Syndrome: Pearls and Pitfalls. J Neuroophthalmol. 2018 Jun;38(2):244-250. doi: 10.1097/WNO.0000000000000608. PMID: 29319559.

• Pelletier J, Koyfman A, Long B. Pearls for the Emergency Clinician: Posterior Circulation Stroke. J Emerg Med. 2023 Nov;65(5):e414-e426. doi: 10.1016/j.jemermed.2023.07.007. Epub 2023 Jul 20. PMID: 37806810. (as well as 2024 J Emerg Med Feb)

• Saber Tehrani AS, Kattah JC, Kerber KA, Gold DR, Zee DS, Urrutia VC, Newman-Toker DE. Diagnosing Stroke in Acute Dizziness and Vertigo: Pitfalls and Pearls. Stroke. 2018 Mar;49(3):788-795. doi: 10.1161/STROKEAHA.117.016979. Epub 2018 Feb 19. PMID: 29459396, PMCID: PMC5829023.

16

Stroke Associated Acute Vestibular Symptoms: Vision's Involvement

- Distinguishing between central (for stroke has the highest occurrence) and peripheral etiology of acute vestibular symptoms involves assessing for:
 - Nystagmus
 - Skew
 - Saccades
 - VOR gain

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Orrmon R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Belloio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. Acad Emerg Med. 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Cohen AH. Vision rehabilitation for visual-vestibular dysfunction: The role of the neuro-optometrist. NeuroRehabilitation 2013; 32: 483-492. DOI:10.3233/NRE-130871.

17

Stroke Associated Acute Vestibular Symptoms: Vision's Involvement

- Once it is determined that there is stroke involvement, asking history questions and observing more basic aspects of sensorimotor vision function in the ED may enhance the overall management of the patient's symptoms

• Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Orrmon R, Sharif S, Siket M, Upadhye S, E Silva LOJ, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Belloio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. Acad Emerg Med. 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.

• Cohen AH. Vision rehabilitation for visual-vestibular dysfunction: The role of the neuro-optometrist. NeuroRehabilitation 2013; 32: 483-492. DOI:10.3233/NRE-130871.

18

Common Vision Deficits Addressed Regarding Visual-Vestibular Symptoms	
Deficit of:	Primary Associated Symptom:
Tear Film Integrity	Distorted clarity/gritty sensation, which <i>varies with blinking</i>
Light-Dark Adaptation	Elevated light sensitivity
Accommodation	Constant/intermittent blur
Vergence Ocular Motility	Constant/intermittent eyestrain/diplopia <i>eliminated with monocular occlusion</i>
Versional Ocular Motility	Slower, less accurate reading /difficulty sustaining gaze, shifting gaze, or tracking targets
Visual processing/ Visual-Vestibular Interaction	Slower speed/impaired visual memory and visual-spatial processing / Vestibular symptoms, <i>exacerbated</i> by: 1) visually-stimulating environs and 2) <i>eye/head/body</i> movements

19

Visual-Vestibular Symptoms

- Typically comprise vestibular symptoms (dizziness, disequilibrium, lightheadedness, and/or vertigo) that may be exacerbated with:
 - multiple visual stimulation, impeding foreground / background discrimination
and / or
 - eye / head / body movement, often accompanied by nausea, vomiting, mood changes, cognitive deficits, and / or headache

Cohen AH. Vision rehabilitation for visual-vestibular dysfunction: The role of the neuro-optometrist. NeuroRehabilitation 2013; 32: 483-492, DOI:10.3233/NRE-130871.

20

Interprofessional Neuro-rehabilitation Colleagues

Deficit of Visual-Vestibular Interaction	For diagnosis: 1) Physiatrist, Neurologist, Neurotologist, or Oto-neurologist – evaluation and management (E & M) of vestibular symptoms (including headache, as with migraine-associated vertigo / vestibular migraine) 2) Primary eye care doctor - E & M of refractive state and integrity of ocular health
	For rehabilitation (rehab): 1) Physiotherapy (PT) or Occupational Therapy (OT) - E & M for vestibular rehab 2) PT, OT, or Optometry - E & M for vision rehab 3) Neuropsychologist or Speech / Language pathologist - E & M for psychological and / or cognitive rehab

