DESCRIPTIVE OUTCOME METRICS OF SENSORIZED UPPER LIMB PERFORMANCE USING OPTIMAL FORAGING THEORY

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ABSTRACT

Modern advancements of upper-limb prosthetic technologies have not been accompanied by advancements in appropriate metrics for assessing the functionality of these technologies. In particular, many of the currently accepted functional metrics of performance for upper-limb prostheses put little or no emphasis on the role of sensory feedback modalities in the prosthesis control loop. We developed a functional metric of Prosthesis Efficiency and Profitability (PEP) which incorporates tactile and proprioceptive elements into a simple motor task. PEP uses Optimal Foraging Theory (OFT), which describes decision making in biological systems based on time versus prey-value tradeoffs, as a platform to evaluate the compensatory interactions between motor command and sensory feedback in a prosthesis control loop. PEP participants are instructed to discriminate between objects of different stiffnesses in a timed search and acquisition task. The primary outcome measures: efficiency and profitability, weigh the accuracy of stiffness discrimination against speed. Additionally, Bayesian statistics are used to determine the frequency of false positive and false negative errors made by the participant during the test to further describe the tradeoff between motor command and sensory feedback. We have found that the PEP test is sensitive to the effects of touch and movement feedback and highlights strategy switches and changes in performance for different devices and feedback settings. We observed subjects switching from relying on motor command to relying on sensory feedback when the feedback was turned on. When feedback was absent, participants on average had lower accuracy but compensated by engaging with objects more quickly. Whereas when feedback was present, participants tended to spend more time engaged with each object but got more objects correct. Additionally, an ability to discriminate stiffnesses beyond chance was demonstrated in prostheses users equipped with touch and movement feedback when the sensory feedback was switched on. The PEP test may provide a general framework for evaluating different sensory modalities; the objects of different stiffnesses may be replaced with objects possessing the property of interest, changing the focus of the test without altering the analysis or interpretation of outcome metrics.