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HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL



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Persisting Symptoms after Concussion (PSaC) and Functional Neurological Disorder (FND)

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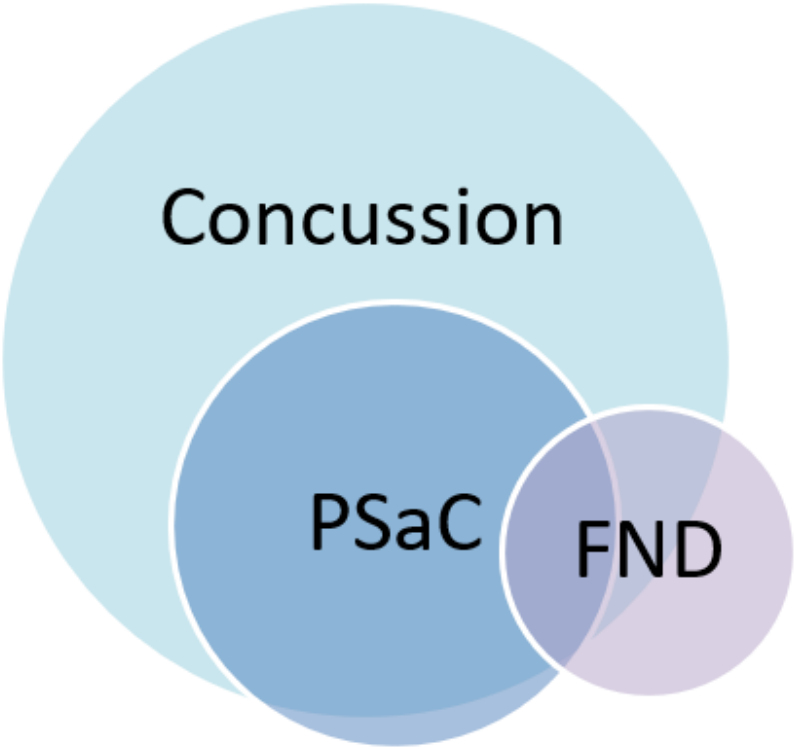
Outline

Shared mechanisms and pathogenesis

Making the diagnosis

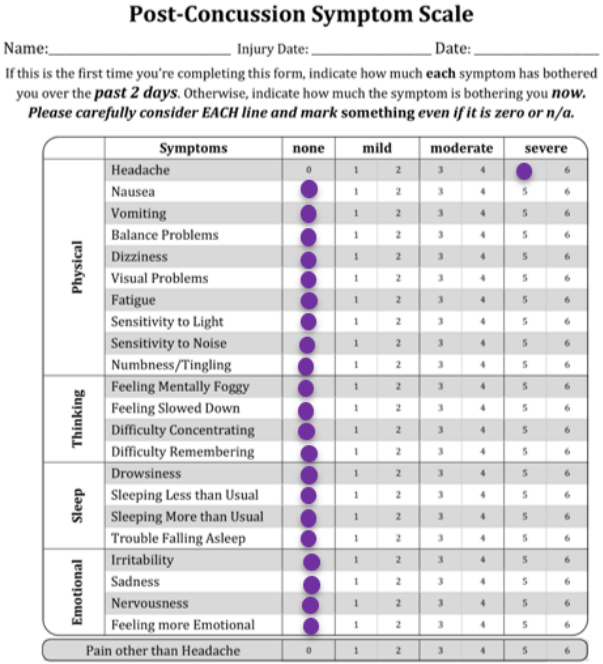
Post-concussive functional phenotypes

Treatment implications



Persisting symptoms after concussion (PSaC) are common

Up to **13-62%** of concussed individuals report symptoms lasting months to years.



Post-Concussion Symptom Scale

Name:_____ Injury Date: _____ Date: _____

If this is the first time you're completing this form, indicate how much **each** symptom has bothered you over the ***past 2 days***. Otherwise, indicate how much the symptom is bothering you ***now.***
Please carefully consider EACH line and mark something even if it is zero or n/a.

	Symptoms	none	mild		moderate		severe	
Physical	Headache	0	1	2	3	4	●	6
	Nausea	●	1	2	3	4	5	6
	Vomiting	●	1	2	3	4	5	6
	Balance Problems	●	1	2	3	4	5	6
	Dizziness	●	1	2	3	4	5	6
	Visual Problems	●	1	2	3	4	5	6
	Fatigue	●	1	2	3	4	5	6
	Sensitivity to Light	●	1	2	3	4	5	6
	Sensitivity to Noise	●	1	2	3	4	5	6
	Numbness/Tingling	●	1	2	3	4	5	6
Thinking	Feeling Mentally Foggy	●	1	2	3	4	5	6
	Feeling Slowed Down	●	1	2	3	4	5	6
	Difficulty Concentrating	●	1	2	3	4	5	6
	Difficulty Remembering	●	1	2	3	4	5	6
Sleep	Drowsiness	●	1	2	3	4	5	6
	Sleeping Less than Usual	●	1	2	3	4	5	6
	Sleeping More than Usual	●	1	2	3	4	5	6
	Trouble Falling Asleep	●	1	2	3	4	5	6
Emotional	Irritability	●	1	2	3	4	5	6
	Sadness	●	1	2	3	4	5	6
	Nervousness	●	1	2	3	4	5	6
	Feeling more Emotional	●	1	2	3	4	5	6
Pain other than Headache		0	1	2	3	4	5	6

Headache

- tension HA
- migraine
- cervicogenic pain
- medication overuse headache
- myofascial pain
- occipital neuralgia
- insomnia/sleep disorder (e.g. OSA)

(McCrea 2003, Le Sage 2022, Broshek 2022)

Multi-symptom presentations – neuroplastic?

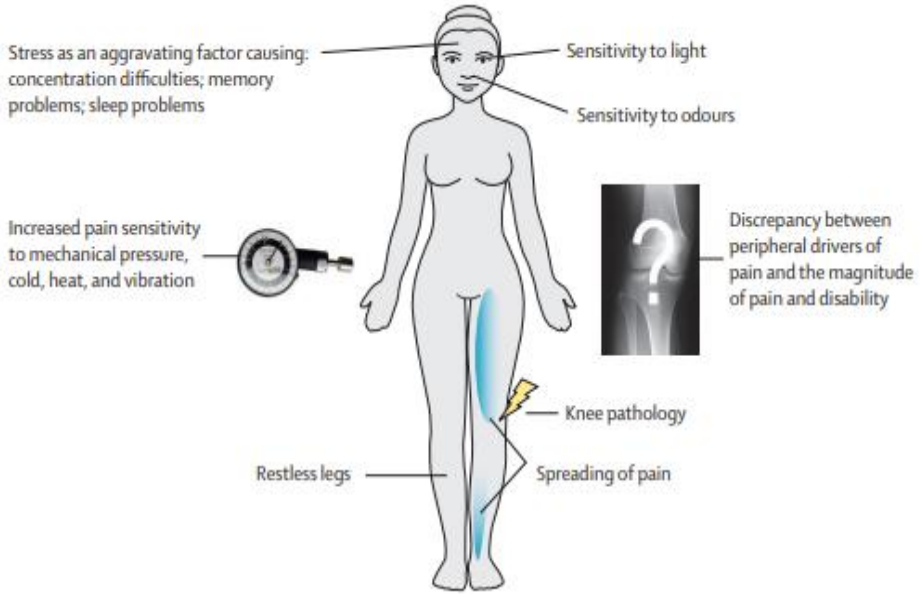
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	Feeling more Emotional	0	1	2	3	4	5	6
Pain other than Headache		0	1	2	3	4	5	6

Akin to nociplastic pain?



