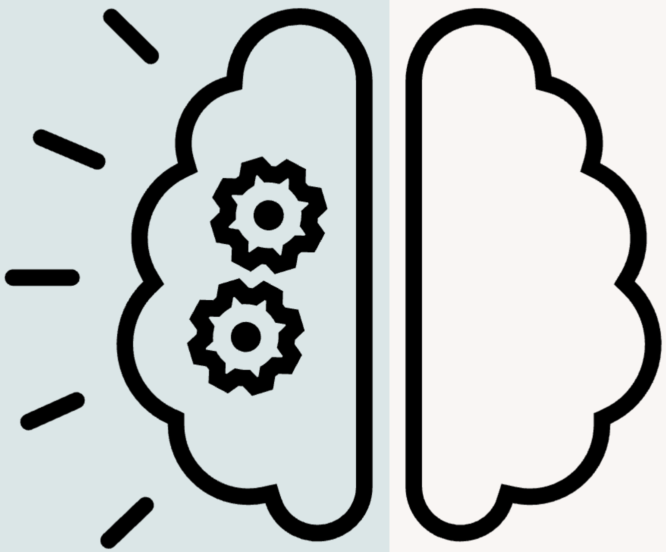
SENSORY CHANGES AFTER BRAIN INJURY



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BACKGROUND

- Bachelor of Arts in Psychology, Bard College
- Master of Science in Occupational Therapy, New York University
- Certified Brain Injury Specialist (CBIS) through the Brain Injury Association of America (BIAA) since 2021
- Experience in inpatient (acute care, ICU) and outpatient rehabilitation, adult and pediatric populations

DISCLAIMERS

I have no financial or non-financial interests to disclose.

OBJECTIVES

1. Discuss common sensory changes occurring in individuals following brain injury.

2. Identify effective strategies to manage sensory changes in acute and chronic phases of brain injury.

3. Examine current strategies for effective education of the individual, caregivers, and other medical professionals regarding sensory changes following brain injury.

I. SENSORY CHANGES AFTER BRAIN INJURY

Five Senses by Judith Wright

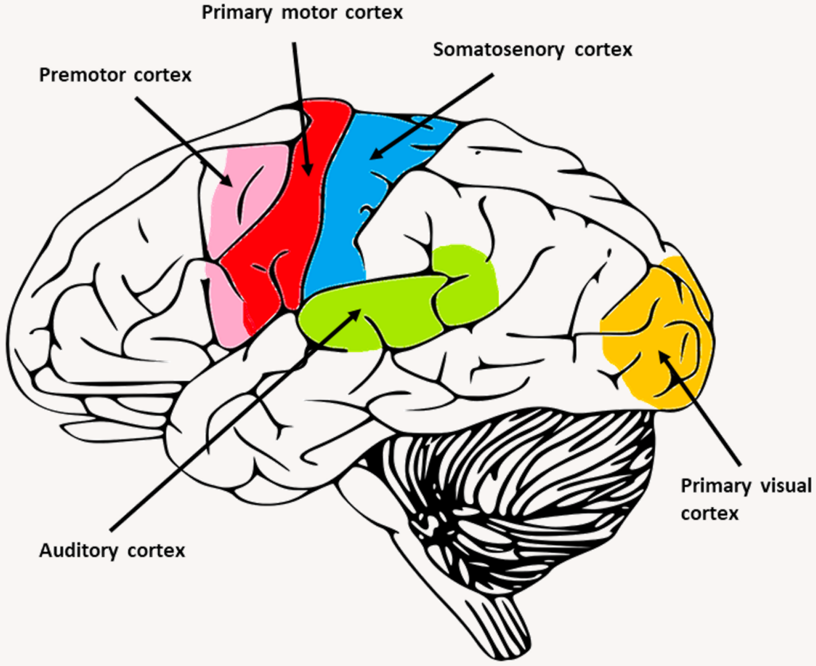
Now my five senses
gather into a meaning
all acts, all presences;
and as a lily gathers
the elements together,
in me this dark and shining,
that stillness and that moving,
these shapes that spring from nothing,
become a rhythm that dances,
a pure design.

While I'm in my five senses
they send me spinning
all sounds and silences,
all shape and colour
as thread for that weaver,
whose web within me growing
follows beyond my knowing
some pattern sprung from nothing-
a rhythm that dances
and is not mine.

SENSORY CHANGES

Sensory deficits following brain injury can include vestibular, auditory, visual, tactile, gustatory, olfactory, and interoceptive challenges.

More than **80%** of patients with acquired brain injury (ABI) have reported sensory stimuli as very overwhelming to experience since their injury (Thielen et al., 2024).



(Faltynek et al., 2019)

Unfortunately, how individuals with brain injury are processing and registering sensory information from their sensory environment is often missed...

SENSORY CHANGES

Seeing, hearing, feeling is used to understand the world around us. Registering and processing sensory input guides more complex behaviors and actions (movement, thought, memory).

Animal studies suggest disrupted sensorimotor processing in mild-moderate TBI through demonstration of abnormal sensory behavior, impacted speeded motor tasks, and response time tasks (Alwis & Rajan, 2014).

Sensory processing changes following brain injury may not only affect cognitive and motor deficits, but also contribute to increased post-traumatic headache and migraine (Hoffman et al., 2019).

