Working Title: Defining Human Readiness for Task Performance with Human Digital Twin.

Background

A digital twin is a digital model of a component, product, or system that exists in the physical space (1). The digital twin is continually connected to its physical counterpart by sensors that seamlessly transmit real-time data from the physical world to the digital space. Within the digital twin, an amalgamation of algorithms continuously update likely outcomes from the most recent inputs of data and this information is relayed back to the physical space. In this way, a digital twin supports the derivation of real-time solutions to optimize a system. The digital twin may extend beyond providing projected outcomes to also providing real time suggestions based on recent data inputs to mitigate predicted negative outcomes. The key component of the digital twin is a bi-directional flow of data that is either continuously updated, or updated at specific cadences (2).

Though used primarily in manufacturing and industry to date, the concept of the digital twin has recently been extended to human beings (1). Conceptually, the human digital twin shares many commonalities with its manufacturing counterpart, however there are important differences. Most notably the human digital twin is aimed at optimizing human health and performance while the industry digital twin is focused on optimizing an inanimate object, though both use real time data inputs from internet of things (IoT) sensors. A human digital twin can exist at both the macro and micro organizational level (i.e digital twin of the cell and organelles all the way up to a digital twin of an athlete interacting with opponents in a sports environment) (3). In addition to the various organizational levels which may be "twinned," digital twins can contain various levels of *fidelity* (detail involved in the model) (2). A high fidelity digital twin of the cardiovascular system would model all elements of the vasculature from the heart, to arteries, veins, capillaries, arterioles, down to functional tissue units and maybe even specific blood cells. It is not yet clear if these high fidelity individualized models of physiological systems provide significantly more utility than lower fidelity modeling of multiple systems, especially in the context of human readiness and performance which is inherently a complex product of multiple system interactions. Importantly, a human digital twin can exist as purely a mathematical representation of the system being modeled all the way up to a robust virtual avatar (1).

The obstacles to a human digital twin are significant. Human systems are extremely complex both at the micro and macro level with changes in homeostasis known to produce divergent multi-directional responses contingent on macro-level behaviors such as sleep and diet, and immutable micro-level profiles (i.e genome) (3). Despite these difficulties in human modeling, a human digital twin would provide powerful insights into the nature of biological systems interactions. Traditionally, the study of human health has adopted reductionist separations between anatomy, physiology, psychology, and specific organ systems that have led to great insights in each of these respective domains. However, it is clear that human readiness, performance, and adaptation is not a product of a single system but rather a complex nuanced harmony of multiple system signals that may ultimately potentiate or inhibit desired outcomes. Scientifically, the human digital twin is a potential tool to integrate multi-system signals and understand how real world perturbations influence human readiness and performance. Practically, the human digital twin would allow robust simulations of real world situations to facilitate the derivation of individualized strategies to improve health and performance. Human digital twin technologies have begun to be used in athlete modeling (3), general exercise and fitness (4), clinical health care and smart cities (2), and neuroergonomics (1).

Primary Questions:

1. What is the necessary detail to include in a sufficiently accurate Human Digital Twin for Task Performance?
2. What is the fidelity architecture that produces the highest utility for the Human Digital Twin?
3. How durable are performance predictions from a Human Digital Twin in the presence of unforeseen perturbations?
4. Can a Human Digital Twin provide real time actionable insights to improve Task Performance?

Methodology Outline:

1. Developing the Digital Twin:
    a. Development of a "wide and shallow" fidelity (i.e some data from lots of systems) Digital Twin vs a "narrow and deep" fidelity (i.e lots of data down to the functional tissue unit of one system).
    b. Data collection and algorithm development for integration of multi-system (HRV, voice data, accelerometry, EEG, imaging, EOG, etc) and multi-organizational level (cell, tissue, organ, system) signals.
        i. Algorithms are expected to include traditional machine learning (random forest, SVM), deep learning neural nets, linear algebra, and probabilistic models (bayesian etc).
    c. Defining task (attention, executive function, memory, physical) and target population (tactical, first responder, athlete).
2. Assess efficacy of different fidelity architecture models at predicting human task performance to find the optimal and minimal acceptable combination (identifying what features lead to sufficiently accurate model)
3. Assess the durability of task performance predictions in the face of homeostatic perturbations (physical stress, cognitive stress, psychosocial stress etc.) using the optimal and minimal acceptable models from step 2.
    a. Use new performance predictions and pre/post perturbation data to refine the parameters of Human Digital Twin in order to increase predictive power following new circumstances
4. Assess potential interventions to improve task performance given outcome predictions from Human Digital Twin
    a. Label and integrate effective interventions into Human Digital Twin

References

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