(Picon 2021; Nijs 2021; Schubiner 2026)

Atypical (functional) symptom presentations





Abnormal gait
Limb paralysis
Limb weakness
Loss of touch/pain
Difficulty swallowing
Loss of voice
Stuttering

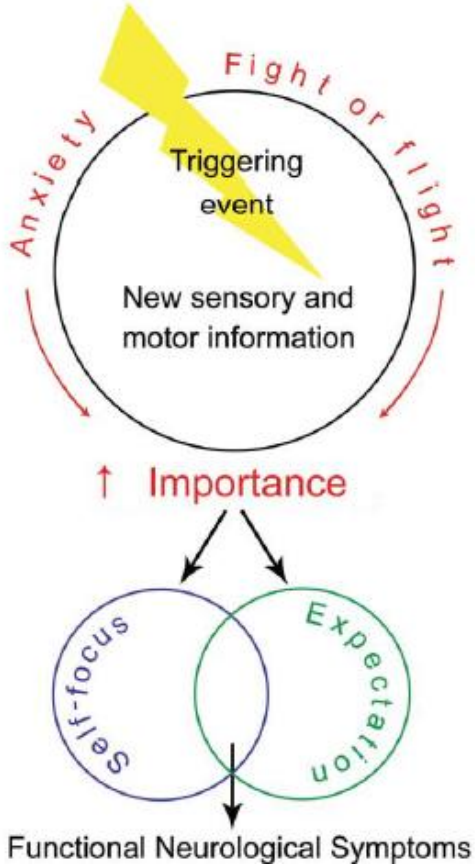
(Picon 2021)

Adding functional diagnoses to the differential

PSaC	Ddx/symptom generators	FND ddx
Headache	Tension HA, migraine, cervicogenic pain, MOH, myofascial pain, occipital neuralgia, insomnia/sleep disorder (e.g. OSA)	Nociplastic pain/somatic symptom disorder
Dizziness/ balance	BPPV, vestibular migraine, medication SEs, labyrinthine concussion, dehiscence, peri-lymphatic fistula, orthostatic dizziness, panic	Persistent postural-perceptual dizziness
Cognitive symptoms	Sleep (insomnia, OSA), depression, anxiety, PTSD, ADHD, chronic pain/fatigue, migraine, meds, substance use	Functional cognitive disorder
Hypokinetic movements	Peripheral nerve injury, radiculopathy, pain-limited movement, deconditioning, vision/vestibular disturbance	Functional movement disorder

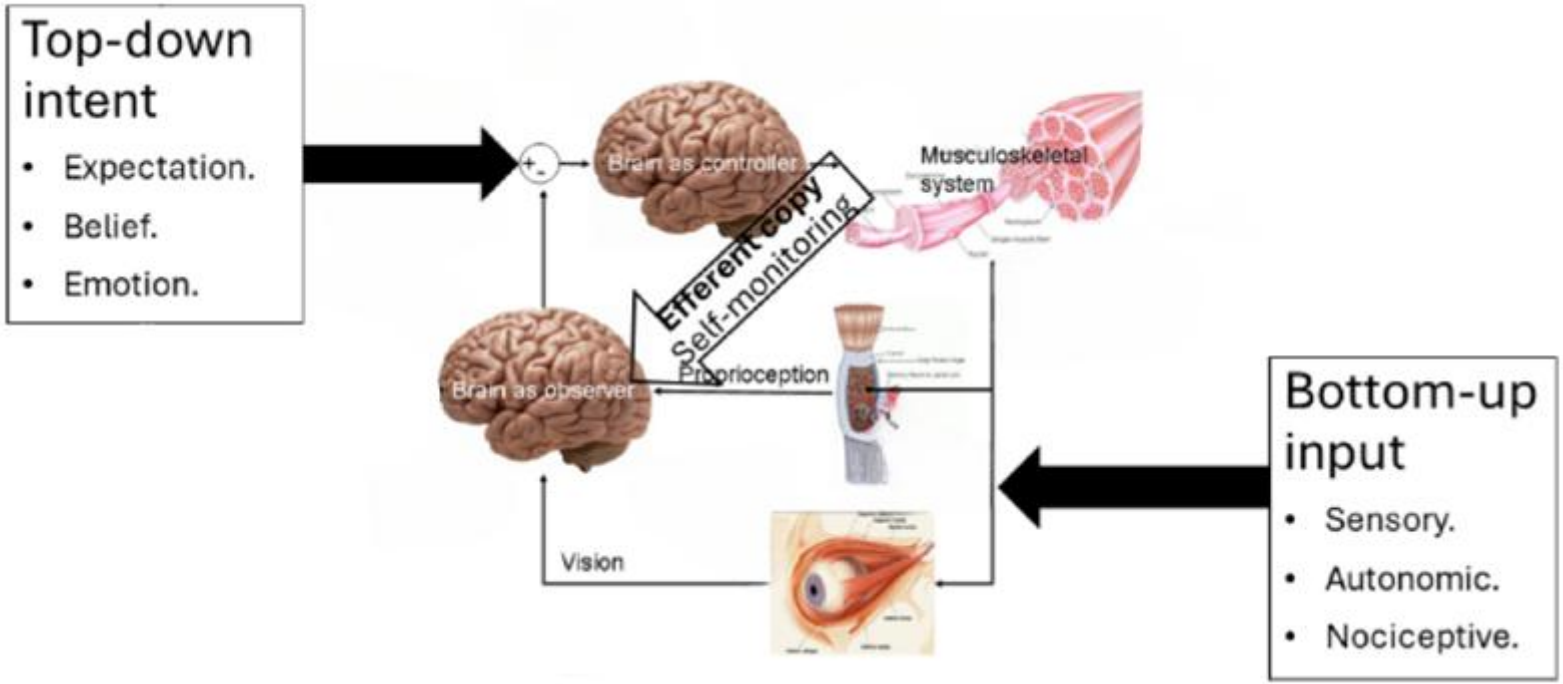
(table adapted from Mollica 2026)

FND pathophysiology



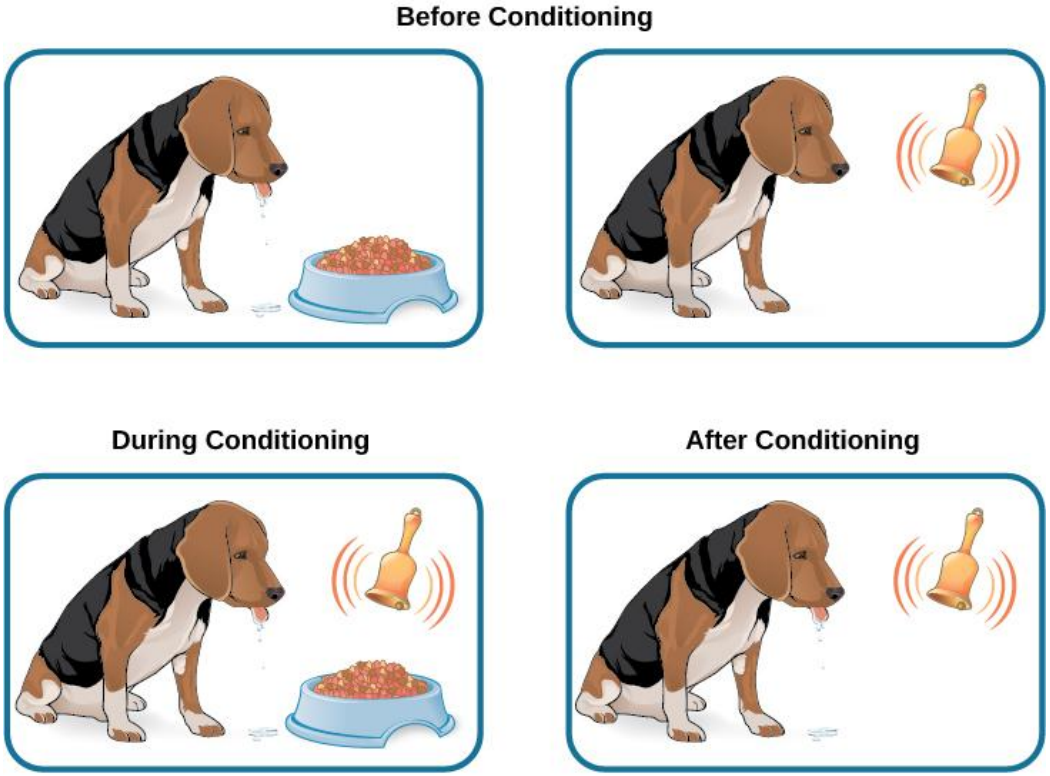
(Pringsheim 2017)

Predictive processing, overweighted top-down influences



(Dutta 2025)

