

Myo-electricity and gaze tracking data to improve hand prosthetics and neuro-cognitive examination.

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Objective

This work presents the Megane Pro project, which has three main objectives: first, to improve hand prostheses by reproducing eye-hand coordination in prosthetic hands; second, to better understand phantom limb sensation and the neurocognitive effects of hand amputations; third to better integrate surgical procedures with prosthetics. The overall aim is thus to improve the capabilities and quality of life of amputees, who are - despite recent scientific progress^{1,2} – still affected by the limited control of prosthetic hands. Phantom limb sensation is a good predictor of how well amputees can control a robotic prosthesis³, but little is known about the mutual interactions between different types of sensation and the use of a prosthesis.

Methods

The data acquisition setup for detecting hand movements includes 12 surface electromyography electrodes, a pair of eye tracking glasses equipped with a scene camera and a laptop⁴.

The acquisition protocol includes four exercises and a set of neurocognitive tests. The first exercise aims at improving robotic hand prostheses control. The subjects are asked to repeat 12 times several hand grasps on a set of various objects. The movements are collected from the hand movement taxonomy literature and they are presented to the subjects as videos. The grasps are repeated both as static and functional movements. The second, third and fourth exercise aim at better understanding phantom limb sensation and the neurocognitive effects of hand amputations. They include the repetition of executed and imagined movements as reported in Sirigu et al.⁵, the classical apparent motion paradigm with body parts introduced by Shiffrar and Freyd⁶, and an experiment based on imagined and executed movement of the hand in presence of an obstacle, aimed to study obstacle shunning^{7,8}. The neurocognitive experiments are enriched with gaze and sEMG measures. Phenomenal characteristics of individual phantom limb sensations are assessed by structured interviews such as the interview on phantom sensations (RAM SIPS⁹) and the phantom and stump phenomena interview¹⁰. The multimodal data are analysed with statistical and artificial intelligence methods^{4,11,12}.

Results

The results highlight the usefulness of the acquisition setup and protocol both for prosthesis control and for neurocognitive research. Surface electromyography, eye tracking and computer vision allow to obtain more complete data. The acquisition protocol allows for a qualitative and quantitative assessment of painful, not-painful and residual phantom limb sensations and examines the properties of a phantom limb when brought “in contact” with material objects. The results suggest that the interaction between sensory-motor imagery and the visual observation of objects in the environment might critically influence the properties of a phantom limb.

Conclusions

This paper provides an interdisciplinary insight into hand amputations and hand prosthesis control. A proper integration between surgical procedures, neurocognitive analyses, multimodal data acquisition and artificial intelligence algorithms can make current prostheses more autonomous, restoring eye-hand coordination, leading to naturally controlled robotic hands with better performance. The experiments are highly informative regarding phantom limb properties, both painful and painless, and when a phantom gets “in contact” with external objects.

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