> "All this sensory input, which begins in the brain, has its effect throughout the body."
> – Norman Cousins

MECHANISM OF ACTION

A big question mark…

- Reduced processing speed and increased sensory sensitivity (de Sain et al., 2022)
- Insular lesions, functional changes in brain activity (Preusser et al., 2015)
- Sensory gating impairment (Kumar et al., 2005)
- Disruption in the integration of sensory information (Brosseau-Lachaine et al., 2008)
- Behavioral mechanisms, attention deficits, sensory threshold changes (Thielen et al., 2022)
- Anxiety hypothesis suggesting sympathetic over-arousal leading to hypervigilance to environmental stimuli (de Sain et al., 2023).

VISION

- Photophobia (light sensitivity)
- Diplopia (double vision)
- Poor depth perception
- Blurriness
- Binocular dysfunction (convergence insufficiency)
- Overstimulation in visually stimulating environments (clutter, patterns, busy places such as the grocery store, mall, or restaurants)
- Intolerance for visual close work (computer screen, reading, writing, etc.)
- Oculomotor and accommodative changes (impaired eye motility, difficulty tracking, focusing on objects at different distances)
- Visual field loss
- Visual acuity loss
- Impaired pupillary function

VISION

Visual changes or vision loss can occur due to injury to the eye, eye orbit, central visual deficits (CN lesions), or damage to the eye muscles.

Binocular dysfunction may be related to damage to afferent, efferent, or other visual pathways in the brain controlling central vision and are common in over **40%** of the population (Faltynek et al., 2019; Lew et al., 2009).

However, vision loss can also occur without direct injury to the eye…

Visual deficits identified in TBI are usually focused on impaired oculomotor function, acuity, visual field, and binocularity. There is little research on the *perception* of visual stimuli or the *integration* of visual information and impact on function following TBI.

VISION

Etiologies of photophobia include: ocular, orbital, visual pathology, certain medications, neurological abnormalities, psychiatric disorders (Abusamak & Alrawashdeh, 2021).

In the general population, prevalence of photophobia is estimated at **10%**. Head trauma (concussion, PCS) is associated with visual symptoms in **69-82%** of patients.

- Photophobia is most severe 1-3 weeks after trauma but can persist up to 6 months or years post head trauma. Most patients rate their photosensitivity as severe. Other common symptoms of light sensitivity include asthenopia, squinting, and headaches.

A prospective study by Brosseau-Lachaine, et al. (2008) showed specific perceptual deficits for complex visual information in children with mTBI despite a normal neuro exam at time of hospital discharge. This discrepancy in perceptual performance was maintained throughout the assessed period (up to 3 months post-injury).

AUDITORY

- Hypersensitivity to certain sounds/frequencies (hyperacusis)
- Phonophobia (persistent, abnormal fear or aversion to sound)
- Misophonia (strong dislike, hatred of certain sounds)
- Auditory processing deficits
    - Difficulty processing oral information
    - Difficulty filtering out background noise
- Tinnitus
- Hearing loss (conductive, sensorineural, mixed)
- *DSI (dual sensory impairment with vision impairment)*

AUDITORY

Lack of consistent terminology used to describe auditory symptoms associated with head injury adds to difficulty in diagnosing and addressing impairments, and accurate estimation of prevalence of auditory symptoms in concussion patient populations. Taxonomy of auditory symptoms likely a combination of peripheral, subcortical, and cortical maladaptive changes that result in persistence of auditory symptoms (Theodoroff et al., 2022).

Auditory deficits themselves can arise from 2 main mechanisms: Injury to area of the brain responsible for auditory processing (central), and injury to the physical structure of the ear or inner ear (peripheral) (Faltynek et al., 2019).

AUDITORY

Studies show that injuries to the auditory system can account for about **20%** of the injuries reported in troops. Studies also note hearing loss in about **70%** of those who experienced a blast and were referred for audiologic evaluation (Lew et al., 2010).

Lew et al. (2007) showed that **38%** of patients with blast-related TBI reported tinnitus compared to non-blast related TBI (**18%**). **62%** of patients with blast-related TBI also reported hearing loss (p=0.04).

Noise sensitivity in the general population is approximately **15%** in adults. **35%** of mTBI patients 3 months post injury report noise sensitivity. Noise sensitivity has been found to be a strong predictor of prolonged post-concussive symptoms and has been linked to longer treatment and rehabilitation times post-TBI (Shepherd et al., 2019).

VESTIBULAR & PROPRIOCEPTION

- Dizziness
  - Disequilibrium
  - Vertigo
  - Lightheadedness
  - Presyncope
- Imbalance (unsteadiness)
- Clumsiness (incoordination)
- Poor postural control and body awareness
- Poor tolerance for positional changes
- Motion sickness

VESTIBULAR & PROPRIOCEPTION

Benign paroxysmal positional vertigo (BPPV) is the most common cause of dizziness following TBI; however, vestibular diagnoses are of unknown origin in **25%** of chronic TBI cases.

Temporal bone fractures are another injury which can cause significant damage to the inner ear and can cause labyrinthine concussion (presence of hearing loss and vertigo). Another major type of peripheral complication resulting in vestibular dysfunction is perilymphatic fistula.

Central nervous system causes of vertigo and dizziness can stem from post-traumatic seizures, anxiety disorders, or damage to the central vestibular structures (cerebellum, brainstem, or vestibular nuclei).