Classical conditioning

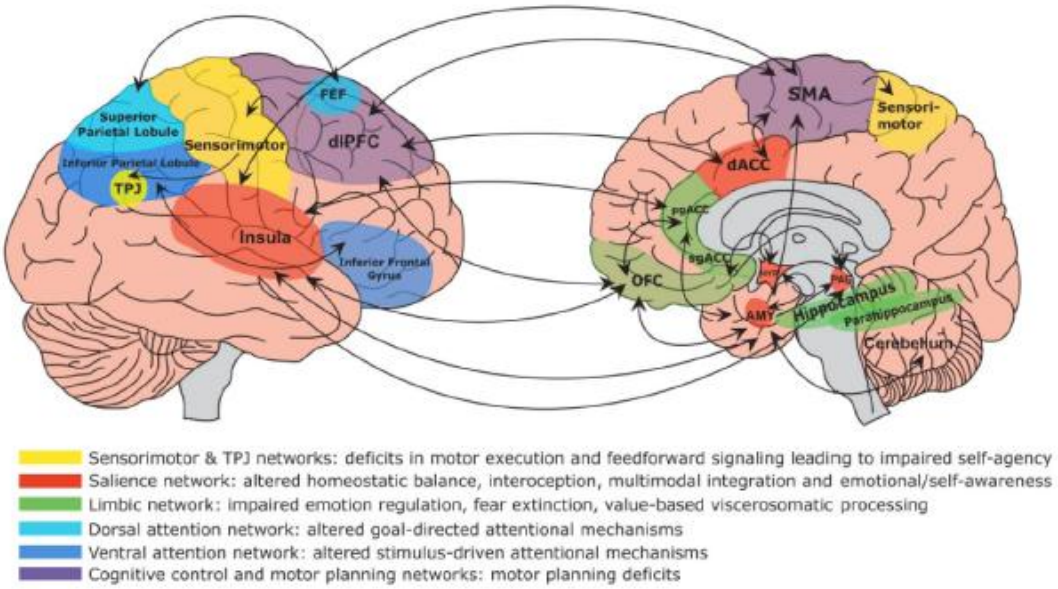


Abnormalities in functional connectivity

1) Attention

2) Emotion processing

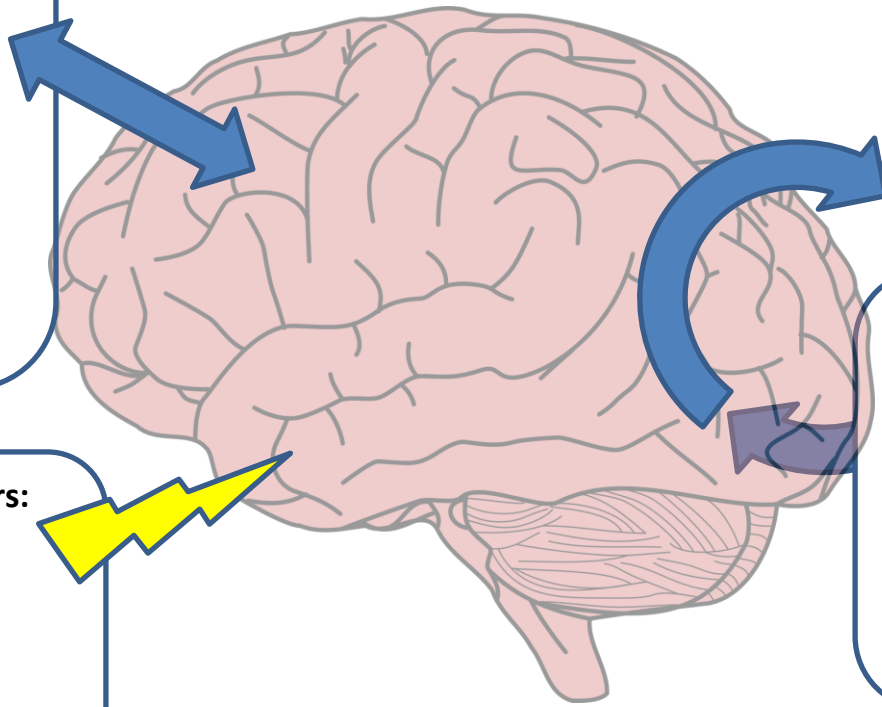
3) Agency



(Pringsheim 2017)

Predisposing factors:

- Medical illness
- Neurological disease
- Pain
- Anxiety and depression
- Emotional reactivity
- Stressful life events / ACE
- Neuroticism
- Perfectionism
- Somatization
- Alexithymia
- Genetics



Precipitating factors:

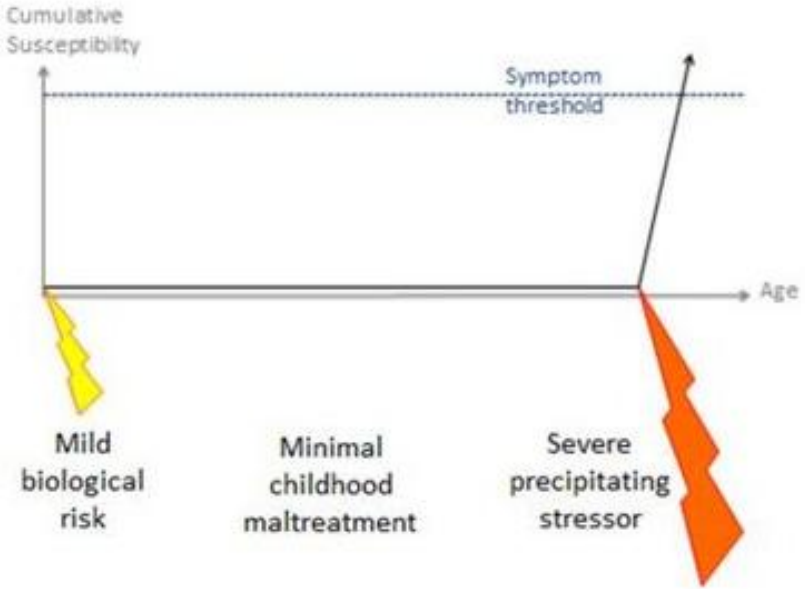
- Medical illness
- Physical injury
- Migraine
- Panic attack
- Drug side effect
- Life event

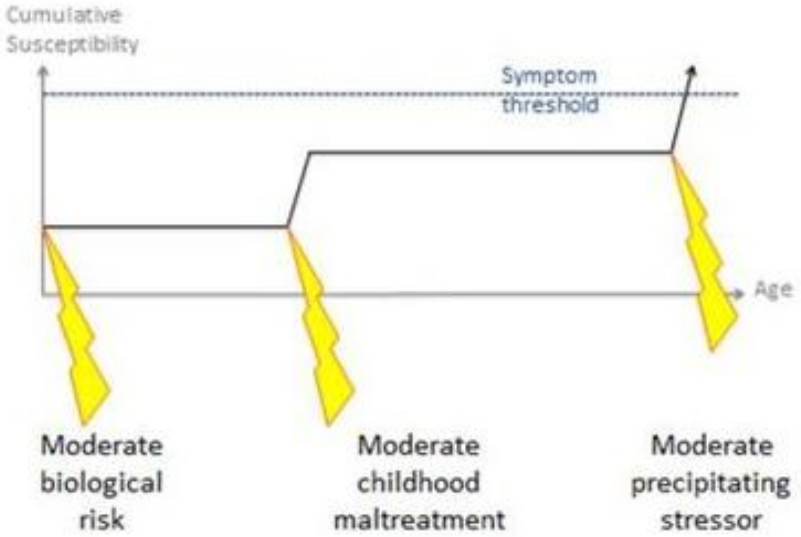
Perpetuating factors:

- Diagnostic uncertainty
- Feeling disbelieved
- Abnormal illness beliefs
- Neuroplasticity / deconditioning
- Secondary gain
- Litigation
- Escape event