21

Common Sensorimotor Vision Deficits Reported with Stroke-related Acute Vestibular Symptoms



22

Common Ophthalmic Treatment Modalities


Optical	<ul style="list-style-type: none"> Lenses Tints (gray, blue, Brain Power Inc's (BPI's) Blue, FL 41, and tints determined with Syntonics) Anti-reflective coating Blue wavelength light-filtering
Correcting (fusional) Prism	<ul style="list-style-type: none"> Large-magnitude deviations Small-magnitude deviations with poor compensatory ability
Occlusion	<ul style="list-style-type: none"> Varying degrees: selective, graded (using translucent material to blur / degrade image), or complete (i.e., opaque patch)

23

Common Optometric Treatment Modalities

Rehabilitation

- Habituated / adaptive
- Compensatory
- Restorative
- OR Some combination of the above



Scheiman M, Wick B: Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders, Fifth Edition. Philadelphia, PA, Lippincott Williams and Wilkins, 2019


24

Common Vision Deficits Addressed Regarding Visual-Vestibular Symptoms	
Deficit of:	Primary Associated Symptom:
Tear Film Integrity	Distorted clarity/gritty sensation, which <i>varies with blinking</i>
Light-Dark Adaptation	Elevated light sensitivity
Accommodation	Constant/intermittent blur
Vergence Ocular Motility	Constant/intermittent eyestrain/diplopia <i>eliminated with monocular occlusion</i>
Versional Ocular Motility	Slower, less accurate reading /difficulty sustaining gaze, shifting gaze, or tracking targets
Visual processing/ Visual-Vestibular Interaction	Slower speed/impaired visual memory and visual-spatial processing / Vestibular symptoms, <i>exacerbated</i> by: 1) visually-stimulating environs and 2) eye/head/body movements


25

Sensorimotor Vision Deficits: Management	
Deficit of Tear Film Integrity	Abbreviated Underlying Neurology: Not definitive, but a probable impact may be via the: 1) lacrimal gland, which is innervated by the facial nerve, OR 2) superior division of the trigeminal nerve
	Primary Associated Symptom: Distorted clarity/ gritty sensation, <i>varying with blinking</i>
	Possible Treatment Options: Compensatory: Prescribe artificial tears and/or insert punctal plugs (if needed)


26

Sensorimotor Vision Deficits: Management	
Deficit of Light-Dark Adaptation	Primary Associated Symptom: Elevated or altered light sensitivity (to all lights OR specifically to fluorescent lights) despite unremarkable ocular health (i.e., no evident ocular inflammation or infection)
	
http://www.chadwickoptical.com/product/nora-polytrauma-filter-kit/ accessed 11 March 2024	<ul style="list-style-type: none"> • Kapoor N, Balcer LJ, and Rizzo JR. (2019) Vision problems. In <i>Textbook of Traumatic Brain Injury, Third Edition</i> (Edited by Silver JM, McAllister TW, and Arciniegas DB). American Psychiatric Publishing, Inc., Washington, DC, pp. 507-524. • Jolie JM, Gustafson JA, Fonda JR, Fortier CB, Milberg WP, Fortenbaugh FC. Association of mild traumatic brain injury, post-traumatic stress disorder, and other comorbidities on photosensitivity. <i>Optom Vis Sci.</i> 2024 Feb 1;101(2):90-98. doi: 10.1097/OPX.0000000000002104. Epub 2024 Jan 10. PMID: 38408306.


27

Sensorimotor Vision Deficits: Management	
Deficit of Light-Dark Adaptation	Neurological Correlates: <ul style="list-style-type: none">• Current hypothesis for neural mechanism: precise location cortical or subcortical substrates remains unknown• However, a retrospective paper by Jotie et al. (2024 in Optometry and Vision Science) suggested that individuals with <u>sensory sensitivity</u> might possess a <u>higher basal level of sympathetic outflow</u> relative to those without sensory sensitivity: <u>high sympathetic outflow could mean increased relative (baseline) pupillary dilation => increased photosensitivity</u>
 http://www.chadwickoptical.com/product/nora-polytrauma-filter-kit/ ; accessed 11 March 2024	Jotie JM, Gustafson JA, Fonda JR, Fortier CB, Milberg WP, Fortenbaugh FC. Association of mild traumatic brain injury, post-traumatic stress disorder, and other comorbidities on photosensitivity. Optom Vis Sci. 2024 Feb 1;101(2):90-98. doi: 10.1097/OPX.0000000000002104. Epub 2024 Jan 10. PMID: 38408306.

