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Particularities of Electrophysiological and Psychoneurological Assessment of Mild Traumatic Brain Injury

Gabriela Mariana MARCU[1]

Abstract

Neuropsychological functioning after mTBI is individualized and dynamic, with no currently known predictors and usually having a trajectory of gradual improvement. It is still a challenge to identify specific cognitive profiles associated with mTBI. One of the causes is the transient character of TBI symptoms as they are not appearing immediately after the injury. Another explanation resides in the individual and group variability of cognitive impairements following mTBI, which also affects the standardisation of the neuropsychological tests to use in mTBI assessment batteries (Iverson et al., 2013; Prince & Bruhns, 2017; Tulsky et al., 2017). Presently concussion has no accepted definition or diagnostic criteria. Also, there is no standard (or gold standard) for screening or properly identifying and diagnosing all population with concussion. (Borg et al., 2004).

Patients with mTBI could evolve in a bunch of physical, cognitive, and emotional symptoms (Permenter et al., 2021) that are usually known as post-concussion syndrome (PCS). In terms of symptoms, we target neuropsychological evaluation of four key domains ("higher-order attention", "executive function", "episodic memory", and "speed of information processing") implicated in chronic impairment after mTBI. Alternatively, studies on the EEG frequency domain shed new light on the possibility to have a diagnostic marker based on QEEG patterns identified in the mTBI population and some prognostic factors for the PCS syndrome (Rapp et al., 2015; Thornton & Carmody, 2009).

Given the particularities of neuropsychological functioning after mTBI we emphasize the need of a mixed methodology, using both electrophysiological and psychoneurological tools, to provide the best sensitivity and specificity in assessing cognitive and functional deficits and in predicting further PCS.

Keywords: *Mild traumatic brain injury, psychoneurological assessment, electrophysiological assessment, QEEG, post concussive syndrome.*

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1. Diagnosis and assessment of Mild traumatic brain injury(mTBI)

Traditionally, mild traumatic brain injuries (mTBI) have been considered insignificant, as the symptoms resolve spontaneously after a few days. However, this idea is facing a growing need for re-analysis.

Despite progress in demonstrating the underlying neuropathology in mTBI, considerable disagreement persists in neuropsychology on the effects of mTBI and assessment tools. About 80- 85% of TBIs are mTBIs, so the prevalence of mild form is pretty high in general picture of brain injuries. While most of the concussion symptoms last at most a few weeks, there could be cases of symptoms that persist for 3 months or more, which were named "post-concussive syndrome" (Kosoy & Feinstein, 2018).

A long-standing controversy surrounding post-concussive syndrome (PCS) concerns its etiology and the degree to which psychological and organic factors involving brain dysfunction are responsible - the debate being called "psychogenesis versus physiogenesis" of PCS.

2. The Post-concussive syndrome

Post-concussive syndrome (PCS) has been much debated in literature, due to conflicting findings on symptom duration, absence of objective neurophysiological findings, inconsistencies in measurements, poorly understood etiology and methodologic problems. Depending on the definition the method, 29%-90% of patients experience PCS after the traumatic event.

Diagnostic criteria for PCS could be found in DSM-IV and also in ICD-10, but there are important differences in the two diagnostic systems. The most important diference is that only the DSM system contains explicit requirement for evidence. Neuropsychological testing is there requested for confirming the diagnosis of PCS, in a "disorder" paradigm.

Interestingly, over the last decade, research has shown that post-concussive-like symptoms are frequently associated with disorders like acute PTSD (40%), depression (57%), anxiety (50%) or somatisation (91%) than with mTBI (only 32%) (Donnell et al., 2012; McCrea, 2007; Smith-Seemiller et al., 2003).

Results are in line with existing literature on PCS signs and symptoms, that elaborates on the idea of these simptoms not being unique to concussion.

Such findings impacted the neuropsychological research that should now have to focus on a specific outcome or domain impaired by mTBI rather than on postconcussion syndrome. The research predominant findings are usually showing a short-time for full cognitive recovery - from days to several weeks. One suggestion (Richards, 2009) was to investigate the persistence of cognitive difficulties by considering other factors such as depression, PTSD, pain and psychological factors. The validity of the association of postconcussional disorder with the mTBI is questioned in the DSM-V, where a new spectrum known as the "Neurocognitive disorders" took the place of former category of "postconcussional disorder"

(American Psychiatric Association, 2013).

