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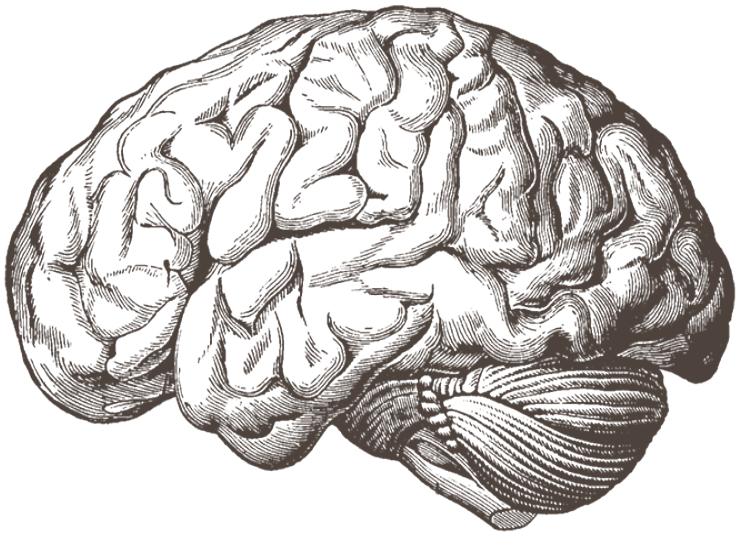

Perceived Risk: Torque3 and Task Orientated Therapy “Plus”

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Introduction

Experience-dependent, Task-Oriented Training (TOT) has emerged as one of the dominant approaches to restoring functional ability after stroke. This type of therapy focuses on recovering function and is used primarily by Occupational and Physical Therapists. In TOT, a person repeatedly performs specific exercises that are related to a given task. The tasks include exercises of large muscle groups in the lower and/or upper extremities, as well as fine motor functions needed for writing, holding a cup, eating with utensils, etc. The exercises generally follow a medical model, meaning that they focus on the function of isolated muscle groups. In contrast to purely motor impairment, damage to high-level cognitive or complex procedural tasks may require a more integrative and holistic approach. Such an approach would engage all of the multi-modal regions of the cortex, as well as the interconnected limbic and subcortical regions. Examples of complex tasks include improving bilateral visuospatial attention, as well as improving the ability to orient one's self within the environment and to navigate through it.

Several principles of TOT are required for successful rehabilitation (Kleim and Jones 2008, Wade and Winstein 2011). These principles should be incorporated into clinical rehabilitation with the aim of improving functional recovery, activities, and quality of life (Straudi 2017). The first principle is that the activity should activate brain regions corresponding to the injury. With these regions activated, the task that is being performed must be repeated an adequate number of times as intensively as possible. Exercising the same set of muscles over and over can be exhausting and boring. One way to address this is to make the activities meaningful and challenging. Finally, exercises or tasks that require active problem solving will maximize the effectiveness of TOT. Both virtual reality and robotics can enhance the activities that follow these principles.

Substantial research has demonstrated that virtual reality and robotics both improve post-stroke recovery, and when the two are combined, the results are even better (Howard et al., 2017, Manuli et al., 2020, Wade and Winstein, 2011). This body of literature includes research protocols that evaluate systems that are not substantially immersive or responsive to the movements of the user. For example, many of the studies use what they call "virtual reality", but the extent of the VR used varies greatly. Many are using approaches that merely consist of watching an animated screen or wearing a headset while doing tasks; or using robotics that is limited in function and focuses on only one body part. Despite their limitations, these systems have been shown to increase patient participation, effort, and outcomes compared with treatment-as-usual (reviewed in Lacy 2022).

"Risk" in Neurorehabilitation

In the field of neurorehabilitation, the term "risk" is generally used to denote the risk of danger, such as falling down, as it would be experienced in the real world. Such risks must be considered carefully and continually as rehabilitation proceeds. Therapists must help a patient recognize potential risks in order to mitigate them. This is especially true for those who have a right hemisphere stroke. Not only may such a person have a loss of motor function in the left upper and lower extremities, but they also may not recognize that they have any kind of impairment whatsoever (anosognosia). Even more troublesome, they may not even recognize that their impaired limbs belong to them (For example, the provider asks, "Whose arm is this?" the patient replies, "not mine"). Such extreme left-sided neglect renders patients like this at high risk of falling or otherwise injuring themselves.

