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Learning cause and effect using a BCI: two case studies

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Introduction: Brain-computer interface (BCI)-based interventions are inherently complex, making causal mechanistic studies difficult and expensive. Consequently, few BCI technologies have been translated to the clinic or to daily use. New recognition that the central nervous system (CNS) remains plastic throughout life, and new understanding of how muscle-based skills are learned and maintained can provide insight into how a BCI might provide opportunities for translation. The new *Heksor/ Negotiated Equilibrium* paradigm explains how skills are acquired and maintained in the continually changing CNS. The network of neurons and synapses that maintains a skill was recently given the name heksor [1]. The concurrent adaptations of overlapping heksors require a *negotiated equilibrium* of CNS properties that ensures the maintenance of all their skills [2]. In this environment, targeted plasticity can have broad effects. Here, we present case studies of two individuals for whom BCI training improved ostensibly unrelated aspects of their CNS function. Further insight into how a BCI might emulate CNS processes and function more like muscle-based skills may improve BCI reliability and hold hope for widespread use of BCIs in translation.

Materials, Methods and Results: Participants were two non-speaking males with no useful motor control. P1, age 16, was diagnosed with cerebral palsy and was blind. P2, age 5, was diagnosed with GM3 synthase deficiency and had impaired vision and audition of cortical origin. Both were discharged from standard-of-care rehabilitation therapy due to failure to progress. Subsequently, they were enrolled in and completed 13 (P1) and 7 (P2) EEG-based motor imagery sessions (S). Signals were recorded with the Emotiv Epoc X cap and 14 saline Ag/AgCl electrodes at standard locations using Emotiv software. At each session, participants were asked to calibrate their BCI by following verbal instructions to either relax or imagine moving [pushing (P1), or hand tapping (P2)] 7-10 times for each condition. During sessions, P1 used the Assistive Technology Hub to turn on music and P2 used the Think2Switch to activate and maintain a switch-adaptive bubble maker. Level of engagement was followed using the Pediatric Rehabilitation Intervention Measure of Engagement - Service Provider version (PRIME-SP) (Scale 0-3, for affective, behavioral, and cognitive involvement) [3].

Both P1 and P2 demonstrated an understanding of cause and effect by session (S)2 of BCI training, i.e., they used motor imagery to successfully control their BCI. Both have re-entered regular hospital therapy where they continue to use a BCI, and, additionally, to practice with a conventional mechanical switch–P1 practicing with either hand and P2 practicing left finger movement. Prior to BCI training, PRIME SP scores for both participants were 0-1 for all categories. At Screening, P1 was rated at 3 for affective, 2 for behavioral and cognitive involvement. P2 was rated at 2 for affective, 1 for behavioral and cognitive. At S13, P1 was rated 3 for affective, behavioral and cognitive, and at S6, P2 was rated: 3 for affective, 2 for behavioral and cognitive. These scores indicate high engagement.

Conclusion: These two examples of improved ostensibly unrelated aspects of CNS function could reflect a re-negotiated equilibrium between heksors. However, these observations must be confirmed through investigation into the signals used for BCI control and into the repeatability and longevity of these effects.

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