(Faltynek et al., 2019)

VESTIBULAR & PROPRIOCEPTION

Balance difficulties following brain injury can have a peripheral vestibular or central nervous system origin. The research literature shows **23-81%** of individuals report balance issues following ABI (Faltynek et al., 2019).

Balance impairment can be attributed to proprioceptive deficits and reduced muscle tone; approximately **65%** of patients with stroke experience loss of proprioception, tactile sensation, and protective reaction (Lee et al., 2015).

Dizziness can present with several different characteristics and result from deficit from the inner ear, brain, cervical spine, or integration of afferent input and tuning with the sensorimotor control system (Hammerle et al., 2019).

VESTIBULAR & PROPRIOCEPTION

Chamelian & Feinstein (2004):

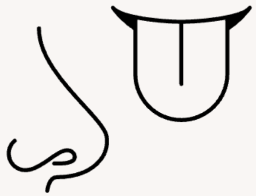
- 6-month cross-sectional study of 207 adults with mild-moderate TBI, **66.7%** had subjective complaint of post-traumatic dizziness.

- Dizziness was closely linked to psychological distress at 6 months following injury.

- Dizziness emerged as an independent predictor for failure to return to work with rates at 6 months reduced from **75%** (in those without vestibular dysfunction) to **33%**.

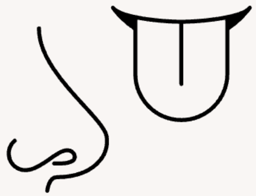
- Psychosocial functioning (**GHQ, RHFUQ, RTW**) was significantly worse in those with dizziness ($p<.01$).

OLFACTORY & GUSTATORY



- Hypersensitivity to certain smells, fragrances (hyperosmia)
- Dysosmia (distorted odor perception)
- Phantosmia/Parosmia (‘false’ smells, perceiving smells that aren’t there)
- Hyposmia (partial loss or decreased sense of smell)
- Anosmia (loss of smell)
- Hypersensitivity to certain tastes
- Dysgeusia (distortion or decreased sense of taste)
- Ageusia (loss of taste)
- Loss of appetite

OLFACTORY & GUSTATORY

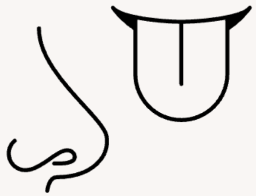


Taste and smell are the 2 primary chemosensory systems. Patients with altered taste and smell perception after BI are at risk for malnutrition, associated complications (gastrointestinal bleeding, pneumonia, other infection), and poorer outcomes impacting rehabilitation and quality of life (Dutta et al., 2013; Proskynitopoulos, 2016).

Impaired taste perception can result from lesions in the pons, specific thalamic nuclei, and insular cortices. Studies suggest central lesions cause disorders of taste perception whereas peripheral nerve lesions cause altered taste interpretation (Dutta et al., 2013).

Pathophysiological mechanisms cited in OD include peripheral lesions involving olfactory fibers arising from the cribriform plate, impaired cranial relay stations, central pathway involvement…brain regions frequently associated with OD include the olfactory bulb, olfactory tract, temporal lobe, and sub-frontal lobe (Proskynitopoulos, et al., 2016).

OLFACTORY & GUSTATORY



Patients affected by smell and taste dysfunction report decreased quality of life:

- Changes in food preferences
- Find certain foods less palatable
- Changes in dietary habits
- Unintentional weight loss
- Adverse health effects secondary to changes in diet (hypertension, malnutrition, etc.)
- Decreased energy level (fatigue)
- Avoidance of social activities
- Depressive symptoms

Impaired smell occurs more frequently in patients diagnosed with major depression and associated with higher scores on depression inventories (Proskynitopoulos, et al., 2016).

TACTILE

- Hypersensitivity to touch
- Paresthesia (pins and needles sensation)
- Pain
- Hypoesthesia (numbness)
- Increased or decreased response to temperature
- Decreased touch discrimination
- Impaired stereognosis

TACTILE

Impairment in sensory perception can commonly occur following stroke resulting in the experience of negative symptoms (numbness or lack of sensation, inability to determine limb position in space, recognize a held object) and positive symptoms (paresthesia, pins/needles, pain).

This can have a serious impact on all levels of motor production (planning, correction, execution), which involve the use of sensory feedback from the environment.

Reviewing the literature, changes in proprioception and touch occurred in 25-85% of patients immediately following stroke, and proprioception (34-63%) and stereognosis (31-89%) modalities were more commonly affected than touch (7-53%).

(Gandhi et al., 2020)

TACTILE

Chronic pain is a common complication of TBI, contributing to morbidity and poor recovery following injury. Mild TBI is associated with a **75.3%** pain rate, moderate-severe TBI associated with a **32.1%** pain rate (Nampiaparampil, 2008).

Little research concerning the mechanisms supporting pain and evidence-based guidelines for treating TBI-related pain. Potential mechanisms include neuroinflammation, excitotoxicity, and axonal degeneration (Irvine & Clark, 2018).

In an animal study by Wattiez et al. (2021), tactile hypersensitivity in cephalic and extra-cephalic areas develops early, persisting for at least 9 weeks in multimodal TBI; in closed head TBI, cephalic tactile hypersensitivity is transient lasting 1-7 days after injury. Following, mice display prolonged tactile hypersensitivity in response to normally sub-threshold doses of migraine triggers.