3. Neuropsychological assessment of mTBI

Given the inconsistent picture of this specific disorder's characteristics, a gold standard diagnostic test or an established battery of objective and subjective measures as well or biomarkers for mTBI are still lacking. Thus, the challenge in diagnosing concussion is to confirm a specific pattern of signs and symptoms, which is mostly subtle and transient, after an injury. Given the case, multiple evaluation tools are recommended, like combining self-reported scales with structured interview, checklists, and neuropsychological assessment to increase the sensitivity and specificity in mTBI assessment. (Graham et al., 2014).

A diagnostic test for a disease is usually analysed by some indicators like sensitivity, specificity, positive or negative predictive value. Those descriptions help to tell how precise is the test in truly identifying the disease. However, interest is also raised by the predictive values (positive or negative). To increase the predictive value, we should stop looking only after PCS's signs and symptoms and to mix the objective and subjective assessment methods in a complex evaluation tool.

Recently, a review of the screening instruments for mTBI diagnosis, conducted by Park & Koo, suggested an extention of the existing toolkit, by adding clinical examinations and symptom checklists to the classic cognitive evaluation. (Park & Koo, 2019). One of these tools is neuropsychological testing but it does not independently determine whether an individual experienced a concussion or else. (Halstead et al., 2010).

For example, below we summarized tools used in literature for the mental fatigue domain of mTBI simptoms and marked the instruments/equipment .

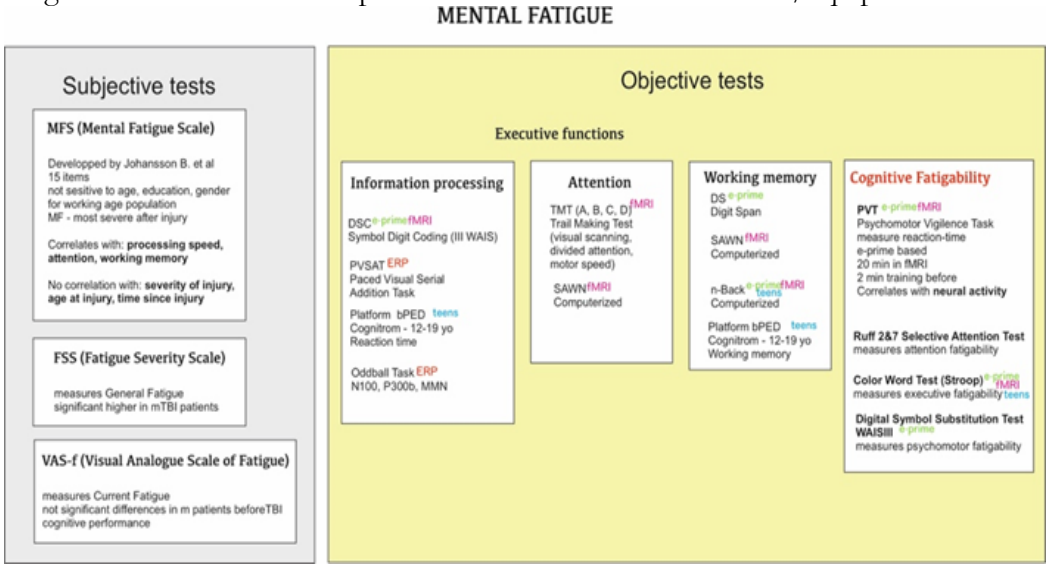


Fig. 1. Example of a mixed assessment for one mTBI domain: Mental Fatigue Source: author's analysis

Even if the neuropsychological assessment is a valuable toolf for a multidimensional approach in evaluation, researchers recommend that it "should not be used as the sole basis for diagnosing concussion". (M. A. McCrea et al., 2017). Research should focus more on it's predictive value, such as to identify patients at high-risk for prolonged cognitive deficits(Cushman et al., 2001). Some possible markers were proposed in an extensive literature. (Alsalaheen et al., 2021; Arch & Ferraro, 2021; Arciniega et al., 2021; Meltzer & Juengst, 2021; Parker et al., 2021; Renaud et al., 2020; Stenberg et al., 2020).

We can conclude that symptoms in the physical, cognitive, and emotional registry could be met in a specific pattern in patients with mTBI – pattern known as post-concussion syndrome (PCS) - but they should not necessary be associated with this specific syndrome. To have a complete assessment of mTBI cognitive symptoms, for example, literature recommends the evaluation of at least four key domains involved in the neuropsychological impairment after mild traumatic brain injury: "1) higher-order attention, 2) executive function, 3) episodic memory, and 4) speed of information processing". (Dambinova et al., 2012).

4. Computerized neuropsychological assessment

Neurocognitive or neuropsychological tests are designed as objective measures of brain function. The "new generation" evolved in computerized testing batteries such as: "Automated Neuropsychological Assessment Metrics (ANAM)", "CogState", "HeadMinder, and Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)".

