Attention, Effort, and Fatigue in People with Traumatic Brain Injuries: Neuroscience Drives Clinical Decision Making

- Donald A. Robin, Ph.D.
- Professor and Chair
- Department of Communication Sciences and Disorders
- Professor
- Interdisciplinary Program in Neuroscience and Behavior
- The University of New Hampshire

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Drs. Robin and Ramage share intellectual property equally and both work full time at the University of New Hampshire which supports this work by providing salaries, office, and laboratory spaces.

About Me

- M.S. (1981) from University of Redlands in SLP
- Ph.D. (1984) from Case Western Reserve University in Psychophysics and Neuroscience
- Faculty positions include University of Iowa, San Diego State University, University of Texas Health Center at San Antonio, University of New Hampshire (Durham; Current)
- Over 200 publications
- Clinician, Educator, Scientist
- Funded by NIH, DoD, VA
- Plays guitar (Royal Punisher)
- 5 kids and 3 grand kids and married to Amy Ramage
- Have trained numerous undergraduate, graduate, and post-doctoral students
- Has worked with Brain Injury since 1979

Outline

- Introduction to Fatigue and Brain Injury
- Define Fatigue and Sense of Effort
- How to measure fatigue
- Neurobiology of brain injury focusing on fatigue
- Clinical Implications
- Future Needs

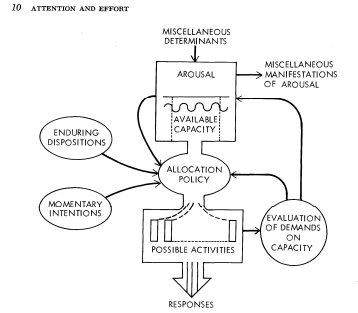
Definitions

- Mental fatigue results from a complex interaction between multiple processes and can be defined by time on task and increased sense of effort.
- Fatigue measures include performance accuracy, reaction time (RT), overall feelings of tiredness, and poor attention and memory.
- The relationships among fatigue, effort, and performance have been modeled by Kahneman (we will get into this in a minute)
- Fatigue is closely tied to cognitive flexibility

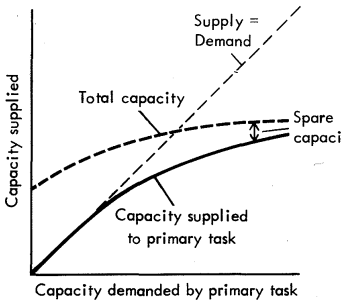
Mental Effort/Sense of Effort

- We have an ability to sense how hard our body and our mind is working and this is known as "sense of effort."
- Sense of effort/cognitive or mental effort is perceived during tasks and relates to task performance.
- Our sense of effort drives how we allocate our resources to a given task.
- With a brain injury, not only is sense of effort impacted but the ability to and the amount of resources available to perform a task are reduced.
- In turn, this leads problems performing and extended periods of fatigue.
- High effort often leads to reduced motivation to perform.

Kahneman, D. (1973). Attention and effort. Prentice-Hall.



Kahneman, D. (1973).



Summary Points

- We have a limited capacity and must have enough "fuel" to perform well.
- We need to allocate our resources strategically in order to be successful.
- Task demand refers to how complex it is and this also needs to be evaluated to be successful.
- When tasks are perceived as hard, we use more researches and reach our limit – once that happens, we cannot perform successfully.
- Our sense of effort is the result of task complexity and resource allocation and as it get high, we fatigue more rapidly.

Brain Injury and Fatigue

In healthy people, mental fatigue occurs under conditions of high cognitive demand

As one performs a task over a period of time, fatigue and sense of effort increase and performance suffers

Following brain injury mental fatigue is persistent/constant and sense of effort is high resulting in debilitating performance decrements

Brain Injury and Effort

Clark, H.M., & Robin, D.A. (1995). Sense of effort during a lexical decision task: Resource allocation deficits following brain damage. *American Journal of Speech-Language Pathology, 4*(4), 143-147. DOI: 10.1044/1058-0360.0404.143

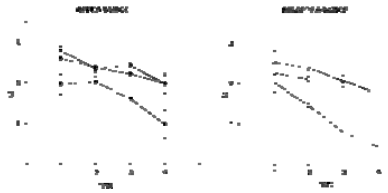
- Participants were health or had suffered a TBI
- They had to make lexical decisions about if a letter string was a real word or a pseudoword and the words varied in complexity.
- The visual display was clear or blurred (higher complexity)
- Participants rated their sense of effort on a scale of 0-200 with 100 being average effort
- Accuracy and RT data were also collected
- Healthy participants had a linear relationship between task complexity and effort. **People with TBI reported higher effort on low and middle complexity levels but no effort on the most complex task**