INTEROCEPTION

- Poor thermoregulation
- Changes in thirst, hunger (appetite)
- Increased pain sensitivity
- Difficulty differentiating between physical sensations (pain vs. itch)
- Heart rate changes
- Difficulty recognizing level of physical exertion
- Difficulty with self-regulation (emotional-regulation)

INTEROCEPTION

In a study by Pistoia et al. (2015):

- Processing, representation, and perception of bodily signals (interoception) plays an important role in the subjective experiencing of emotional stress.

- Individuals with SCI (n=10) did not differ from healthy controls (n=20) in recognizing emotions via facial expressions; however, they were significantly less accurate than healthy controls in identifying and judging emotionally evocative scenes eliciting fear and anger.

- Results support the idea that afferent sensory feedback is involved in emotional experience. The higher the level of injury of spinal cord, the potentially greater degree of experienced emotional dysfunction.

INTEROCEPTION

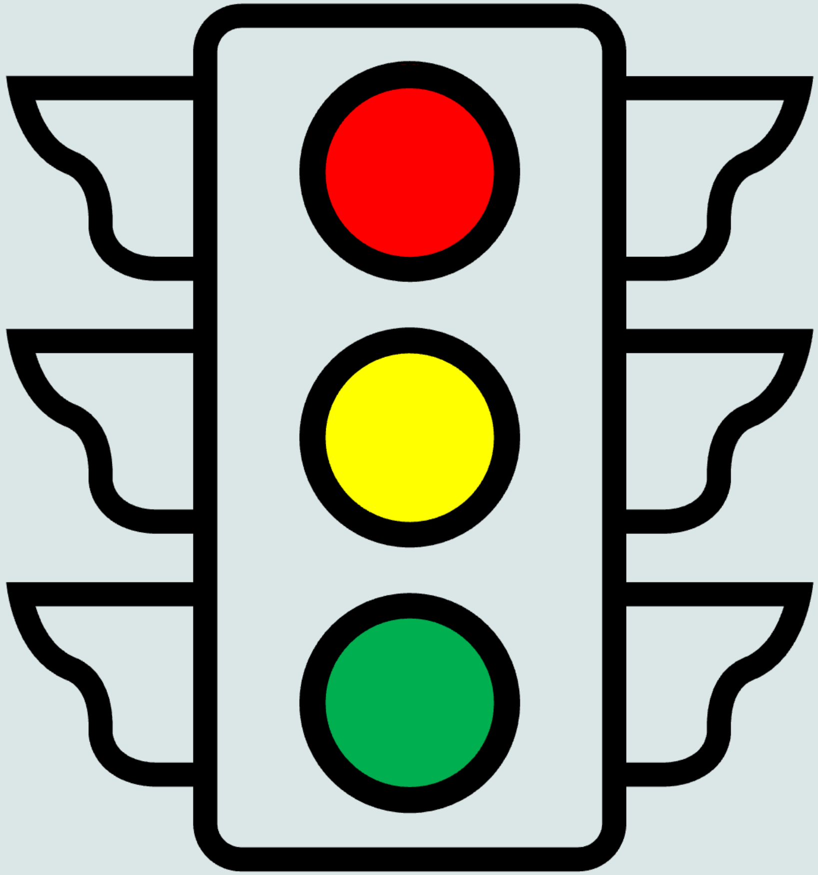
Maladaptive interoceptive sense: Hypervigilance of body sensations, catastrophization.

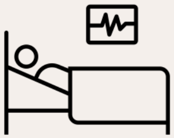
Adaptive interoceptive sense: Attention to, regulation, acceptance, of body sensations.

Desdentado et al. (2023) found individuals with ABI were less likely to ignore unpleasant sensations, have increased severity of depressive symptoms, have greater difficulty in emotional regulation, and exhibit worse performance on emotional awareness than neurotypical individuals. Results indicate benefit in addressing both interoceptive and emotional difficulties in treatments targeting psychosocial sequelae of ABI.

Kharrazian (2015) discusses disruption of the brain-gut axis and alterations in autonomic function in BI; dysautonomia has been found in 8-33% of individuals with TBI per literature review. A common presentation of dysautonomia is persistent sympathetic overactivity in response to nociceptive stimuli and development of chronic pain.

II. IDENTIFYING & MANAGING SENSORY CHANGES IN ACUTE AND CHRONIC PHASES OF BRAIN INJURY





ACUTE PHASE

The primary goal of acute care (hospitalization) is to keep the patient alive and minimize mortality. Rehabilitative goals center on preparing for the next level of care and longer-term considerations.

Managing cognitive-behavioral issues in acute rehabilitation involves teasing out what the problems are and how to address them (behavioral management, environmental modifications, and pharmacological intervention).

Rehabilitative therapies can play a role in addressing visual dysfunction, vestibular dysfunction, and other somatosensory deficits.

(Zasler et al., 2013, p. 388)

ENVIRONMENTAL MODIFICATIONS

Non-pharmacological intervention for agitation is typically recommended as a first-line approach (environmental modification, behavioral strategies, education for staff, family).