28

Sensorimotor Vision Deficits: Management	
Deficit of Light-Dark Adaptation	Possible Restorative Treatment Options: by incorporating syntonics to alter the patient's neurologic response to light
 http://www.chadwickoptical.com/product/nora-polytrauma-filter-kit/ ; accessed 11 March 2024	Possible Compensatory Treatment Options: <ul style="list-style-type: none">• Applications (such as with google chrome) for digital devices with blue wavelength light-filtering, reverse contrast, or color contrast, to name a few• Overlays and/or blue wavelength light-filtering for the viewing material (hard copy or screen)

29

Sensorimotor Vision Deficits: Management	
Deficit of Light-Dark Adaptation	Possible Compensatory Treatment Options: <ul style="list-style-type: none">• For the spectacle lens:<ul style="list-style-type: none">• Anti-reflective coating• Tints (e.g., 60-70% for outdoors and 15-30% for indoors). For photosensitivity that is:<ol style="list-style-type: none">1) <u>general</u>, consider tints that are brown, gray, and kalichrome2) <u>selective</u> (to fluorescent lighting, computers, and digital devices), consider a Brain Power Inc (BPI) Omega blue, tints determined by Syntonics, gray, FL-41 tint, or blue wavelength light-filtering (e.g., https://shopfelixgray.com/)
 http://www.chadwickoptical.com/product/nora-polytrauma-filter-kit/ ; accessed 11 March 2024	

30

Common Vision Deficits Addressed Regarding Visual-Vestibular Symptoms	
Deficit of:	Primary Associated Symptom:
Tear Film Integrity	Distorted clarity/gritty sensation, which <i>varies with blinking</i>
Light-Dark Adaptation	Elevated light sensitivity
Accommodation	Constant/intermittent blur
Vergence Ocular Motility	Constant/intermittent eyestrain/diplopia <i>eliminated with monocular occlusion</i>
Versional Ocular Motility	Slower, less accurate reading /difficulty sustaining gaze, shifting gaze, or tracking targets
Visual processing/ Visual-Vestibular Interaction	Slower speed/impaired visual memory and visual-spatial processing / Vestibular symptoms, <i>exacerbated</i> by: 1) visually-stimulating environs and 2) eye/head/body movements

31

Signal Detection Theory (SDT)

Fundamental Principle of Human Sensory Processing (including vision): the ability to detect the signal from the noise (i.e., **signal detection theory**):

- is a psychophysical principle of neurologically-mediated perceptual function
- precedes the requisite sensorimotor response.

•Vernet M, Japee S, Lokey S, Ahmed S, Zachariou V, and Ungerleider LG. (2019) Endogenous visuospatial attention increases visual awareness independent of visual discrimination sensitivity. *Neuropsychologia*. 2019 May; 128:297-304. doi:10.1016/j.neuropsychologia.2017.08.015
 •Gepshtein S, Wang Y, He F, et al. (2020) A perceptual scaling approach to eyewitness identification. *Nat Commun* 11, 3380. <https://doi.org/10.1038/s41467-020-17194-5>
 •Baek J, Doshier BA, and Lu Z-L (2021). Visual attention in spatial cueing and visual search. *Journal of Vision*. 2021; 21(3):1, 1–24. <https://doi.org/10.1167/jov.21.3.1>.
 •Landry M, Da Silva Castanheira J, Sackur J, & Raz A (2021). Investigating how the modularity of visuospatial attention shapes conscious perception using type I and type II signal detection theory. *Journal of Experimental Psychology: Human Perception and Performance*, 47(3), 402–422. <https://doi.org/10.1037/xhp0000810>

32

SDT and Visual-vestibular Conditions

My hypothesis is that, in those with visual-vestibular symptoms:


- **signal detection** (or, as it is more colloquially referred to, “filtering”) becomes impaired such that **everything (both stimulus/signal and noise) is perceived as a “stimulus” or “signal”**
- impaired **signal detection (SD)** impedes the initiation of an appropriate sensorimotor response to the actual stimulus

WVU Langone Health

33

SDT and Visual-vestibular Conditions

- An example of impaired **SD**: difficulty identifying, tracking, as well as reaching and / or interacting with a stimulus in a visually-crowded environment: this is common in those with visual-vestibular symptoms
- Vision rehabilitation works to improve **SD** by increasing the accuracy and speed of initiating an appropriate response to the actual stimulus regarding the following areas of sensorimotor vision processing:
 - Accommodation
 - Vergence ocular motility
 - Versonal ocular motility
 - Visual processing / Visual-vestibular interaction



34

Proposed SDT-Based Paradigm for Sequencing Rehabilitation Techniques for Vision Deficits


For sequencing rehabilitation techniques for these four aspects of sensorimotor vision function, consider the "start low and go slow" approach:

Starting with:	Systematically/gradually:
No (or minimal) targets in the background	Increase the number of targets in the background
A lower number of repetitions of the given technique	Increase the number of repetitions of the given technique
A slower velocity of the given vision rehab technique	Increase the velocity of the given vision rehab technique
The patient being seated	Transition (when possible) the patient from sitting to standing to marching/stepping in place

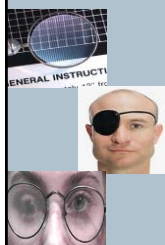
35

Sensorimotor Vision Deficits: Management

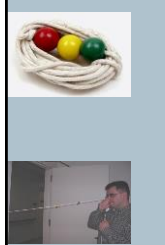
Deficit of Accommodation (for pre-presbyopes)	Abbreviated Underlying Neurology: Stimulated by defocus blur / mediated by the autonomic nervous system (ANS)
	Primary Associated Symptom: Constant/ intermittent blur
	Possible Treatment Options: 1) Compensatory: Prescribe lenses. 2) Restorative: build and equalize amplitudes, normalize facility, and build sustainability using techniques at near or far either in <i>free space</i> or with <i>computerized software programs</i> .




36

Sensorimotor Vision Deficits: Management	
Deficit of Vergence Ocular Motility 	Abbreviated Underlying Neurology: Mesencephalic reticular formation, medial longitudinal fasciculus (MLF), midbrain, pons, cerebellum, and frontal eye fields (FEF)
	Primary Associated Symptom: Constant/ intermittent eyestrain / overlapping images/ diplopia <i>eliminated with monocular occlusion</i>
	Possible Compensatory Treatment Options: <ol style="list-style-type: none"> 1) Prescribe fusional prism when possible. 2) If not possible, then consider occlusion: partial, sectoral, graded, or complete.


37

Sensorimotor Vision Deficits: Management	
Deficit of Vergence Ocular Motility 	Possible Restorative Treatment Options
	If fusion is possible in any position of gaze at any viewing distance, commence vergence training (ramp and step) to increase the range over which fusion is perceived and build vergence facility/ sustainability with techniques performed at near and/or far: <ol style="list-style-type: none"> 1) in <i>free space</i>. 2) with <i>computerized software programs</i>.

38

Sensorimotor Vision Deficits: Management	
Deficit of Versional Ocular Motility (fixation, saccades, pursuit) 	Abbreviated Underlying Neurology: FEF, supplemental eye fields, dorsolateral prefrontal cortex, cingulate eye field, parietal lobe, paramedian pontine reticular formation (PPRF), basal ganglia, superior colliculus, and cerebellum
	Primary Associated Symptom: Slower, less accurate reading/difficulty sustaining gaze, shifting gaze, or tracking targets
	Possible Compensatory Treatment Options: <ol style="list-style-type: none"> 1)Employ typoscopic approach and double-spacing of text. 2)Utilize large-print if habitual VA is poorer than 20/40. 3)Prescribe yoked prism for gaze palsies

39

Sensorimotor Vision Deficits: Management	
Deficit of Versional Ocular Motility (fixation, saccades, pursuit)	Possible Restorative Treatment Options
	Build accuracy of fixation, saccadic scanning and searching, and smooth pursuit with small-, moderate-, and large-angle eye movements using techniques at near or far: 1) in <i>free space</i> . 2) with <i>computerized software programs</i> .
	