Figure adapted from FND Hope

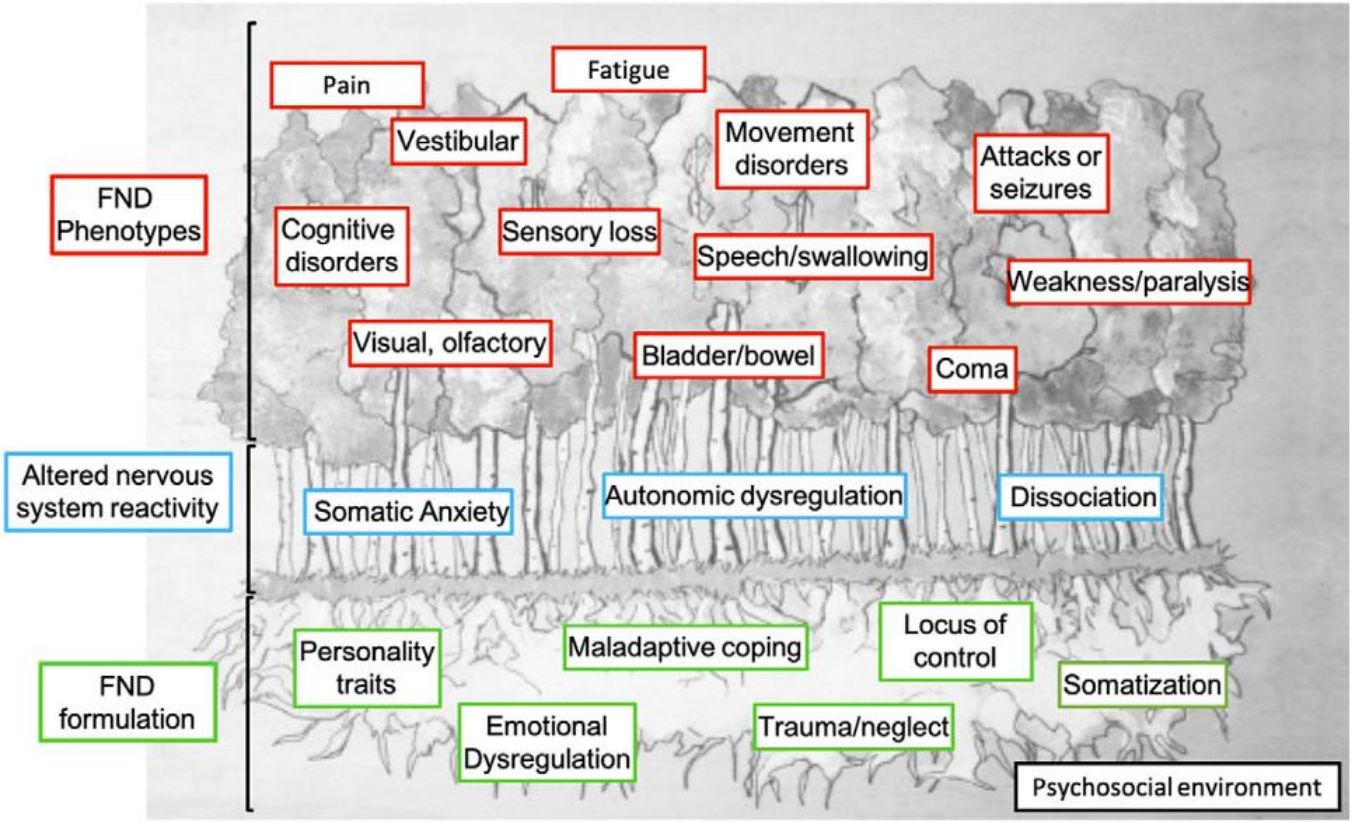
Stress-diathesis model





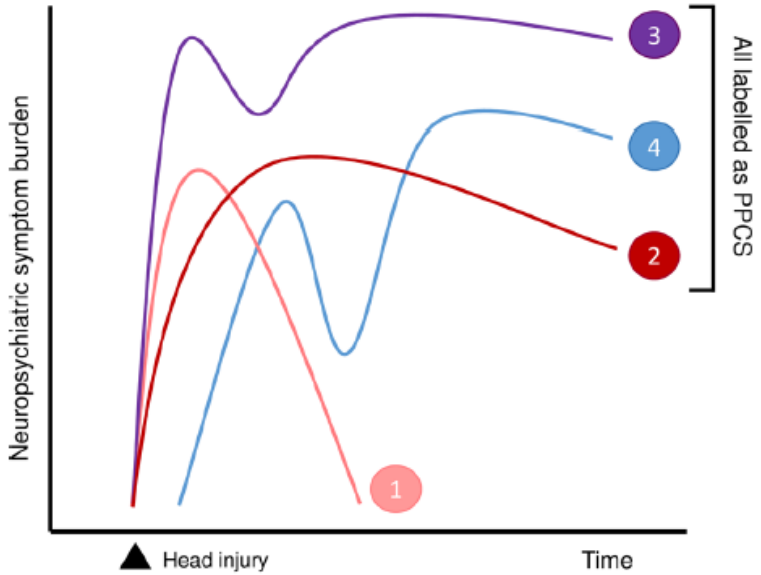
(Keynejad 2018)

Seeing the whole picture



(Lidstone 2020)

Natural history of PSaC/FND



1 Concussion

2 Concussion with prolonged symptoms

3 Concussion and FND

4 FND triggered by head injury (without concussion)

(Burke 2025)

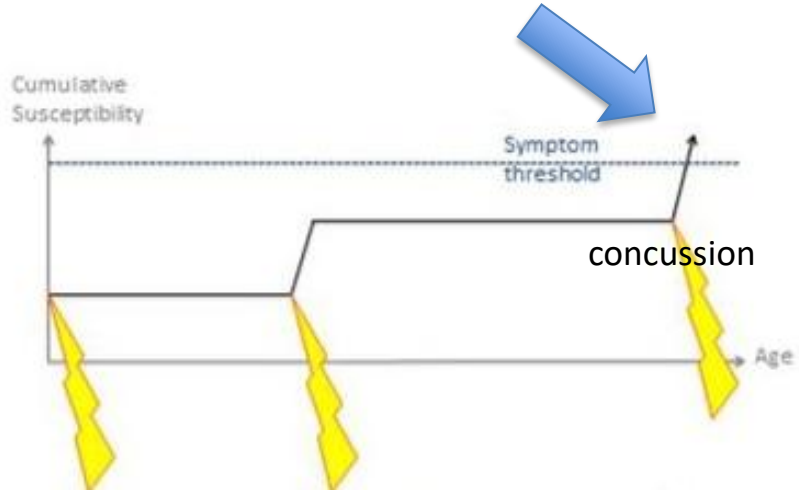
Natural history of PSaC/FND

N = 50 consecutive concussion → FND in PMR, neurology, neuropsychiatry clinics

Time of onset:
<1wk: 46%
1wk-3mo: 26%
>3mo: 28%

There is often a second event, e.g. migraine, loud noise, stressor or cumulative burden that tips the threshold

Concussion neurobiology
Acute stress reaction
Physical symptoms
Emotional symptoms
Functional impairment
Psychosocial stressors

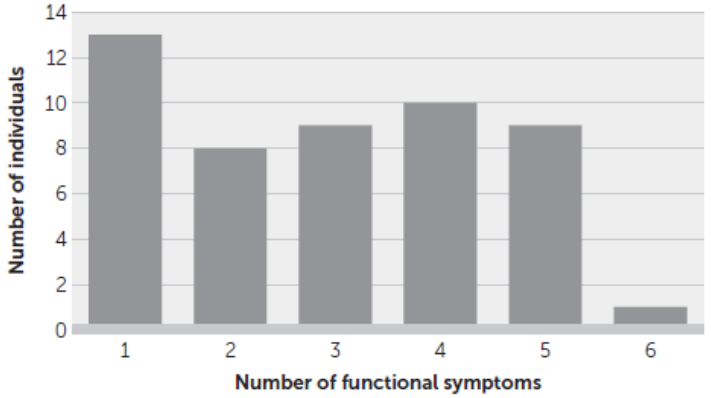


(Polich 2024)

FND phenotypes after concussion

Phenotype	N	%
Mixed functional neurological symptoms	37	74
Functional gait	31	62
Functional seizures	24	48
Functional speech and language symptoms	23	46
Functional weakness	21	42
Functional sensory symptoms	22	44
Functional movements	15	30
Functional oculomotor or vision symptoms	11	22

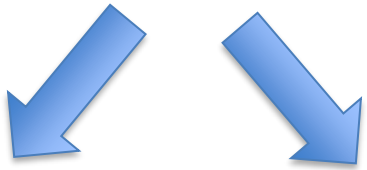
*did not include PPPD, FCD



If one symptom is functional, others may be as well

(Polich 2024)

Uncoupled versus coupled PSaC/FND symptoms



Functional hemiplegia

Functional paraparesis

Functional tremor

Balance difficulties → Functional gait disorder

Vestibular → Functional dizziness

Convergence insufficiency → Functional oculomotor disorder

Word retrieval → Functional stutter

Dazed, slow → Functional cognitive disorder

Disoriented → Functional seizure

Yellow flags for FND



- Implausible mechanism of injury
- Atypical neurological symptoms
- Delayed onset / atypical natural history
- Severe appearing symptoms out of proportion
- Symptoms that extensively wax or wane
- Discrepancy between reported symptoms and daily functional capabilities
- Pre-injury or comorbid trauma/abuse history, PTSD, or functional somatic syndromes

(Burke 2024; Polich 2025)

Diagnosing functional symptoms based on H&P

1) Rule out alternative neurologic disorders (imaging, labs, electrodiagnostics)

2) A positive diagnosis of FND is made

   - *Incongruency*
   - *Inconsistency*
   - *Distractibility*
   - *Suggestibility*

3) Formal versus informal examination



Case #1

64F hx trauma, anxiety, depression with MVA and concussion 6 months prior.