In a study by Carrier et al. (2021): **99%** (n=305) of clinicians reported using at least 1 non-pharmacological approach to manage agitation with environmental modifications being most common (**98%**), followed by patient program modifications (**94%**), behavior modification techniques (**88%**).

Behavioral strategies and non-pharmacological interventions that target specific triggers of agitation and how it manifests, are important for the patient's rehabilitative progress. Aim is not to just resolve behavioral issues, but to understand underlying causes and equip the individual with appropriate tools to promote participation and re-integration (Janzen et al., 2014).

ENVIRONMENTAL MODIFICATIONS

- Reducing stimuli (light, noise, distractions)
    - Placing patient in bed
    - Drawing curtains, turning off lights, dimming brightness of computer monitors
    - Turning off TV/radio
    - Limiting number of visitors
    - Speaking in low volume, slowly
    - Avoid sudden grabbing or touching of the patient, approach from the front
- Obtaining hearing devices, vision aids from home to improve orientation
- Create a familiar environment (allow family to bring in personal possessions)
- Minimize tubes and lines (may cover them – abdominal binder)
- Consistent schedule and staff (timed toileting, sleep hygiene)
- Avoid/minimize restraints (1:1 staff supervision)

(Carrier et al., 2021; Janzen et al., 2014)

ACUTE PHASE (NICU)

"The Supporting and Enhancing NICU Sensory Experiences (SENSE) program was developed to promote consistent, age-appropriate, responsive, and evidence-based positive sensory exposures for the preterm infant every day of NICU hospitalization…The mismatch between the underdeveloped coping skills of the infant and the intensely stimulating NICU environment may cause physiologic instability, adversely affect growth and development, and ultimately impact long term neurodevelopmental outcomes [3–7]" (Pineda et al., 2019).

- Combines need for parent engagement in the NICU environment with the infant's need for consistent positive sensory exposures.
- Week-by-week sensory exposure plan outlines what type and timing of exposures are developmentally appropriate.
- Weekly assessments performed by the SENSE administrator or neonatal clinician (nurse, PT, OT, SLP), with log sheets used to track daily, positive sensory exposures.

(Pineda et al., 2019)

CHRONIC/SUBACUTE PHASE

Patients with post-injury hypersensitivity to sensory stimuli are at risk of:

- Mental health difficulties
    - Sensory processing changes after TBI may contribute to PTSD comorbidity, post-traumatic headache, and migraine (Hoffman et al., 2019).
- Physical health difficulties
- Poorer functional outcomes

Systematic literature review showed a limited number of studies (**36%**) used a validated questionnaire to assess sensory changes after ABI (Thielen et al., 2024).

- Rivermead Post-concussion Symptom Questionnaire (**RPQ**) – measures light, noise hypersensitivity, other common post-concussion symptoms
- Sensory Sensitivity Questionnaire **(SSQ)**, Sensory Profile (adult/adolescent, child) **(SP)**, Glasgow Sensory Questionnaire **(GSQ)** – **not standardized to ABI population**

CHRONIC/SUBACUTE PHASE

Thielen et al. (2024):

- Post-injury hypersensitivity was reported by **76%** of stroke patients, **89%** of TBI patients, and **82%** of brain tumor patients. Complaints occurred across all modalities (multi-sensory, visual, auditory hypersensitivity most prevalent).
- Study on 818 neuro-typical adults, 341 with ABI showed that **79%** of ABI patients reported experiencing an increase in sensitivity to at least 1 sensory modality that was still present in the month previous to study participation.

Multi-Modal Evaluation of Sensory Sensitivity (MESSY-NL): Patient-friendly questionnaire to assess sensory sensitivities across multiple sensory modalities (visual, auditory, tactile, olfactory, gustatory, motion sensitivity, temperature sensitivity).

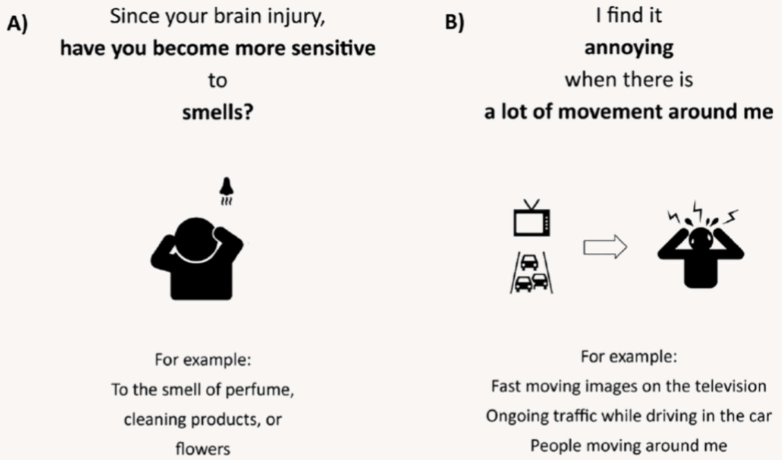


Figure 1. An open-ended (Panel A) and a multiple-choice (Panel B) item of the MESSY.

CHRONIC/SUBACUTE PHASE

Cognitive Behavioral Therapy (**CBT**) is considered a diverse set of problem-specific interventions incorporating physical, psychological, and behavioral approaches to managing pain. The individual is taught to use self-regulation, self-control, and coping strategies for pain, depression, and anxiety associated with chronic headaches.