40

Sensorimotor Vision Deficits: Management	
Deficit of Visual processing	Primary Associated Symptom: Slower or impaired visual spatial memory/ visual-motor integration/ visual-spatial processing
Ventral Stream (“what is it?”)	Ventral Stream Pathway
<ul style="list-style-type: none"> Uses a representational system that is rich and detailed, but not precise metrically, for: <ul style="list-style-type: none"> form perception object identification (i.e., examines the visual array and identifies different objects in the scene) 	<ul style="list-style-type: none"> V1 in the occipital cortex moving anteriorly through V2, the ventral posterior aspect of V3, V4, and finally reaching the posterior inferior temporal lobe for processing changes in ventral stream processing are directed by the ventral lateral prefrontal cortex (VLPFC)


41

Sensorimotor Vision Deficits: Management	
Deficit of Visual processing	Primary Associated Symptom: Slower or impaired visual spatial memory/ visual-motor integration/ visual-spatial processing
Dorsal Stream (“where/how is it?”)	Dorsal Stream Pathway
<ul style="list-style-type: none"> Uses precise egocentric coding of location and orientation of object for: <ul style="list-style-type: none"> spatial representation via the inferior parietal lobule visually-guided action and motion perception of objects, as well as ocular and limb motility, in the superior parietal lobule 	<ul style="list-style-type: none"> V1 in the occipital cortex moving anteriorly through V2, the dorso-medial area of V3, the middle temporal area (V5/MT), and finally reaching the parietal lobe for processing. changes in dorsal stream processing are directed by the dorso-lateral prefrontal cortex (DLPFC)


42

Sensorimotor Vision Deficits: Management	
Deficit of Visual Processing	<p>Possible Management Options:</p> <p>Compensatory, Habituated, and Restorative:</p> <ul style="list-style-type: none"> Starting at a slower speed to ensure accuracy of the action. Employ visual-motor integration while seated/ standing or stationary/ ambulatory Perform techniques (for visual motor, visual perceptual, and visual spatial training) at near and/or far either in free space or with computerized software programs.

43

Sensorimotor Vision Deficits: Management	
Deficit of Visual-Vestibular Interaction	<p>Abbreviated Underlying Neurology:</p> <p>Vestibular ocular reflex (VOR)-specifically, the horizontal VOR is generated by CNs III and VI communicating with CN VIII via the MLF</p>
	<p>Primary Associated Symptoms:</p> <p>Vestibular symptoms, which are exacerbated with:</p> <ol style="list-style-type: none"> multiply visually-stimulating environments, impeding foreground / background discrimination, and / or eye / head / body movements


44

Sensorimotor Vision Deficits: Management	
Deficit of Visual-Vestibular Interaction	<p>Possible Compensatory Management Options:</p> <ul style="list-style-type: none"> Optimize tear film and refractive correction. Prescribe separate single vision distance and near corrections (eliminate multifocal spectacles when possible- in particular for ambulation), with: <ul style="list-style-type: none"> prism as indicated. tints / filtering treatments as indicated, such as 15-20% {BPI's omega blue, gray, FL-41} tint, tints determined with Syntonics, and / or blue wavelength light-filtering
	

45

Sensorimotor Vision Deficits: Management

<p>Deficit of Visual-Vestibular Interaction</p>	<p>Possible Habituaive and Restorative Treatment Option - Visual-vestibular habituation paradigm:</p> <ul style="list-style-type: none"> • Start with <u>slower</u> velocity, <u>lower number of repetitions</u> of pursuit and saccades, <u>minimal targets</u> in the background, and being <u>seated</u>. • Systematically and gradually: <ul style="list-style-type: none"> • Increase <u>velocity</u> of EOMs • Increase the <u>number of repetitions</u> of task • Increase the <u>number of targets</u> in the background • Then move the patient from <u>sitting to standing to marching in place</u>
--	---



46

Take-home Points

Regarding management of vision's involvement with stroke-related acute vestibular symptoms, you should now be familiar with:

- 1) Common ophthalmic terminology
- 2) Common types of stroke with vestibular and visual symptoms
- 3) Visual-vestibular symptoms, which refer to vestibular symptoms that are exacerbated with:
 - a) multiply visually-stimulating environments, and/or
 - b) eye / head / body movement
- 4) The benefit of referring for PT, OT, rehabilitative optometry, or neuro-optometry to address stroke-related visual-vestibular symptoms from a management perspective

47

Take-home Points

Regarding management of visual-vestibular symptoms, you should now be familiar with:

- 5) Common vision deficits reported in those with visual-vestibular symptoms, including the:
 - a) Abbreviated neurology
 - b) Primary vision symptom(s)
 - c) Management options being habituaive, compensatory, and restorative
 - d) Restorative management approach for certain sensorimotor vision deficits often utilizing a signal detection theory (SDT)-based paradigm

48

Special Thanks to All of You --- and:


- Drs. Salman Azhar, Laura Balcer, Matthew Fink, Steven Flanagan, Steven Galetta, Jamshid Ghajar, Brian David Greenwald, Douglas Katz, Dana Leifer, John Laddy, Gregory O'Shanick, J.R. Rizzo, Joel Stein, Ross Zafonte, and Nathan Zasler
- Drs. Kenneth J. Ciuffreda, Allen Cohen, Jeffrey Cooper, Irwin B. Suchoff, and Barry Tannen.
- Faculty / Staff / Administration at NYU-Langone Health
- Optometric organizations for their support regarding increasing awareness of vision care:
 - American Optometric Association
 - American Academy of Optometry
 - Optometric Vision Development and Rehabilitation Association
 - Neuro-Optometric Rehabilitation Association



49

**Stroke-related Acute Vestibular Symptoms:
Relevant Publications**


- Bastani PB, Rieiro H, Badhian S, Otero-Millan J, Farrell N, Parker M, Newman-Toker D, Zhu Y, Saber Tehrani A. Quantifying Induced Nystagmus Using a Smartphone Eye Tracking Application (EyePhone). J Am Heart Assoc. 2024 Jan 16;13(2):e030927. doi: 10.1161/JAHA.123.030927. Epub 2024 Jan 16. PMID: 38226513; PMCID: PMC10926800.
- Edlow JA, Carpenter C, Akhter M, Khoujah D, Marcolini E, Meurer WJ, Morrill D, Naples JG, Ohle R, Omron R, Sharif S, Siket M, Upadhye S, E Silva LO, Sundberg E, Tarrt K, Vanni S, Newman-Toker DE, Bellolio F. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): Acute dizziness and vertigo in the emergency department. Acad Emerg Med. 2023 May;30(5):442-486. doi: 10.1111/acem.14728. PMID: 37166022.
- Jaganathan N, Mohamed MH, Md Pauzi AL, Mahayidin H, Hanngai AF, Wan Sulaiman WA, Basri H, Inche Mat L. Video head impulse test in stroke: a review of published studies. Front Neurol. 2024 Mar 1;15:1339039. doi: 10.3389/fneur.2024.1339039. PMID: 38497038; PMCID: PMC10940455.
- Kung NH, Van Stavern GP, Gold DR. HINTS in the Acute Vestibular Syndrome: Pearls and Pitfalls. J Neuroophthalmol. 2018 Jun;38(2):244-250. doi: 10.1097/WNO.0000000000000608. PMID: 29319559.
- Michailidou E, Korda A, Wyss T, Bardins S, Schneider E, Morrison M, Wagner F, Caversaccio MD, Mantokoudis G. The value of saccade metrics and VOR gain in detecting a vestibular stroke. J Vestib Res. 2024;34(1):49-61. doi: 10.3233/JVES-230083. PMID: 38160379.
- Pelletier J, Koyfman A, Long B. Pearls for the Emergency Clinician: Posterior Circulation Stroke. J Emerg Med. 2023 Nov;65(5):e414-e426. doi: 10.1016/j.jemermed.2023.07.007. Epub 2023 Jul 20. PMID: 37806810. (as well as 2024 J Emerg Med Feb)