There are both advantages and disadvantages of computer testing: testing a group of patients simultaneously with automatic and accurate scoring is a clear advantage. Disadvantages include chance of misunderstanding the instructions, a less supervised environment, or restrictions given by the lack of open-ended questiomns. Also, there are still in debate their psychometric properties and clinical utility. (Arrieux et al., 2017).

A recent scoping review (Jones et al., 2021) of the neurocognitive assessment tools (NCATs) revealed that the NCATs mostly used among the 33 studies were "Automated Neuropsychological Assessment Metric" (46%), "Defense Automated Neurobehavioral Assessment" (15%), and "Immediate Post-Concussion Assessment and Cognitive Testing" (10%). However, one challenging finding was that the diagnosis of mTBIs varied across all studies (and that could affect validity). One of the recommendations was that NCATs should be used cautiously and "only as one source of information from many other types of clinical tools and observations" (Jones et al., 2021).

These results are congruent with an extensive research about the validity and clinical utility of NCATs. Results show support for NCAT's validity and some specificity in identifying concussed individuals form controls. Other aspects of validity are still questionable., as well as their clinical utility, outside the timeframe of the injury. Literature, however, confirms the validity of four NCATs which can be

applied for clinical and research purposes: "Automated Neuropsychological Assessment Metric (ANAM)", "CNS-Vital Signs (CNS-VS)", "CogState" and "Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)".

5. QEEG markers

Quantitative EEG (QEEG) techniques are using the electric signal read by the electroencephalogram (EEG) to make computations resulting in brain maps that could be compared with normative databases. QEEG proved efficiency in brain signal changes identification, when meaaured after concussion (Gosselin et al., 2009) and even after the behavior deficits withdraw (McCrea et al., 2010; Prichep et al., 2013).

Findings that QEEG continue to identify differences that suggest abnormalities in brain function, despite the absence of the behavioral signs and symptoms, were constantly confirmed in literature, in some cases even 45 days post injury (Barr et al., 2012).

A paper published in April 2021 supports the use of QEEG as an efficient and cost-effective screening tool, especially when visual EEG inspection provides no cues of possible concussion. (Kerasidis & Simmons, 2021). It is stated that qEEG shows sensitivity and specificity both in acute and convalescent settings.

Some QEEG patterns reported in TBI eyes-closed protocols, include low alpha (rel. power) in the posterior sites, increased theta (rel. power) to O1-O2, increased slow frequencies (delta, theta, slow alpha <10Hz), decrease in alpha and beta (Thatcher et al., 1989; Thornton & Carmody, 2009).

These findings may have a positive impact on treatment design, especially when choosing to apply neuroregulation techniques like EEG-Neurofeeback.

6. Event-related potentials in mTBI

The event-related or evoked potentials (ERPs) are EEG partitions that are time-locked to a stimulus onset. Time-locking means recording only the part of an EEG wave that follows the word, sound, or picture stimulus. (Molfese et al., 2001). Research shows encouraging results in using this cost-effective measurement of brain activity, showing strong associations with findingsn from fMRI, MEG, FNIRS and PET techniques. One big advantage is the temporal resolution of the information, which is high.

Findings in ERP research show that ERP measurement successfully indicated association with othe assesement tools in contrasting concussed with non-concussed athletes (Broglio et al., 2011). Also, the P300 or P3b component was found to be smaller in children, adolescents, and adults with concussion history than in individuals without concussion (Baillargeon et al., 2012). Like in the QEEG studies, ERP studies (like persistent abnormalities in the P3b) show that recorded differences may continue even in the absence of other indications of concussive injury (behavioral or somatic). Neurocognitive functioning was altered in mTBI teenage population while assessing ERP's components related to executive control and attention (N2b and P300) and to the automatic pre-conscious awareness

(MMN). The N2b and P300 was atenuated in mTBI adolescents, while the N2b latency correlated with the number of days since injury, making this last component a possible marker of the recovery process (Ruiter et al., 2020).

We also advise that one should be careful with the interpretation of these results, given application of a limited set of tasks for a narrow selection of cognitive abilities. This is why a combined assessment would ensure more precision and validity.

7. Conclusions

Even if the differences found are useful for grouping subjects in symptom clusters, there is still a lot of individual variability and lack of stability in some of the measured variables. This is why our opinion is that the neuropsychological tests should be used to characterize function, to contribute to diagnosis, not to make diagnosis.

Given the peculiarities of neuropsychological functioning after mTBI, we conclude that more research is needed to define a post-concussion phenotype and we propose an assessment approach with objective and standardized measurements, to provide the best sensitivity, specificity an predictive value for detecting possible cognitive and functional deficits in mTBI.

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