

THE CONTRIBUTION OF SENSORIMOTOR MEMORIES TO IMPLICIT MOTOR LEARNING AFTER CONCUSSION

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ABSTRACT

Kinematic performance was examined during goal-directed reaching against unpredictable spring-like loads to quantify the impact of concussion on sensorimotor memories used in implicit motor learning. Seventeen healthy and eight concussed college students participated in four experimental sessions: 1) as soon as possible post injury ("Time 0", T_0); 2) return-to-play (RTP) date (T_0+10 days for healthy); 3) T_0+3 months, and 4) T_0+6 months. During each session, subjects performed an out-and-back reaching task and the Cogstate Research II computerized cognition test. The Post-Concussion Symptom Scale (PCSS) was used to measure initial concussion severity. In the reaching task, subjects performed 20 practice reaches with concurrent visual feedback of hand motion. These reaches were made against a spring-like load that varied randomly from trial to trial. Subjects then performed 200 reaches against random spring-like loads without visual feedback. A fast process adaptation model was fit to reach error and spring stiffness values to evaluate trial-by-trial sensorimotor memories contributing to implicit learning of the environmental loads. Reach precision and movement times were also measured. Working memory was assessed via Cogstate. On the first day of testing we found considerable heterogeneity in the concussed group; some reported a higher severity of symptoms than others based on the cumulative PCSS. Cogstate testing confirmed subjects had working memory deficits that resolved by Session 3. In Session 1, concussed subjects showed kinematic performance deficits and altered adaptation model parameters compared to controls. Across sessions, control subject performance in these same variables reached steady state by Session 2 whereas concussed individuals did not reach values similar to controls until Session 3. Thus in Session 2, despite being cleared for RTP, concussed individuals showed persistent deficits of sensorimotor adaptation to unexpected environmental changes. These findings may have implications for reinjury risk reduction when returning to sports.

Keywords: concussion, implicit, memory, learning, prediction, proprioception, sensorimotor, return to play

INTRODUCTION

Mild traumatic brain injury (mTBI, i.e. concussion) transiently degrades memory and attention, which can lead to persistent cognitive and sensorimotor performance deficits such as memory, vision, reaction times, and attention [1]. Cognitive field tests such as the Sport Concussion Assessment Tool (SCAT) and computerized testing such as the Immediate Post-concussion Assessment and Cognitive Test (ImPACT) or Cogstate are currently used to determine if an athlete has sustained a concussion by comparing post-injury cognition scores with healthy preseason scores. These tests depend on subjective symptom reporting or simplified measures where participants have an approximate idea as to how they are performing during the test. As a result, these tests have been known to be intentionally falsified or "sandbagged" by athletes during preseason to lower their baseline score such that when they receive a concussion their pre- and post-injury scores are comparable [2]. This can confound return-to-activity (RTA) or return-to-play (RTP) decisions which increases the risk of reinjury [1]. Due to this limitation, some are working to develop assessments of concussion that cannot be intentionally falsified.

Recent experimental work has found concussion-related degradation in the precision and speed of a visually decoupled and rotated reaching task mostly in individuals that are asymptomatic several months post-injury [3]. However, this work did not track changes in behavior over the time course of recovery, and so its utility for diagnosis or recovery decisions is uncertain.

We have designed a novel assessment that not only evaluates reach precision and movement time, but also evaluates how sensorimotor memories contribute to motor adaptation due to environmental changes – an implicit form of motor learning [4]. The assessment requires subjects to repeatedly "capture" a remembered non-moving visual target by moving the hand in an unpredictable environment. Here,