50

**Stroke-related Acute Vestibular Symptoms:
Relevant Publications**

- Pimentel BN, Filha VAVDS. Evaluation of vestibular and oculomotor functions in individuals with dizziness after stroke. Arq Neuropsiquiatr. 2019 Jan;77(1):25-32. doi: 10.1590/0004-282X20180154. PMID: 30758439.
- Saber Tehrani AS, Kattah JC, Kerber KA, Gold DR, Zee DS, Urrutia VC, Newman-Toker DE. Diagnosing Stroke in Acute Dizziness and Vertigo: Pitfalls and Pearls. Stroke. 2018 Mar;49(3):788-795. doi: 10.1161/STROKEAHA.117.016979. Epub 2018 Feb 19. PMID: 29459396; PMCID: PMC5829023.
- Schneider AM, Neuhaus AA, Hadley G, Balami JS, Harston GW, DeLuca GC, Buchan AM. Posterior circulation ischaemic stroke diagnosis and management. Clin Med (Lond). 2023 May;23(3):219-227. doi: 10.7861/clinmed.2022-0499. PMID: 37236792; PMCID: PMC11046504.
- Tarnutzer AA, Gold D, Wang Z, Robinson KA, Kattah JC, Mantokoudis G, Saber Tehrani AS, Zee DS, Edlow JA, Newman-Toker DE. Impact of Clinician Training Background and Stroke Location on Bedside Diagnostic Test Accuracy in the Acute Vestibular Syndrome - A Meta-Analysis. Ann Neurol. 2023 Aug;94(2):295-308. doi: 10.1002/ana.26661. Epub 2023 Apr 27. PMID: 37038843; PMCID: PMC10524166.



51

Visual and Vestibular Symptoms: Relevant Publications

- Bronstein AM. Vision and vertigo: some visual aspects of vestibular disorders. *Journal of Neurology* 2004; 251:381-387.
- Bucci, M.P., Kapoula, Z., Yang, Q., Wiener-Vacher, S., & Bremond-Gignac, D. Abnormality of vergence latency in children with vertigo. *Journal of Neurology* 2004; 251: 204-213.
- Chandrasekhar S, Kapoor N. Neuro-optometric evaluation and rehabilitation as a useful adjunct in the management of the complex dizzy patient. *Annual meeting of the American Neurology Society* in San Diego, CA April 28, 2007.
- Sambur I, Chandrasekhar S, Kapoor N. Migraine-associated dizziness: neuro-optometric findings and treatment. *Annual meeting of the American Neurology Society* in Las Vegas, NV on May 2, 2010.
- Kapoula Z, Gaertner C, Yang Q, Denise P, Toupet M. Vergence and Standing Balance in Subjects with Idiopathic Bilateral Loss of Vestibular Function. *PLoS ONE* 2013; 8(6): e66652.
- Cohen AH. Vision rehabilitation for visual-vestibular dysfunction: The role of the neuro-optometrist. *NeuroRehabilitation* 2013; 32: 483-492, DOI:10.3233/NRE-130871.
- Leigh RJ, Zee DS. *The Neurology of Eye Movements*, 5th Ed. New York: Oxford University Press, 2015.
- Wallace B and Lifshitz J. Traumatic brain injury and vestibulo-ocular function: current challenges and future prospects. *Eye and Brain* 2016; 8: 153-64, <http://dx.doi.org/10.2147/EB.S82670>