The rehabilitation therapist attempts to minimize the risk of danger while encouraging a patient to maximize motor effort. Whether left-sided or right-sided impairment, patients are challenged to push through fear in order to regain functioning. Understandably, patients with significant impairment are often frightened, overwhelmed, and demoralized by the impact of the stroke. Physical and Occupational Therapists routinely play the role of coach and encourager in an effort to help patients overcome what is called risk avoidance and fear avoidance. Patients must risk failing, not being able to take that next step, not being able to move a leg up to that next stair, and so on. From this perspective, risk is not to be avoided but faced directly and overcome if one is to make any progress. But the risk must be faced while maximizing patient safety.

The Torque3 Platform

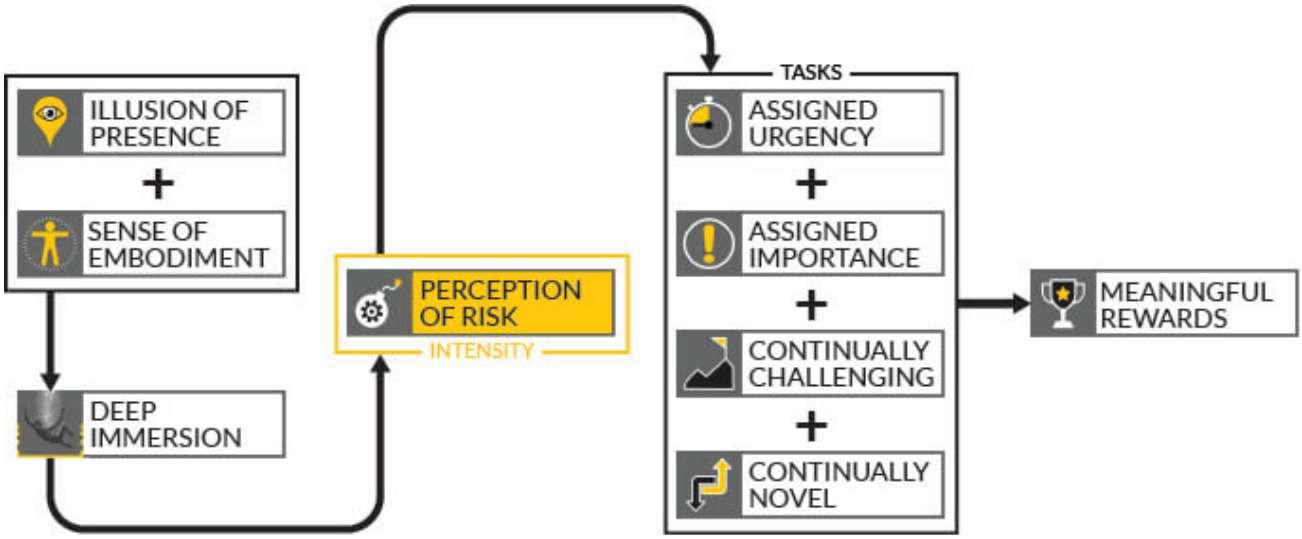
The Torque3 platform consists of a robotic-assisted simulator that works the entire body, including all the senses and cognitive abilities when performing rehabilitation therapies, and engages all multimodal, limbic, and subcortical regions. The platform consists of robotic hardware and software that form an integrated computer-controlled system. These technologies include deeply immersive and responsive virtual simulations and advanced robotics, both with integrated and synchronized machine learning. This system allows for an immersive and responsive environment that can be customized for each person.