Ongoing HAs, dizziness, gait difficulties despite PT/OT.

CTH negative

Requires use of a walker.

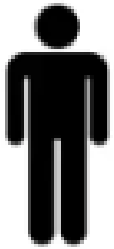
No longer able to work.

Exam:

- Strength intact.
- Sensation including proprioception intact.
- Normal FFM, FNF
- VOMs: VOR+, VMS+ mildly



Post-concussive gait abnormalities



Standing



Single task gait
(simple straight)



Dual-task gait
(e.g. cognitive task)



Complex gait
(uneven surfaces, obstacles)

Subacute/
intermediate



(Fino 2018)

Incongruent, inconsistent, distractible







Incongruent, inconsistent, distractible







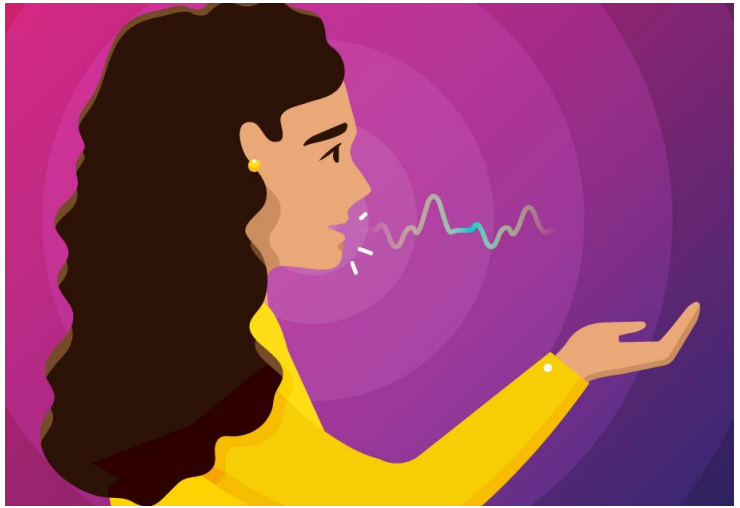
Functional gait disorders

Feature	Example
Incongruency	mTBI without structural damage does not typically result in severe gait symptoms Typically assistive devices are not needed
Inconsistency	Gait features are variable (listing either direction, halting)
Distractibility	Improves with tandem/improves with complex gait

Functional speech disorders

Moderate-severe TBI can cause motor speech disorders (dysarthria, apraxia of speech, stutter), aphasia and are associated with structural lesions.

Concussion is more often associated with milder, higher order speech deficits, e.g. word retrieval, and/or pronunciation of low-frequency, complex words.



(Lungren 2010; Ludlow 2003; Duffy 2016; Cannito 2014; Crawford 2007)

Functional speech disorders

Feature	Example
Incongruency	No facial, tongue weakness, oral mechanisms otherwise intact Normal imaging
Inconsistency	Worsens in times of stress
Distractibility	Effortful, halting when describing symptoms, otherwise fluent
Reversibility	Can respond rapidly to SLP

(Duffy 2016 and 2009; Picon 2021)

Functional cognitive disorders (FCD)



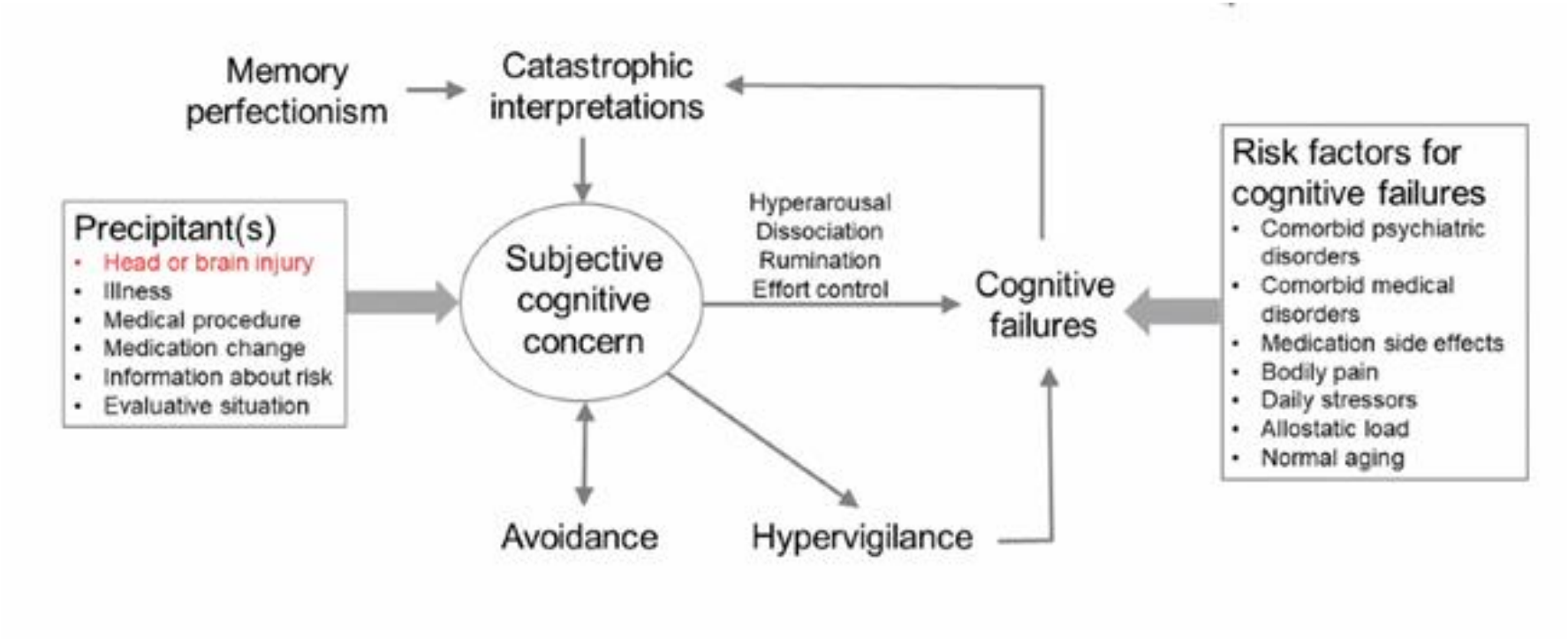
Persistent, memory or thinking problems + distress, impairment

- Poor concentration, forgetfulness, lapses, “autopilot”, WFD.
- Report excellent premorbid memory
- Thinking may feel hard and slow and provoke somatic symptoms
- Subjective difficulty with highest-level tasks

May worsen as individual withdraws from more activities, but thereafter stable, fluctuating, or improving.

(McWhirter 2025)

FCD: attention, meta-cognitive beliefs, cognitive control



(Silverberg 2023)

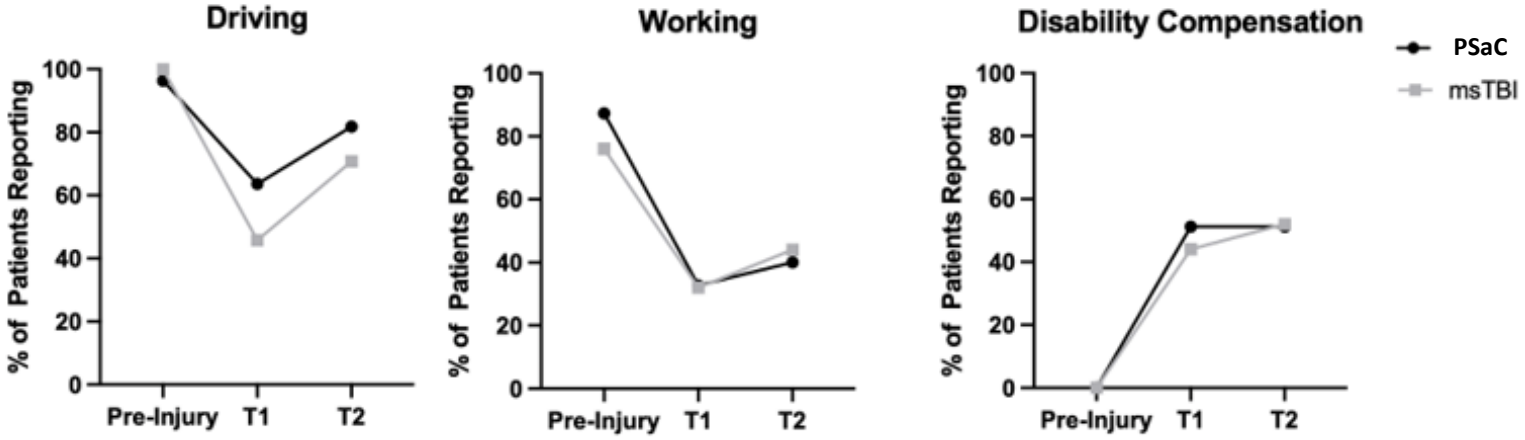
Inconsistency in FCD

Inconsistency	Example
Conversational ability	Provides detailed, linguistically rich examples of forgetting. Reports WFD but not clinically observed.
Collateral	Partner, friend, colleague not in agreement
NP testing versus daily life	Does extremely well on NP testing with functional impairment in daily life. Can function well in daily life, but does extremely poorly on NP testing.
NP testing (within)	Failed validity measures (less common) Sporadic domain-specific difficulties