Other non-pharmacological interventions have been explored to reduce pain and headaches following ABI:

Biofeedback	Yoga	Red light therapy
Relaxation training	Mindfulness	Cryotherapy
Acupuncture	Meditation	Craniosacral therapy

Limited evidence for these interventions to support their efficacy with ABI population. Use may be appropriate on a specific case by case basis.

(Faltynek et al., 2019)

VISION

Due to the variety of visual deficits following ABI, identifying specific deficits and visual intervention is important for positive outcome by an appropriate clinician (ophthalmologist/optometrist, neuro-ophthalmologist, rehabilitative clinicians with expertise in visual rehabilitation).

- Prisms to correct double vision, eye misalignment, other visual processing problems
- Patching to correct double vision
- Vision therapy to improve oculomotor function and visual processing
- Low vision aids and/or training to correct for severe acuity loss, field loss, neglect, or scanning issues

(Faltynek et al., 2019; Lew et al., 2010)

VISION

Treatment approaches for photophobia include:

- Optical filters, tinted lenses (FL-41 lenses, yellow tinted driving lenses)
- Polarized sunglasses (wear of sunglasses indoors is discouraged)
- Hats, hoodies, other headwear to reduce effects from overhead lighting
- Anti-glare covers for electronic devices
- Non-liquid crystal displays
- Topical ocular lubricants and other medications for neuropathic pain, photophobia (treatment of dry eye, anti-epileptics, serotonin-norepinephrine reuptake inhibitors, and tricyclic antidepressants)
- Sympathetic blocks of the superior cervical ganglion has shown significant results in reducing ocular pain and photophobia in refractory cases

(Abusamak & Alrawashdeh, 2022)

AUDITORY

Referral to audiology is recommended to assess auditory dysfunction potential structural and functional changes that occur in the peripheral and central auditory system post head injury.

Sensorineural and conductive hearing loss will often benefit from use of hearing aid/assistive listening devices (ALD's).

Treatment and management of tinnitus is emerging: Sound therapy, masking relief therapy, hearing aid, relaxation and stress management (CBT), desensitization techniques (hyperacusis), TRT (tinnitus retraining therapy; auditory habituation).

- Important to note the type of tinnitus (subjective, neurologic, somatic, and objective) as treatment may differ.

(Faltynek et al., 2019)

AUDITORY

Auditory training is shown to be an effective method to improve auditory processing. Auditory exercises are provided to the patient that use central processes known to influence listening comprehension in more challenging listening environments.

- A variety of auditory training options are available including software (Earobics, FastForWord, Posit Science Brain Fitness) the patient can use at home and others administered by an audiologist or speech-language pathologist (Dichotic Interaural Intensity Difference training) (Lew et al., 2010).

Hearing protection when exposed to loud sounds (concerts, band practice, etc.) is recommended for patients with noise sensitivity. It is generally not recommended to use hearing protection in quiet environments as this can result in the auditory system becoming more sensitive (Theodoroff et al., 2022).

VESTIBULAR & PROPRIOCEPTION

Vestibular rehabilitation therapy (**VRT**) with physical and occupational therapy is the most common management for vestibular dysfunction following brain injury.

Type	Description
Habituation	Habituation exercises operate under the principle that the body will eventually reduce its response to unpleasant or noxious stimuli through exposure.
Adaptation	Encouraging long-term plastic change is part of the adaptive strategy, exercises are designed to reinforce a reorganization of the vestibular system through similar means of exposure.
Substitution	This approach involves using different eye-movement systems to substitute the eye-movement strategies normally used on specific tasks (such as saccade versus smooth eye movement strategies).
Treatment of BPPV	As BPPV is thought to be caused by the inappropriate movement of otoconia (bio-crystals within the semicircular canals). Treatment for BPPV involves a variety of maneuvers attempting to make the crystals responsive to gravity again (e.g., Canalith Repositioning Maneuver).

(Faltynek et al., 2019)

VESTIBULAR & PROPRIOCEPTION

In a study by Hammerle et al. (2019):

- Research shows that dizziness following mTBI improves with sensorimotor control exercises combined with manual therapy for the cervical spine due to abnormal cervical proprioception or afferent input to the sensorimotor control system.

- Retrospective records review of patients treated for dizziness following mTBI showed that patients who received cervical spine proprioception retraining (**CSPR**) were **30x** more likely to report improvement in dizziness symptoms compared to those who received VRT.

- **85%** of individuals in the CSPR group and only **18%** in the usual care group had dizziness improved, suggesting that by identifying altered CSP with no clear central or peripheral signs present, that CSPR may be beneficial for individuals with dizziness following TBI.

VESTIBULAR & PROPRIOCEPTION

Study by Lee et al. (2015) of 36 patients post-stroke to examine the effects of exercise image training in treating balance and proprioceptive deficit; 18 patients received proprioceptive training, 18 patients received additional motor imagery training.

- Significant improvements in outcome measures with time ($p<0.05$), the motor imagery training group had significantly greater improvements than the proprioception training group ($p<0.05$).

Randomized controlled pilot study by Lim et al. (2019) randomly assigned 30 patients post-stroke to a multi-sensorimotor training group (Reha-Bar, balance platform, TENS) or a treadmill training group to improve proprioception and balance.