Robin, D.A., Max, J.E., Stierwalt, J.A.G., Guenzer, L.C., & Lindgren, S.D. (1999). Sustained attention in children and adults with traumatic brain injury. *Aphasiology, 13*(9-11). DOI: 10.1018/026870399401812

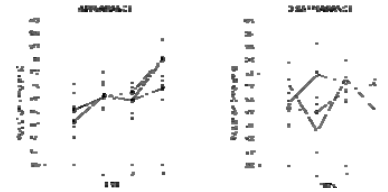
Starry Nite – sustained visual attention task that measures accuracy and RT

49 participants with TBI ranging from mild to severe

Data measured over a 12-minute period



Accuracy Results



RT Results

Neurobiology of Mental Fatigue/Sense of Effort Following TBI

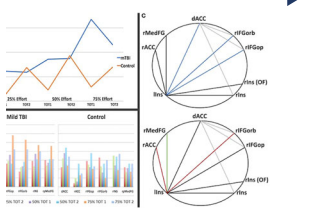
Ramage, A.E., Tate, D.F., New, A.B., Lewis, J.D., & Robin, D.A. (2019). Effort and fatigue-related functional connectivity in mild traumatic brain injury. *Frontiers of Neurology, 18,* 01165. DOI: 10.3389/fneur.2018.011165

- Studied fMRI activity during a sense of effort-fatigue task
- Participants were asked to maintain a certain level of effort while pushing an air-filled bulb. The began by matching the level of pressure to a visual display, closed their eyes, and held effort constant.
- When doing this, you exert less and less pressure in order to keep effort the same.
- Task reflects central sense of effort and subsequent fatigue.
- Hold arm out to the side and close eyes and keep effort level the same.
- Image analysis used graph theory metrics to determine brain networks involved in fatigue/effort and their relationship to behavioral measures.

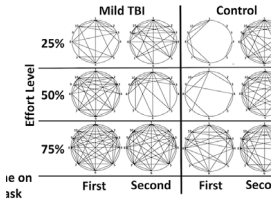
Participants

- 61 individuals with mild TBI (mean age = 33)
- 42 individuals with orthopedic injuries (mean age = 37)
- Mostly males
- Mostly White though there were a total of 19 African Americans and 2 Native Americans
- 26 were Hispanic or Latino
- Education levels ranged from GED/Diploma in High School or higher

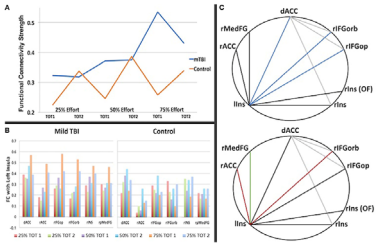
mTBI hyperconnected



Effect of Time on Task



Strength of Network Connectivity, Regional Connectivity within Networks, and Time on Task (TOT)



What's it mean?

- Functional connectivity (network) analysis is key at understanding brain mechanisms of fatigue and sense of effort
- In TBI, individuals elevated effort level incrementally so that all network regions are co-active to initiate performance
- BUT – the strong connectivity rapidly declines and is not used to sustain attention or help with fatigue or sense of effort
- Health individuals only increased connectivity when sustained attention was required or when fatigued
- Using the constant effort task provides quantitative data on sense of effort and cognitive fatigue

The Cignulo-Opercular - Frontoparietal Network and Effort

Ramage, A.E., Ray, K.L., Franz, H.M., Tate, D.F., Lewis, J.D., Robin, D.A. (2022). Cingulo-opercular and frontoparietal network control of effort and fatigue in mild traumatic brain injury. *Frontiers in Human Neuroscience, 15*, 788091. DOI: 10.3389/fnhum.2021.788091

- Tested hypothesis that the pathophysiology of TBI results in damage to diffuse cognitive control networks that disrupts coordination of moment-to-moment monitoring, prediction, and regulation of behavior.
- The cingulo-opercular and frontoparietal networks are designed to regulate sustained attention and to maintain performance.
- As such, they are key in cognitive fatigue, sense of effort, and resource allocation.
- Same task and participants as described above.

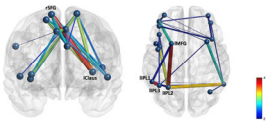
State and Trait Measures of Fatigue

We were particularly interested in state versus trait measures of fatigue and their relation to neural processing.