(McWhirter 2025)

High rates of functional impairment in the PSaC population

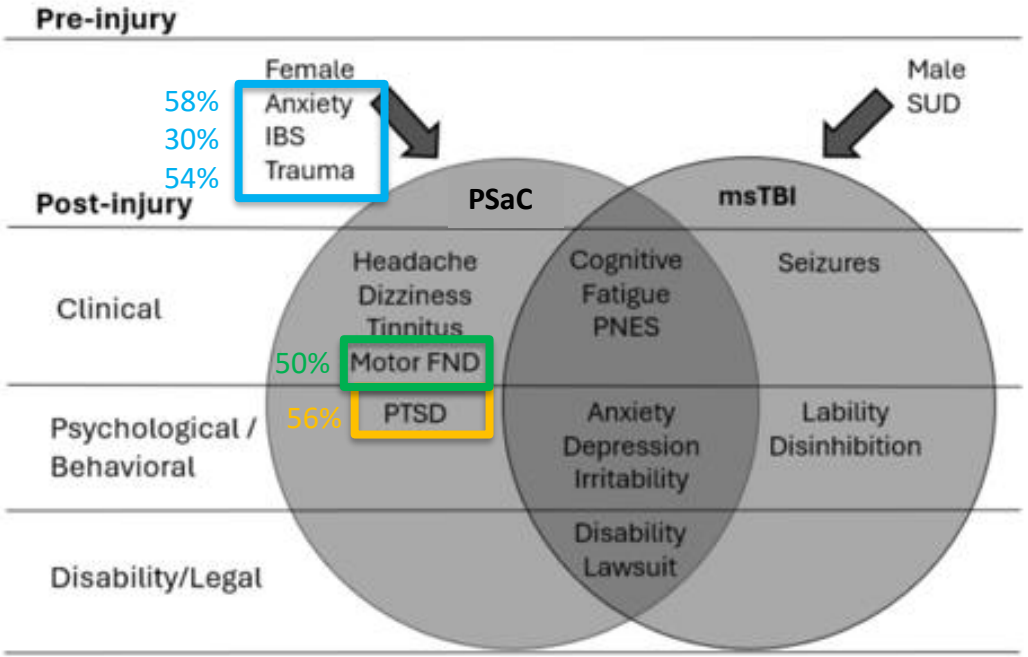
N=81 community-dwelling PSaC vs msTBI in a multidisciplinary clinic



PSaC are just as disabled as individuals with mod-severe TBI?

(Olson, in preparation)

Those with PSaC likely have multiple RFs for poorer outcomes

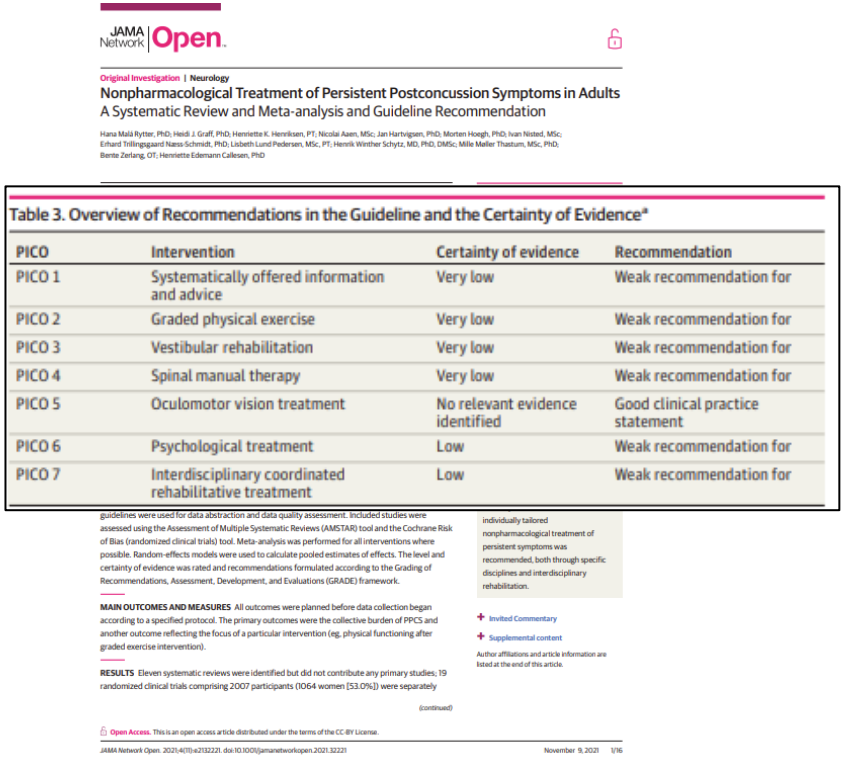


PSaC-FND vs PSaC-only

↓ assisted mobility (35.7% vs 3.6%)
↓ not driving (37% vs 0%)
↓ return to work (17.9% vs 63%)
↑ disability (70.4% vs 33%)

(Olson, in preparation)

Treating PSaC / FND is difficult



JAMA Network Open.

Original Investigation | Neurology

Nonpharmacological Treatment of Persistent Postconcussion Symptoms in Adults
A Systematic Review and Meta-analysis and Guideline Recommendation

Hana Malá Rytter, PhD; Heidi J. Graff, PhD; Henriette K. Henriksen, PT; Nicolai Aaen, MSc; Jan Hartvigsen, PhD; Morten Hoegh, PhD; Ivan Nisted, MSc; Erhard Trillingsgaard Nanss-Schmidt, PhD; Lisbeth Lund Pedersen, MSc, PT; Henrik Winther Schytz, MD, PhD, DMSc; Mille Møller Thastum, MSc, PhD; Bente Zerlang, OT; Henriette Edemann Callesen, PhD

Table 3. Overview of Recommendations in the Guideline and the Certainty of Evidence[a]

PICO	Intervention	Certainty of evidence	Recommendation
PICO 1	Systematically offered information and advice	Very low	Weak recommendation for
PICO 2	Graded physical exercise	Very low	Weak recommendation for
PICO 3	Vestibular rehabilitation	Very low	Weak recommendation for
PICO 4	Spinal manual therapy	Very low	Weak recommendation for
PICO 5	Oculomotor vision treatment	No relevant evidence identified	Good clinical practice statement
PICO 6	Psychological treatment	Low	Weak recommendation for
PICO 7	Interdisciplinary coordinated rehabilitative treatment	Low	Weak recommendation for

guidelines were used for data abstraction and data quality assessment. Included studies were assessed using the Assessment of Multiple Systematic Reviews (AMSTAR) tool and the Cochrane Risk of Bias (randomized clinical trials) tool. Meta-analysis was performed for all interventions where possible. Random-effects models were used to calculate pooled estimates of effects. The level and certainty of evidence was rated and recommendations formulated according to the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) framework.

MAIN OUTCOMES AND MEASURES All outcomes were planned before data collection began according to a specified protocol. The primary outcomes were the collective burden of PPCS and another outcome reflecting the focus of a particular intervention (eg, physical functioning after graded exercise intervention).

RESULTS Eleven systematic reviews were identified but did not contribute any primary studies; 19 randomized clinical trials comprising 2007 participants (1064 women [53.0%]) were separately

(continued)

individually tailored nonpharmacological treatment of persistent symptoms was recommended, both through specific disciplines and interdisciplinary rehabilitation.

+ Invited Commentary
+ Supplemental content

Author affiliations and article information are listed at the end of this article.