- Results showed significant improvement in proprioception variation and balance in both groups ($p<0.05$); multi-sensorimotor training showed more significant changes in proprioception ($p=0.002$) and balance ability ($p=0.033$).

VESTIBULAR & PROPRIOCEPTION

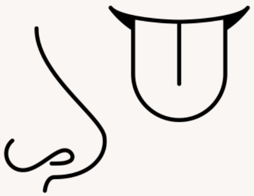
Assessments for balance

- Berg Balance Scale (BBS)
- Sensory Organization Test (SOT)
- Functional Gait Assessment (FGA)
- Dynamic Gait Index (DGI)
- Timed Up and Go (TUG)
- Rivermead Mobility Index
- Functional Reach Test
- Bruininks-Oseretsky Test of Motor Proficiency (Balance subtests)

Assessments for proprioception

- Active/Passive Joint Position Recognition
- Cervical Joint Position Error Test
- Romberg Test
- Heel-Shin Test
- Finger-Nose-Finger Test
- Thumb Localization Test

OLFACTORY/GUSTATORY



Screening for olfactory and gustatory dysfunction may involve:

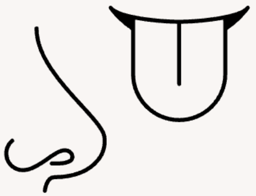
- Asking questions regarding changes in taste, diet, and meals in clinical interview
- Objective quality assessments of smell and taste (University of Pennsylvania Smell Identification Test (UPSIT), Alberta Smell Test (AST))
- Formal testing with taste strips or electrogustometry

Attention to patient nutrition and activity has shown to reduce risk of malnutrition, weight loss, improve certain functional outcomes, and quality of life.

Education to care providers and implementing practices to identify eating difficulties, providing supplementary nutrition to reduce incidence of malnutrition are important in the acute phase to facilitate rehabilitation progress.

(Dutta et al., 2013)

OLFACTORY/GUSTATORY



Treating olfactory and gustatory dysfunction:

- Steroid (prednisolone) has been shown to have significant effects on recovery rates and may minimize any further decline of olfactory dysfunction and promote regeneration (Proskynitopoulos, et al., 2016).
- Meta analysis of 13 studies' effect on smell training using the Sniffin' Sticks Test. Positive, statistically significant effects of olfactory training with large effects on identification, discrimination, and threshold-discrimination-identification (TDI) score, and small-moderate effect for threshold of odor detection. Significant improvement noted across all olfactory disease subgroups (Parkinson's disease, olfactory disease, post-infectious olfactory loss, patients with post-infectious and post-traumatic olfactory loss, healthy controls) (Sorokowska, et al., 2017).
- May look to COVID-19 research on olfactory and gustatory dysfunction for further understanding of mechanism and treatment options.

TACTILE

Literature review of post-stroke sensory dysfunction (**PSSD**) by Gandhi et al. (2021):

Rehabilitation of PSSD is provided by using sensory inputs, categorized as:

1. **Sensory stimulation approach (SSA)** – Passive, externally applied sensory stimulation (electrical, thermal, tactile, repetitive peripheral magnetic stimulation, etc.)
2. **Sensory retraining approach (SRA)** – Active, graded re-education using principles of learning (mirror therapy, graded sensory discriminative activities, mental imagery, graded sensory recognition strategies, combined protocols, etc.)

Of the studies reviewed, improvements reported with mechanical sensation and motor function with alternating hot/cold stimulation, improved somatosensation and motor impairment with intermittent pneumatic compression (IPC), improved quality of life, motor function, tactile and proprioceptive sense with intensive tactile stimulation, functional re-education, and mental imagery over multiple therapy sessions.

TACTILE

Gironda et al. (2009) on management of chronic pain, post-trauma headache:

- Pharmacological management is complex (multiple injuries, risk of polypharmacy)
    - *Nociceptive: NSAIDs, topical agents, acetaminophen, antispasticity, opiods*
    - *Neuropathic: Topical agents, anticonvulsant, antidepressants, anticonvulsants, opioids*
- Interventional techniques (trigger point injections, nerve blocks, epidural steroids)
- Rehabilitative interventions (thermal modalities, ROM/stretching, US therapy, TENS), graded exercise approach with pain neuroscience education (PNE)
- Cognitive-Behavioral interventions (address emotional/cognitive issues, pain coping skills, address pain-related fear and activity avoidance, medication abuse, PNE)
- Post-trauma headache treatment: NSAIDs, acetaminophen with caffeine or sedative in a single medication, abortive/preventative medications for migraine, relaxation training, biofeedback, trigger identification, stress-management, spinal manipulation, lifestyle regulation, sleep hygiene

INTEROCEPTION

Research by Desdentado et al. (2023):

Little research that explores changes in ability to regulate emotions following ABI; however, it is known that individuals with TBI are more likely to have maladaptive coping mechanisms, difficulty controlling behavior, and depressive symptomatology.

Interoception and emotional regulation are especially relevant to ABI, since poor insight into deficits ("anosognosia") is a common sequela in brain injury.

Findings lend support to the application of mindfulness-based approaches on emotional processing (meditation, breath work, body scan, etc.).

INTEROCEPTION

Raimo et al. (2019):

Study on a small sample of patients with unilateral BI that completed the Self-Awareness Questionnaire (SAQ) showed that patients with right brain lesions and extra-personal and/or personal neglect performed significantly worse than controls and patient with left brain lesions on visceral sensations.