52

Objective Efficacy of Rehabilitating Sensorimotor Vision: Relevant Publications

- Kapoor N, Ciuffreda KJ, and Han Y. Oculomotor rehabilitation in acquired brain injury: a case series. *Arch Phys Med Rehabil* 2004; 85(10): 1667-1678.
- Ciuffreda KJ, Han Y, Kapoor N, and Ficarra AP. Oculomotor rehabilitation for reading in acquired brain injury. *NeuroRehabil* 2006; 21(1): 9-21.
- Green W, Ciuffreda KJ, Thiagarajan P, Szymanowicz D, Ludlam DP, Kapoor N. (2010) Accommodation in mild traumatic brain injury. *Journal Rehabilitation Research and Development* 47(3):183-200.
- Thiagarajan P, Lakshminarayanan V, Bobier WR. Effect of vergence adaptation and positive fusional vergence training on oculomotor parameters. *Optom Vis Sci* 2010; 87 (7): 487-93.
- Szymanowicz D, Ciuffreda KJ, Thiagarajan P, Ludlam DP, Green W, Kapoor N. Vergence in mild traumatic brain injury: a pilot study. *Journal Rehabilitation Research and Development* 2012;49 (7): 1083-1100.
- Thiagarajan P, Ciuffreda KJ. Effect of oculomotor rehabilitation on vergence responsivity in mild traumatic brain injury. *J Rehabil Res Dev.* 2013;50(9):1223-40.
- Thiagarajan P, Ciuffreda KJ. Effect of oculomotor rehabilitation on accommodative responsivity in mild traumatic brain injury. *J Rehabil Res Dev.* 2014;51(2):175-91.
- Thiagarajan P, Ciuffreda KJ. Versional eye tracking in mild traumatic brain injury (mTBI): effects of oculomotor training (OMT). *Brain Inj.* 2014;28(7):930-43.
- Scheiman MM, Talasan H, Mitchell GL, Alvarez TL. Objective assessment of vergence after treatment of concussion-related CI: a pilot study. *Optometry and Vision Science* 2017; 94(1): 74-88.



53

Signal Detection Theory: Relevant Publications

- Vernet M, Japee S, Lokey S, Ahmed S, Zachariou V, and Ungerleider LG. (2019) Endogenous visuospatial attention increases visual awareness independent of visual discrimination sensitivity. *Neuropsychologia*. 2019 May; 128:297-304. doi:10.1016/j.neuropsychologia.2017.08.015
- Gepshtein S, Wang Y, He F, et al. (2020) A perceptual scaling approach to eyewitness identification. *Nat Commun* 11, 3380. <https://doi.org/10.1038/s41467-020-17194-5>
- Baek J, Doshier BA, and Lu Z-L. (2021). Visual attention in spatial cueing and visual search. *Journal of Vision*. 2021; 21(3):1, 1-24. <https://doi.org/10.1167/jov.21.3.1>.
- Landry M, Da Silva Castanheira J, Sackur J, & Raz A (2021). Investigating how the modularity of visuospatial attention shapes conscious perception using type I and type II signal detection theory. *Journal of Experimental Psychology: Human Perception and Performance*, 47(3), 402-422. <https://doi.org/10.1037/xhp0000810>



54

General Vision References

- Chang A, Cohen A.H., Kapoor N (2013) Top-down visual framework for optometric vision therapy for those with traumatic brain injury, *Optometry and Visual Performance*: Vol. 1, Issue 2, 82-93
- Chang A, Yu XX, and Ritter S. (2016) *Neurovision Rehabilitation Guide (First Edition)*. Boca Raton, FL, CRC Press (<https://www.amazon.com/Neurovision-Rehabilitation-Guide-Amy-Chang/dp/1498762668>)
- Jotie JM, Gustafson JA, Fonda JR, Fortier CB, Milberg WP, Fortenbaugh FC. Association of mild traumatic brain injury, post-traumatic stress disorder, and other comorbidities on photosensitivity. *Optom Vis Sci*. 2024 Feb 1;101(2):90-98. doi: 10.1097/OPX.0000000000002104. Epub 2024 Jan 10. PMID: 38408306.
- Kapoor N, Ciuffreda KJ. (2009) Vision deficits following acquired brain injury. In *Medical management of adults with neurologic disabilities* (Edited by Cristian A). Demos Medical Publishing, New York, NY, pp. 407-423.
- Kapoor N, Balcer LJ, and Rizzo JR. (2019) Vision problems. In *Textbook of Traumatic Brain Injury, Third Edition* (Edited by Silver JM, McAllister TW, and Arciniegas DB). American Psychiatric Publishing, Inc., Washington, DC, pp. 507-524.
- Kravitz D, Saleem KS, Baker CI, Mishkin M (April 2011). A new neural framework for visuospatial processing. *Nature Reviews* volume 12.
- Scheiman M, Wick B (2019). *Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders, Fifth Edition*. Philadelphia, PA, Lippincott Williams and Wilkins

55

Any Questions?

Please feel free to e-mail me at:
neera.kapoor@nyulangone.org



56