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JAMA Network Open. 2021;4(11):e2132221. doi:10.1001/jamanetworkopen.2021.32221 November 9, 2021 1/16

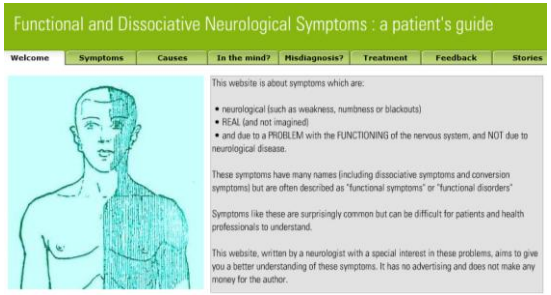
- Often very impaired with the most complex interaction of factors
- Evidence-based interventions for acute/subacute concussion are less well studied and may be less effective.
- Care is often fragmented
- Resource-intensive (multiple specialists, subspecialists, repeated courses of rehab over time)

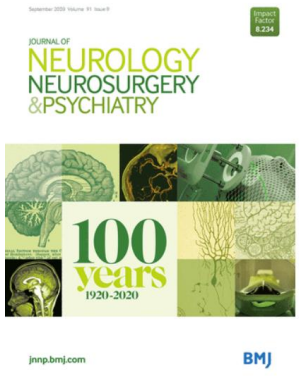
(Rytter 2021; Mollica 2026)

Multidisciplinary approach for FND

Physician

- **Making the diagnosis**
- Psychoeducation



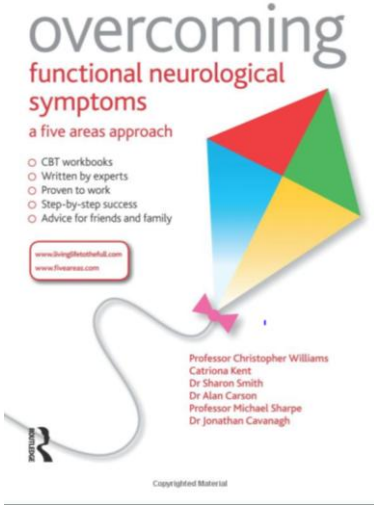


PT/OT/SLP

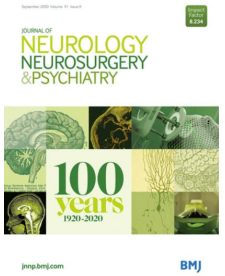
- Normalize motor programs
- Graded exercise program
- Behavioral approaches
- Distraction techniques

Mental health

- Treat psychiatric comorbidities
- Building awareness of triggers
- Affect tolerance
- Stress management
- “Function of symptoms”



Motor FND PT/OT/SLP consensus recommendations



Motor-relearning/behavioral

- Diverted attention
- Emotional regulation
- Agency

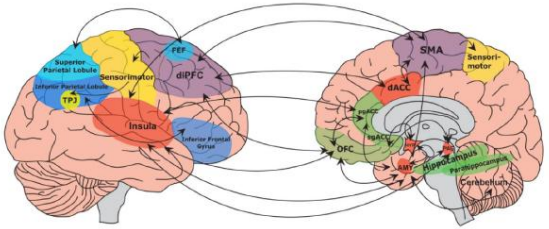


Table 3 Examples of techniques for specific symptoms to normalise movement

Symptom	Movement Strategy
Gait disturbance	Speed up walking (in some cases, this may worsen the walking pattern) Slow down walking speed Walk by sliding feet forward, keeping plantar surface of foot in contact with the ground (ie, like wearing skis). Progress towards normal walking in graded steps Build up a normal gait pattern from simple achievable components that progressively approximate normal walking. For example—side to side weight shift, continue weight shift allowing feet to 'automatically' advance forward by small amounts; progressively increase this step length with the focus on maintaining rhythmical weight shift rather than the action of stepping Walk carrying small weights/dumbbells in each hand Walking backwards or sideways Walk to a set rhythm (eg, in time to music, counting: 1, 2, 1, 2…) Exaggerated movement (eg, walking with high steps) Walking up or down the stairs (this is often easier that walking on flat ground)

(Nielsen 2015; Nicholson 2020; Baker 2021)

Divergent PSaC versus FND strategies for gait rehabilitation

PSaC	Functional gait disorder
Progressively challenging balance tasks: Stable to unstable Static to dynamic Single to dual task	Retrain movement with diverted attention, encourage autonomic movements, minimize self-focused attention. Instead of walking: Running Tandem gait Walking backwards Walking with music Tossing a ball while walking
Address vestibular-oculomotor issues	Minimize fear/hyperarousal with CBT/mindfulness, e.g. in session breathing and grounding
Stepwise progression, advance stages, e.g. RTP	Respectfully point out normal movements to patient when they occur

Functional gait disorders







Symptoms may not improve until a FND approach is applied

Pediatric concussion clinic: 5/84 (6%) with psychogenic gait

FND PT or mental health

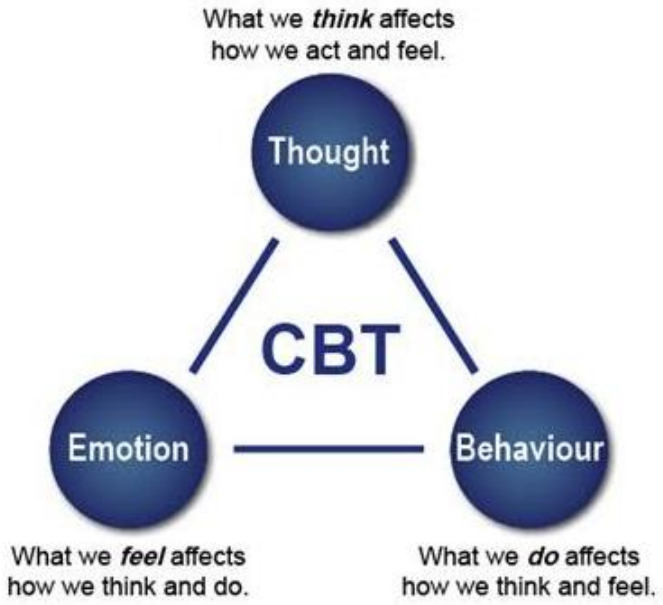
TABLE
Relevant Descriptors of Patients With Concussion With Psychogenic Gait

Patient/Gender	Age	Mechanism of Injury	Duration of Symptoms at Consultation (Weeks)	Risk Factor Before Injury	Non-gait Primary Presenting Symptoms	PT* or MHI	Time to Recovery (Weeks)
1: F	14	Low-velocity impact	4	Anxiety CDH	Cognitive Daily headache†	Both	3
2: M	12	Football: head-to-head hit	12	None	Daily headache†	PT	6
3: F	13	Low-velocity impact	6	Anxiety Episodic migraine	Daily headache† Anxiety	Stopped bullying Both	12
4: F	15	Motor vehicle collision	4	Personality disorder	Cognitive Daily headache ASD†	MHI	8
5: F	15	Heavy object fell on head	2	Episodic migraine Prior concussion	Daily headache† Depression	PT	4

*transient recurrence in times of stress

(Otallah 2020)

Broad-spectrum CBT is the best studied in PSaC (systematic review)



CBT improves PSaC:
Mental wellbeing
Anger
Anxiety
Depression

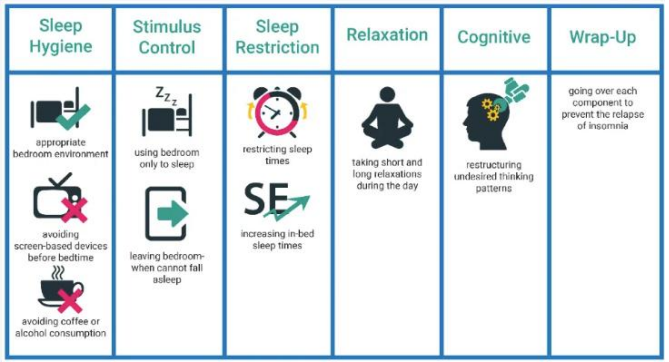
Evidence is lacking for:

- Reductions in global symptom burden
- Reductions in physical symptom burden (e.g. headache, fatigue)

(Smith 2024)

Targeted (symptom-based) CBT in PSaC

Several studies support the efficacy of CBT-insomnia (CBT-I) following ABI.