This deficit of awareness of visceral sensations possibly reflects differences in brain activation patterns for processing somatic and visceral sensation.

Assessing interoceptive awareness could improve rehabilitation gains and promote greater accuracy of body signals.

III. EDUCATION OF SENSORY CHANGES FOLLOWING BRAIN INJURY.

"Please take responsibility for the energy you bring into this space."
- Jill Bolte Taylor

IMPACT OF SENSORY DYSFUNCTION

Subjective sensory hypersensitivity is known to reduce one's quality of life:

- Social isolation
- Reduced mental health (increased negative affect, depression)
- Reduced physical health (fatigue, sleep disturbance)
- Inability to carry out instrumental activities of daily living (IADL's, leisure)

"After my stroke, I had to start wearing sunglasses while watching television because of my hypersensitivity to the bright light of the television screen and the flashing images on the screen."

"When I sit in a moving elevator or wheelchair, I feel very uncomfortable. The feeling of those movements is terrible."

"When I am surrounded by a lot of sensory stimuli, I feel tired, nauseous, and anxious."

"Just a small increase in temperature causes me to feel overwhelmed. I do not like when my husband turns on the heating in our house, even when it is cold outside."

"Everything tastes like dirt"`

(Thielen et al., 2023; Dutta et al., 2013)

QUALITY OF LIFE

Lew et al. (2009): Study of 62 patients with diagnosed sensory impairments (53, **85.5%**; **DSI** 20, **32.3%**), using the Functional Independence Measure (**FIM**) as the outcome measure:

- At discharge, the DSI group presented with lower scores in all 4 subcomponents of the motor FIM (self-care, mobility, locomotion, sphincter control). Group mean values differed significantly in the self-care subcomponent ($F(3, 58) = 2.93$, $p<0.05$).

Shepherd et al. (2020): Health-related quality of life was measured 12 months post-TBI with the Short-Form 36 Health Survey (**SF-36**) and measures of noise, light sensitivity were taken from the Rivermead Post-concussion Symptom Questionnaire (**RPQ**).

- Approximately 1 in 5 individuals are struggling with either noise, light, or both, 12 months following a mTBI. Sensory sensitivities may impede ability to engage in and perform tasks affecting community participation (such as return to meaningful employment).

QUALITY OF LIFE

Impact of sensory impairments (especially DSI) on neuro-psychological performance:

- Patients with TBI-related, but undetected hearing impairment or DSI may be at risk of being labeled with cognitive or memory impairment.
- Minimal visual blur (20/40 acuity) reduces performance on neuropsych testing

(Lew et al., 2010).

Patients report that fatigue plays a role in sensory hypersensitivity (more sensitive to sensory stimuli when tired). They describe physical consequences (headache, fatigue, feeling restless, moist hands, nausea), cognitive consequences (less focus and concentration, feeling distracted), and emotional consequences of sensory hypersensitivity (feeling more irritated, angry, frustrated, acting rude towards others in the environment) (de Sain et al., 2023).

EDUCATION

Identifying sensory impairment during the acute stage and sub-acute stages of mTBI is important for best-practice rehabilitation and patient quality of life.

- Standardized assessment protocols are lacking; however, we can use subjective report (clinical interview), post-concussion inventories (RPQ), and other tools identified in the literature to address sensory dysfunction.
- Dual sensitivity impairment of noise and light sensitivity should be a focus of clinical assessments of post-concussive symptoms, as these can have a significant influence on long-term recovery and outcome (Shepherd et al., 2020).

Patient education plays a critical role in management of chronic conditions. Research shows that even basic information can improve patient and caregiver self-efficacy and motivation for rehabilitation (Hart et al., 2018).

ADDITIONAL RESOURCES

Lost & Found: Dealing with Sensory Overload After Brain Injury B. J. Webster, Lash & Assoc. https://www.brainline.org/article/lost-found-dealing-sensory-overload-after-brain-injury

Sensory Overload ('Hypersensitivity') after Acquired Brain Injury from the Scottish Acquired Brain Injury Network https://www.acquiredbraininjury-education.scot.nhs.uk/impact-of-abi/sensory-overload-hypersensitivity/

Pain after Stroke https://www.stroke.org.uk/stroke/effects/physical/pain-after-stroke

The Vestibular Traumatic Brain Injury (TBI) Connection

https://vestibular.org/article/diagnosis-treatment/types-of-vestibular-disorders/tbi/

Supporting and Enhancing NICU Sensory Experiences https://chan.usc.edu/nicu/sense

READING RECOMMENDATIONS

The Ghost in My Brain: How a Concussion Stole My Life and How the New Science of Brain Plasticity Helped Me Get It Back by Clark E. Elliott

Over My Head: A Doctor's Own Story of Head Injury from the Inside Looking Out by Claudia L. Osborn

My Stroke of Insight: A Brain Scientist's Personal Journey by Jill Bolte Taylor

Volume Control: Hearing in a Deafening World by David Owen

Fixing My Gaze: A Scientist's Journey Into Seeing in Three Dimensions Paperback by Susan R. Barry

The Man Who Mistook His Wife for a Hat and Other Clinical Tales by Oliver Sacks

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THANK YOU

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