The robotic component of the platform envelops the patient and keeps them safely secured on what feels like an extremely secure recumbent bike. Once the virtual reality sensory systems are engaged, the recumbent bike is transformed into a "virtual quadracycle". The patient will experience being fully present in the immersive simulated world and experience the illusion that they have a different body. That is, they will have a sense of "embodied presence" (Riva et al. 2004, Riva et al. 2019). Thus embodied, when they look down towards their physical body, they see a virtual body, or avatar, that is spatially coincident with their real body (Slater and Sanchez-Vives 2014). The physical body sitting on a recumbent robot is transformed, and the patient becomes the avatar who is riding a quadracycle through a virtual simulated world. It is the avatar that navigates through the virtual world, not the real-world, physical person.

The Torque3 Platform, cont'd.

In our system, one can be safely secured to the platform in the real environment while safely taking risks in the simulated one. For stroke survivors who are severely impaired, frightened, or anxious, our platform contains environments that are peaceful and non-structured, such as gentle explorations of rivers, lakes, temples, and ponds. But the Torque3 platform also provides more advanced environments that are more challenging. These environments consist of various paths that require one to attend to both visual fields and environmental spaces, orient themselves in space and time, navigate various turns, avoid obstacles and solve problems.

The avatar can go right up to the edge of a path or go so fast around a corner that it is a struggle to stay on the path. Importantly, it is the avatar that is taking risks, not the real physical body that is secured safely atop a robot. In other words, the patient has the cognitive experience of risk without actually being in harm's way. What results is the "perception of risk", or more accurately, "the illusion of risk". The illusion of risk becomes an integral part of the entire experience. We think of these risks as "desirable difficulties" that serve to increase anxiety and other emotions that intensify the experience of presence and the illusion of embodiment (Barrett et al., 2015, Banos et al., 2004, Bouchard et al., 2008, Widdowson et al. 2016). These challenges are most effective when they are novel, unexpected, and create a sense of surprise and urgency (Perez-Marcos et al., 2018). The temporarily stressful experiences increase norepinephrine, which in turn increases neuroplasticity. When a patient successfully meets challenges and completes challenging tasks, they have a feeling of reward that is mediated by dopamine, which enhances reward-based motor learning and neuroplasticity (Borodovitsyna et al., 2018).



The sense of threat, danger, anxiety, surprise, and urgency that a risk includes must be sufficiently intense to increase physical effort but must not be so intense that they exceed what is optimal for any particular patient (Panic et al. 2011). The Torque3 interactive platform allows us to fine-tune a user's experience and achieves a harmonious balance between the difficulty of the task on the one hand and a patient's physical and cognitive abilities on the other (Perez-Marcos et al., 2018, Gilead and Dix 2004, Barrett et al. 2015). This balance is required to maximize motor learning and to achieve what is called a state of "Flow". In this state of flow, one feels safe, comfortably challenged, and highly engaged (Csikszentmihalyi, 1990). As flow increases, the sense of presence deepens, and the motivation to engage in rehabilitative tasks increases. When one successfully faces and overcomes challenges, they also experience an increased sense of self-efficacy, which is positively associated with improved recovery from stroke (Bandura 1985, Korpershoek 2011). Self-efficacy is associated with an increasing level of confidence, a greater sense of agency and ability to change, and an increased degree of both self-competence and mastery (Riva et al. 2004). In a state of flow, one is able to perform rehabilitation tasks more efficiently and with greater intensity over time. As a patient progresses in rehabilitation in our paradigm, they will have an ever-increasing feeling of confidence and satisfaction as well as the belief that they can overcome challenges, face fears, and regain some of their unimpaired self again.

