9-2015

Constructing a Dynamic Model of Concussion

Erin S. Kenzie
Portland State University, erin.kenzie@pdx.edu

Elle L. Parks
Portland State University

Wayne W. Wakeland
Portland State University, wakeland@pdx.edu

Constructing a Dynamic Model of Concussion

Erin Kenzie[1*], Elle Parks[1], & Wayne Wakeland[1]

[1]Systems Science Program, Portland State University, Portland, Oregon USA, *erin.kenzie@pdx.edu

CCS'15 Conference on Complex Systems

Track: Complexity in Biological Systems

1 Aim

To construct a causal-loop diagram and corresponding system dynamics model of concussion pathology and recovery at the individual scale. These models will contribute to a greater understanding of the factors involved in concussion recovery and will inform the development of a new classification system for traumatic brain injury.

2 Problem

• Traumatic brain injury has been called "the most complicated disease of the most complex organ of the body" (Marklund and Hillered 2011).

• In the United States, an estimated 1.7 million people suffer a traumatic brain injury per year (Faul et al 2010). Seventy to ninety percent of these cases are mild TBI, or concussion (Cassidy et al. 2004). Concussion is vastly underreported; one study found that at least 88% of cases might go unrecognized (Delaney et al. 2005).

• No single definition of concussion (also known as mTBI) is accepted across disciplines, though several different definitions are available (Comper et al. 2005; Hawryluk & Manley 2015).

• Injury occurs in context. Traumatic biomechanical forces in the brain can occur from direct (to the head) or indirect (to the body) impact (e.g., sports, workplace accidents, violent trauma), fast acceleration or deceleration (e.g., motor vehicle accidents), or intense changes in pressure (e.g., blast exposure) (Patterson & Holahan 2012).

• Following a concussion many people become symptom-free within a short period of time. However, an estimated 15% of people experience longer-term symptoms and deficits, although this number has been disputed (Zasler et al. 2007). These impairments can cause significant distress and debilitation.

• The medical field currently lacks reliable and accessible means of identifying individuals at risk for more prolonged or complicated recoveries from concussion.

• The current classification system for traumatic brain injury (mild, moderate, severe – based on the Glasgow Coma Scale) lacks precision and does not reliably predict recovery. The field is engaged in developing a new classification system.

• No clinically useful biomarker or imaging technique has been identified for concussion, although several show promise.

• A wide variety of medical disciplines and specialties study and treat individuals with concussions.

3 Methods

• Model development led by methodology team in cooperation with a large team of researchers and clinicians gathered by the Brain Trauma Evidence-Based Consortium (B-TEC)

• Conducted extensive review of relevant literature, interviewed many key researchers, clinicians and athletic trainers, and conducted focus groups with young athletes suffering from prolonged recovery from concussion and their parents

• Iterative model development with frequent review by experts

Funding: This material is based upon work supported by the US Army Contracting Command, Aberdeen Proving Ground, Natick Contracting Division, through a contract awarded to Stanford University (W911QY-14-C-0086), and a subcontract awarded to the Brain Trauma Foundation. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the US Army Contracting Command, Aberdeen Proving Ground, Natick Contracting Division, Stanford University, or the Brain Trauma Foundation.

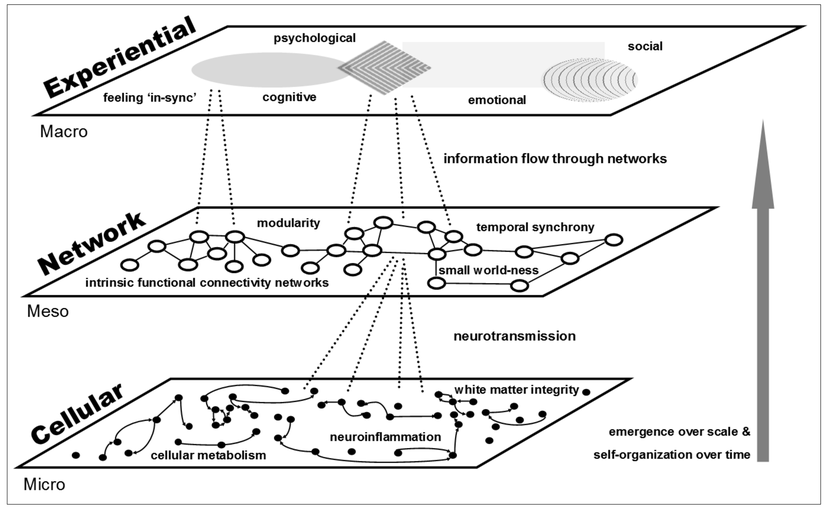

Figure 1: DRAFT diagram of multiple scales of concussion. Our analysis focuses on factors at three primary levels of analysis: cellular, network, and experiential.