CBT-post-traumatic headaches (CBT-H)

- Improved: pain days/duration, QoL, disability
- No improvement: pain intensity, headache frequency

(Sanford 2025; Smith 2024; Vanderploeg 2019; Zhu 2026)

CBT for FCD after concussion (pilot feasibility)

Help normalize how to use memory and reduce reactivity to memory lapses

- In vivo exposure to avoided activities that risk memory failure
- Cognitive reappraisal to reinterpret memory lapses
- Allow for automaticity (versus increased effort) when retrieving information.
- Phase out of safety behaviors (checking, compensation)
- Monitor memory successes



Improved memory satisfaction

(Rioux 2024)

Acceptance and Commitment Therapy (ACT) for PSaC



(Quasi-experimental feasibility study)

"Context versus content of distress"

<u>ACT vs CBT</u>

Improved PSaC symptoms
Improved stress/anxiety reduction
Improved psychological flexibility
Improved disability

Similar improvements in depression

(Faulkner 2025)

Graded Exposure Therapy for Fear Avoidance

Planned Canadian multi-site RCT

16 sessions: psych (8hrs) and OT (8hrs) + homework

Exposure to valued activities/situations avoided due to fear of symptom exacerbation, re-injury, etc. (e.g. cognitive, exercise).

Grade on hierarchy and progressive exposure.

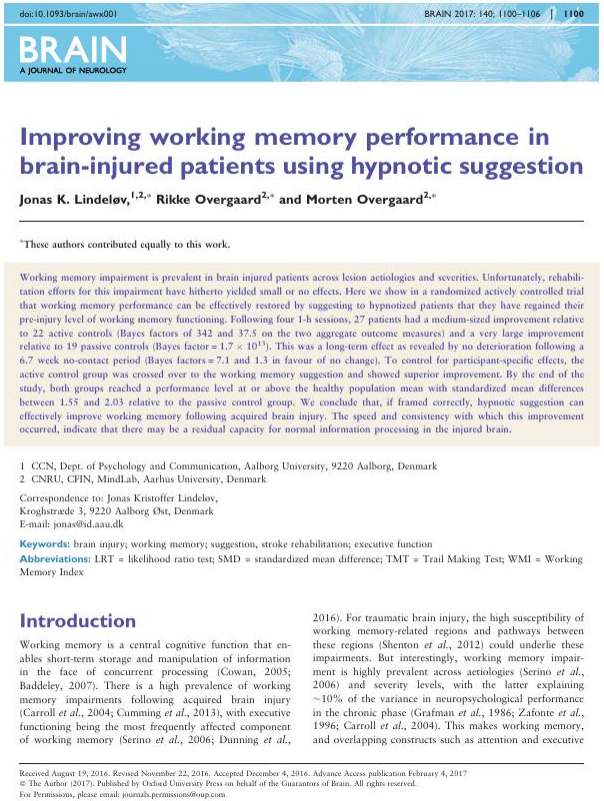
Work to reduce hypervigilance of somatic symptoms and cognitive reappraisal to address catastrophizing.





(Rioux 2025; Mikolic 2024)

Medical hypnosis (RCT)



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BRAIN
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Improving working memory performance in brain-injured patients using hypnotic suggestion

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*These authors contributed equally to this work.

Working memory impairment is prevalent in brain injured patients across lesion aetiologies and severities. Unfortunately, rehabilitation efforts for this impairment have hitherto yielded small or no effects. Here we show in a randomized actively controlled trial that working memory performance can be effectively restored by suggesting to hypnotized patients that they have regained their pre-injury level of working memory functioning. Following four 1-h sessions, 27 patients had a medium-sized improvement relative to 22 active controls (Bayes factors of 342 and 37.5 on the two aggregate outcome measures) and a very large improvement relative to 19 passive controls (Bayes factor = 1.7×10^{13}). This was a long-term effect as revealed by no deterioration following a 6.7 week no-contact period (Bayes factors = 7.1 and 1.3 in favour of no change). To control for participant-specific effects, the active control group was crossed over to the working memory suggestion and showed superior improvement. By the end of the study, both groups reached a performance level at or above the healthy population mean with standardized mean differences between 1.55 and 2.03 relative to the passive control group. We conclude that, if framed correctly, hypnotic suggestion can effectively improve working memory following acquired brain injury. The speed and consistency with which this improvement occurred, indicate that there may be a residual capacity for normal information processing in the injured brain.

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Keywords: brain injury; working memory; suggestion, stroke rehabilitation; executive function

Abbreviations: LRT = likelihood ratio test; SMD = standardized mean difference; TMT = Trail Making Test; WMI = Working Memory Index

Introduction

Working memory is a central cognitive function that enables short-term storage and manipulation of information in the face of concurrent processing (Cowan, 2005; Baddeley, 2007). There is a high prevalence of working memory impairments following acquired brain injury (Carroll *et al.*, 2004; Cumming *et al.*, 2013), with executive functioning being the most frequently affected component of working memory (Serino *et al.*, 2006; Dunning *et al.*, 2016). For traumatic brain injury, the high susceptibility of working memory-related regions and pathways between these regions (Shenton *et al.*, 2012) could underlie these impairments. But interestingly, working memory impairment is highly prevalent across aetiologies (Serino *et al.*, 2006) and severity levels, with the latter explaining ~10% of the variance in neuropsychological performance in the chronic phase (Grafman *et al.*, 1986; Zafonte *et al.*, 1996; Carroll *et al.*, 2004). This makes working memory, and overlapping constructs such as attention and executive

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- ABI average 5-7 years
- RCT with four 1-hour hypnosis vs active control
- Suggestions about enhancing WM - preinjury ability in the present using age regression and brain plasticity visualizations
- Post-intervention WAIS: WM and TMT A and B at or above healthy population mean
- Rapid improvement would not expected with structural injury (likely FCD phenomenon)

Big picture considerations

Consider FND on the ddx for PSaC

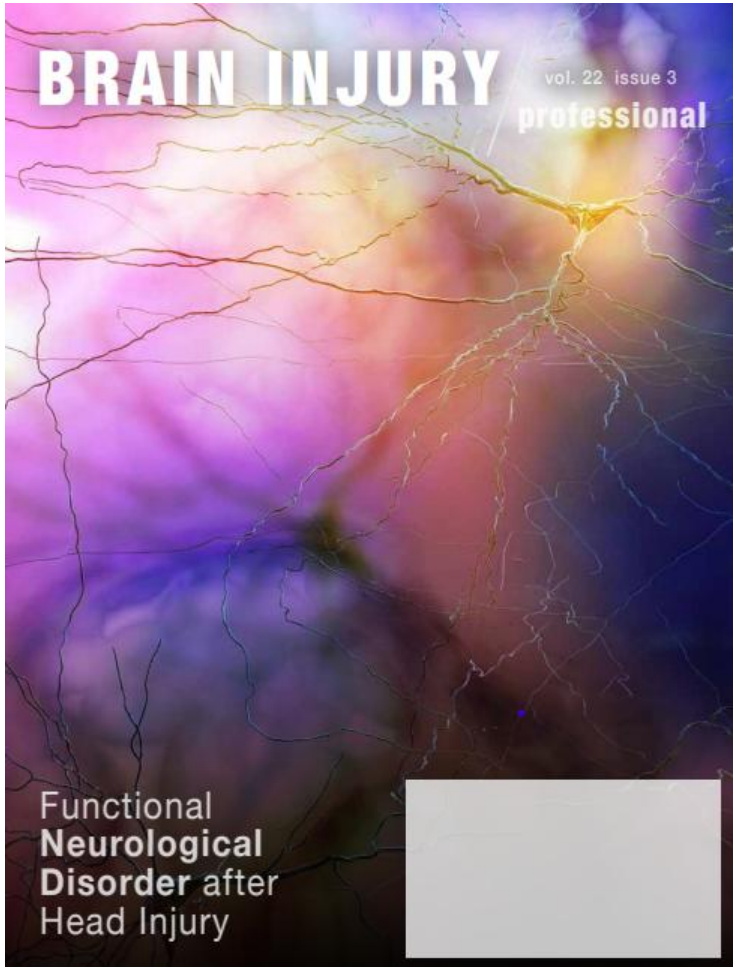
Individuals with PSaC likely have multiple RFs for symptom persistence

Consider incongruency, inconsistency, distractibility and suggestibility when making the FND dx.

Symptoms may not improve until FND-approaches are applied, including rehab and psychotherapy

Research into further integrated approaches is ongoing: CBT, targeted (symptom-based) CBT, ACT, Graded exposure, hypnosis





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Thank you!