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Using Systems Methods to Create a Dynamic Model of Concussion Recovery

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Disclosures

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Introduction

- 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).

- 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.

- Treatments are lacking, and **recovery trajectories remain largely unpredictable**.

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Methods

- Systems science is a transdisciplinary field that examines the nature of complex systems and develops theories and methods to better understand and manage those systems. By specializing in understanding the complex aspects of systems, such as nonlinearity, emergence, and dynamic change over time, systems science can address questions that are often inaccessible with traditional linear or reductionist methods. System dynamics is a modeling method within system science that makes relationships between key system variables explicit in order to endogenously generate dynamic system behavior.

- A methodology team of systems scientists at Portland State University conducted extensive review of relevant literature; interviews with key researchers, clinicians, and athletic trainers; and a focus group with young athletes suffering from prolonged recovery from concussion and their parents.

- Interviews with experts in the field emerged through collaboration with a team of researchers and clinicians gathered by the Brain Trauma Foundation (BTF) from the fields of neurotrauma, neurosurgery, psychiatry, sports medicine, rehabilitation, neuroscience, and others.

- We aimed to create a conceptual systems model of concussion that synthesizes knowledge of the physiological, cognitive, network-scale, psychological and social mechanisms underlying concussion.

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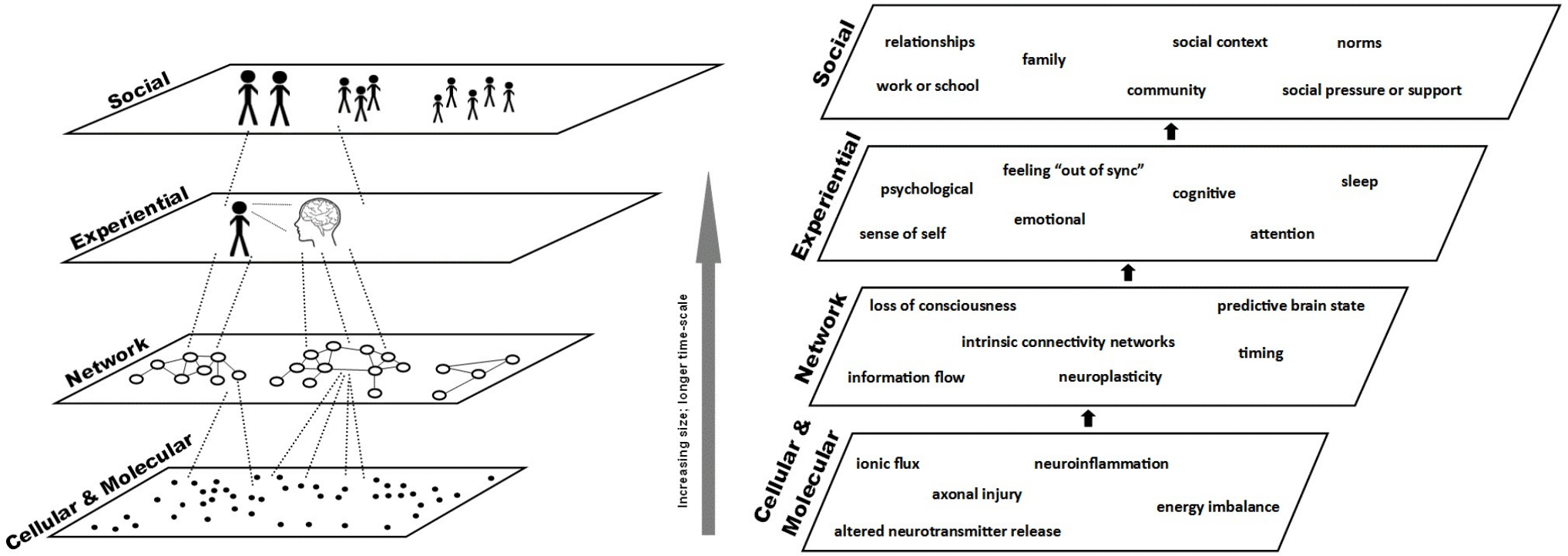
Results

- We created two conceptual models for concussion:
  - A multi-scale conceptual model emphasizes emergence and interactions between molecular, cellular, network, experiential and social levels of concussion. This model introduces key system variables and provides a framework for researchers and clinicians to better understand concussion as a whole system with many concurrent variables acting across multiple scales.
  - A causal-loop diagram (CLD) describes how the system works by making cause-and-effect relationships and feedback loops explicit between specific system variables and through time. The precise structure of the CLD model allows for the dynamics of the system to be clearly articulated, providing specialists from many disciplines a common platform for communicating about how different recovery trajectories are generated. (CLD still in development.)
- Injury and recovery contexts set recovery trajectories. Location of brain injury can be better understood through a system dynamics perspective.

Results: Multi-scale framework



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Conclusion

- Concussion is a transdisciplinary problem involving multiple stakeholders, disciplines, perspectives, and forms of knowledge.

- Concussion is highly heterogeneous. Patients suffer a wide variety of impairments, with 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. Dynamic feedback loops continue to shape recovery moment to moment.

- 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 "black boxes" remain, including the mystery of consciousness itself.

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Next Steps

- Publish conceptual models (in process).
- Work in collaboration with other researchers and clinicians to use concepts of emergence and scale to better understand how concussion manifests on molecular, cellular, network, experiential, and social levels.
- Use models to contribute to ongoing efforts to improve TBI classification.
- Begin development of computational system dynamics model of recovery trajectories based on causal-loop diagram.
- Collaborate on data mining project (OCCAM) with researchers at Portland State University and Brain Trauma Foundation to synthesize approaches and identify clinical parameters relevant to recovery.