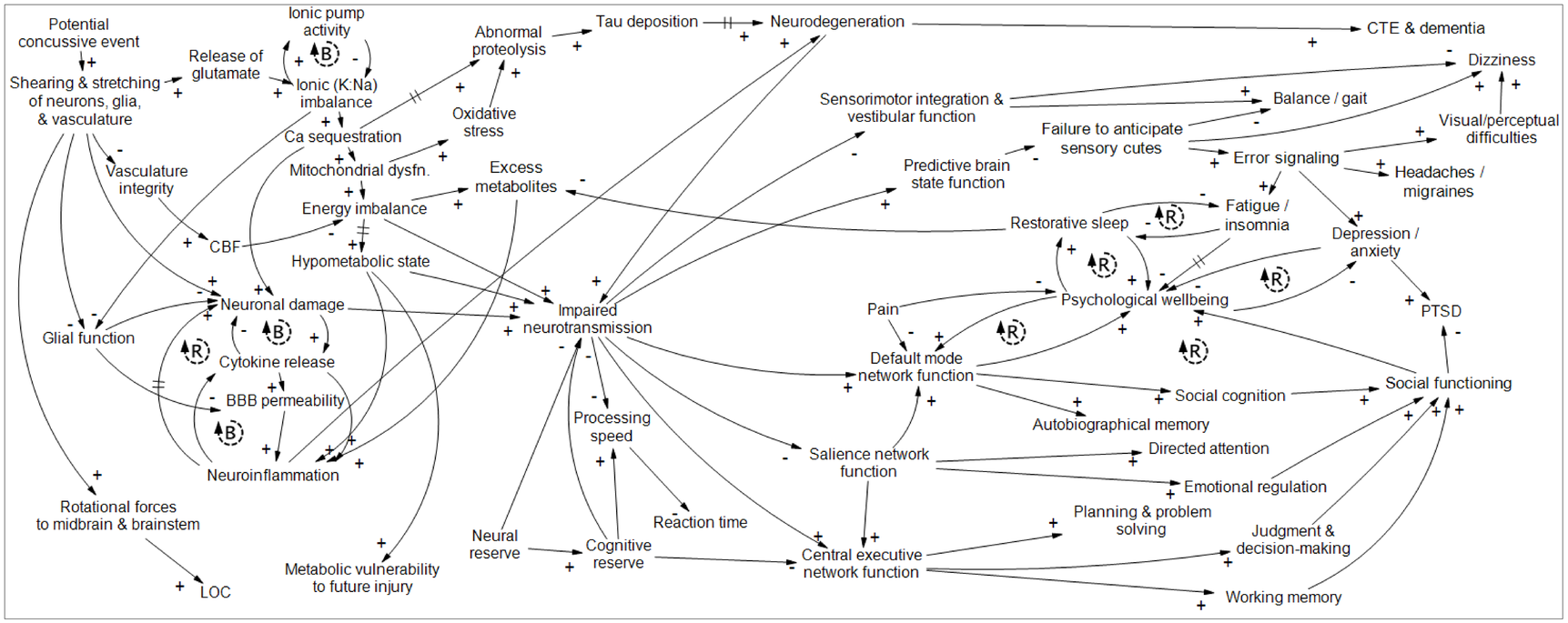

Figure 2: DRAFT causal-loop diagram of concussion. Created in MapSys.

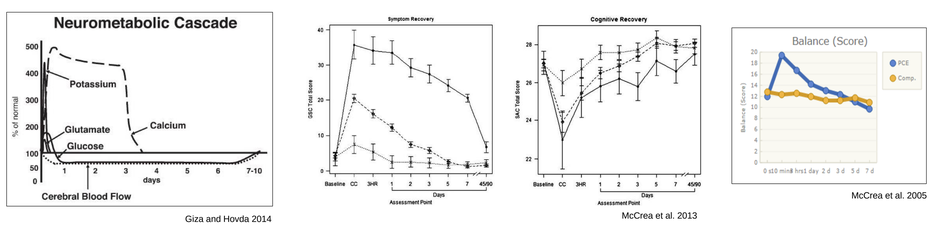

Figure 3: Reference behavior at group scale for concussion recovery trajectories.

4 Concussion through a systems lens

• The brain is a highly complex system, with billions of neurons and trillions of connections. In concussion, damage is diffuse and spread throughout the brain.

• Concussion is a highly heterogeneous phenomenon. Patients suffer a wide variety of impairments, including cognitive, physiological, social, and emotional effects. Brains themselves are highly heterogeneous, as are modes of injury.

• Many factors interact dynamically to influence an individual's recovery trajectory. The influence of these variables can differ across individuals, and can change over time.

• Concussion can be understood through Ahn's systems biology concepts of context, space, and time. Injury and recovery contexts set recovery trajectories, location of injury in the brain is important, and patients report feeling 'out of sync.' Concussion is also said to disrupt a person's predictive brain state (Ghajar and Ivry 2008).

• Concussion symptoms and deficits impact the emergent properties of the individual, such as consciousness and self-identity.

• Multiple stakeholders, disciplines, perspectives, and forms of knowledge pertain to concussion.

5 Next steps

• Enhance conceptual model based on information from interviews and literature review

• Acquire reference behavior data (recovery trajectories at the individual level)

• Develop system dynamics computational model that will generate estimated recovery trajectories based on individual inputs for key parameters. The model will assist in the development of a new classification system for TBI, identify research gaps, aid in the design of successful clinical trials (especially appropriate inclusion/exclusion criteria), and promote discussion among experts.

• Collaborate with a related B-TEC project that is creating data-driven models using OCCAM reconstructability analysis software.