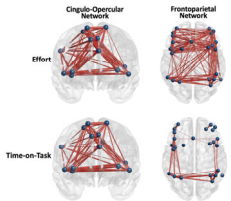
State fatigue is the real-time, in the moment sensation of being tired or feeling a high sense of effort and was assessed with the constant effort task.

Trait fatigue relates to a person's is a measure of long-term fatigue. This refers to a general, constant sensation of tiredness or high sense of effort. It was assessed with the Fatigue Severity Scale and indexes the impact of fatigue on motivation, activity level, and social participation.

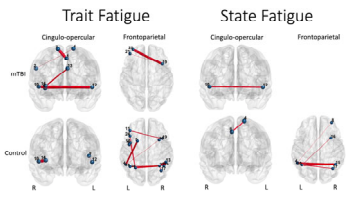
Group Differences



Sense of Effort and Time on Task



State versus Trait Fatigue



What does it all mean?

- Cingular-Opercular network connectivity is associated with sustaining performance and fatigue in TBI but much less so in healthy individuals.
- Frontal-Parietal network connectivity is associated with monitoring task performance and resource allocation/cognitive flexibility and is weaker in TBI than healthy individuals and associated with state and trait fatigue only in health.
- Fluctuation of frontal-parietal connectivity with time on task is found in healthy individuals but not those with TBI show a *mismatch between task demand and amount of effort expended to complete a task*.
- In TBI, the data show that there is excess neural energy in the CO network at the cost of prediction errors and updating predictions due to errors needed to complete the task.
- In health, the FP network modulates adjustment to task demands and prediction errors

Participation in Life and Effort/Fatigue

People who have suffered a TBI have difficulty with:

- Sustained attention
- Resource allocation
- Task performance

People who have suffered a TBI have:

- Increased sense of effort when performing tasks
- State fatigue when performing tasks
- Trait fatigue which causes stress, impaired motivation

Participation in Life Continued

The effect of high sense of effort causes mental and physical fatigue

High effort levels reduce motivation to perform and creates a situation wherein there is a sense of helplessness and that doing activities is just too hard.

High effort levels result in rapid fatigue so that performing an activity for even 5 minutes can be exhausting. The task we used in the fatigue studies was only 30 seconds.

Fatigue causes performance to decrease systematically over time and that fatigue often takes hours to recover.

How can we help?

- Help people develop daily strategies to deal with high effort and fatigue
  - Pacing oneself
  - Sleep well (this is needed for learning too)
  - Exercise regularly its good for the fatigue and for the brain
  - Eat well
  - Monitor medications that can induce fatigue and/or reduce concentration
  - Modify the environment to avoid distractions, keep the client calm
  - Use cognitive strategies to help reduce effort levels such as alarms, writing checklists to get daily activities accomplished, and more
  - Identify fatigue triggers

How can we help?

Mindfulness Interventions

- Acceptance and Commitment Therapy (ACT)
  - Involves mindfulness and behavioral activation
  - Focus on acceptance of one's condition and committing to moving forward

Mindful Meditation

- Awareness of body
- Feeling tone
- Mental states
- Mental contents

Yoga and other forms of mindfulness training

How can we help?

- Cognitive training can help by slowing the rise to a limited capacity
  - If tasks become "easier" fatigue is reduced
  - Use comparative tasks such as easy then hard
  - Use salient tasks
  - Increase time on task gradually (e.g. starry nite training)
  - Activities during perturbations
    - Don't use "no distraction" therapy room gradually add distractors
    - Add sensory perturbations during session
  - Use dual performance tasks (e.g., Gopher task) – doing two things at once
  - Use high number of repetitions and high intensity training

How can we help?

Communication Partner training

- Family
- Employers
- Teachers
- Friends

Educate about fatigue and sense of effort

Provide accommodations as needed and guided by clinician

Summary and Future Directions

Fatigue is a debilitation, long-term

Fatigue is the rest of high cognitive effort

Difficulty with resource capacity and allocation underlie state and trait fatigue

People with TBI use the wrong network to predict and correct for errors and are unable to modulate neural activity to complete tasks.

The neural networks involved in sense of effort and fatigue in health and TBI are relative unknown but being uncovered

Treating fatigue and sense of effort should be part of intervention for people suffering from TBI

While I have suggested strategies for treatment, evidence-based practice is lagging the need for intervention

Questions