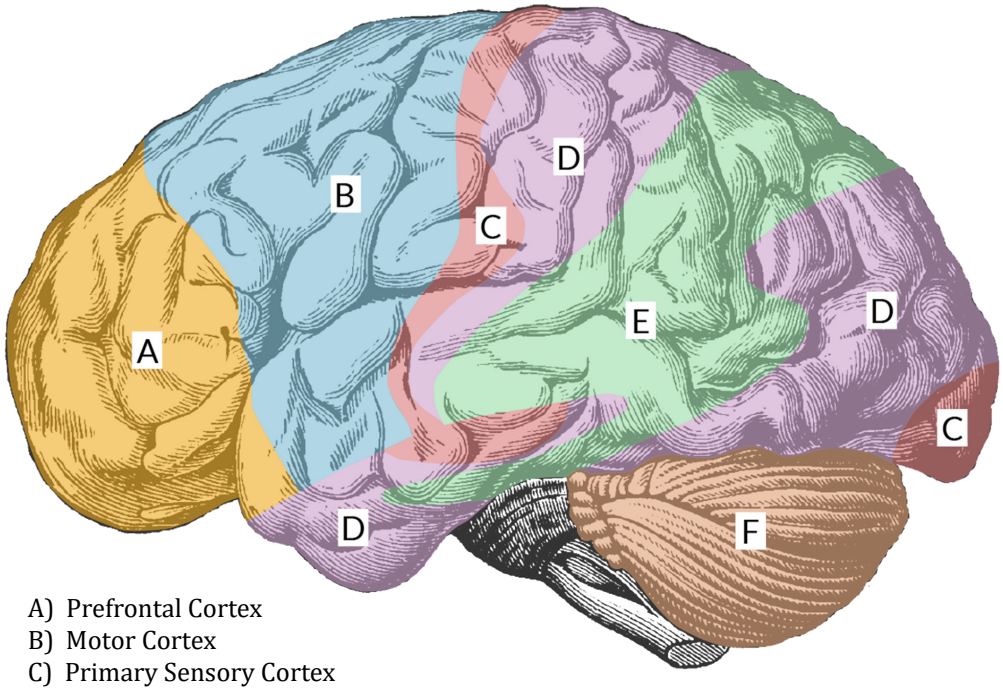
The Torque3 Platform Engages all Regions of the Multi-Modal Brain

Virtual and robotic technologies have been shown to activate multiple regions of the brain and thereby enhance neuroplastic healing (Kleim and Jones 2008, Schultz et al. 2008; Peckna et al. 2012, Prueshoff et al. 2006, Payzan-LeNestour et al. 2003, Hsu et al. 2009, Riva et al. 2019, Tran et al. 2016, Wade and Winstein 2011, Lacy 2022).

Unlike most systems that use these technologies in isolation, the Torque3 multimodal platform engages all aspects of sensory and motor systems and recruits all brain regions that play a role in visuospatial perception, attention control, motor planning and action, threat detection, enjoyment, fun, emotional experience, and reward/satisfaction. This integrated activation of multi-modal brain regions can facilitate organized neuroplasticity (reviewed by Lacy 2022).

These regions include but are not limited to:
(1) Primary, Unimodal, and Multimodal cortical regions that encompass the spatial and sensory functions of each hemisphere; (2) Frontal cortical systems responsible for executive functions, attending to spaces bilaterally, planning and initiating motor actions; (3) Amygdala, which constantly scans the environment for potential challenges, threats, or risks; (4) Dorsal striatum, which plays a key role in motor activity; (5) Ventral striatum and Nucleus Accumbens, which play key roles in reward, pleasure, fun; (6) Limbic system that elaborates upon emotions and places experience in the context of space and time; and (7) Norepinephrine and Dopamine neurotransmitter systems.

The Multimodal Brain



A) Prefrontal Cortex
B) Motor Cortex
C) Primary Sensory Cortex
D) Unimodal Association Cortex
E) Multimodal Association Cortex
F) Cerebellum

Summary

The Torque3 platform takes advantage of multiple technologies that maximize deep immersion and embodied presence to create an Immersive Simulation experience. One novel element of the platform is that it allows a stroke survivor to safely experience the illusion of risk. The introduction of risk engages multiple brain regions and neurotransmitter systems that enhance neuroplastic healing, deepens the experience of embodied presence, and maximizes positive psychological states associated with improved immersive experiences. It also fosters a greater sense of self-efficacy, confidence, a feeling of wholeness, and decreased levels of demoralization. In these ways, we believe that the unique element of the illusion of risk found in the Torque3 platform can potentially improve rehabilitative outcomes when compared with currently existing systems.

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