Understanding the Capacity for Children with Congenital Upper Limb Deficiency to Actuate their Affected Muscles

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Abstract

For adults with upper limb loss, pattern recognition algorithms can be rapidly trained to recognize unique patterns in electromyographic signals (muscle electrical activity, sEMG) from their residual muscles [1]–[4]. Unlike conventional myoelectric prosthetic control techniques, these pattern recognition techniques allow adults to more readily control the variety of grasping movements offered by modern dexterous prostheses. Similar dexterous prosthetic hands are beginning to emerge for pediatric prosthetic users, but the child's ability to actuate their residual muscles in order to operate multi-grasp devices with pattern recognition-based control paradigms is not well understood. This is especially relevant because most pediatric prosthetic users have congenital limb deficiencies as opposed to acquired limb loss and their muscles will have never actuated a fully formed hand [5]. Together, these factors present a significant barrier to effectively translating dexterous devices to pediatric populations. Our work lays the foundation to address this gap in knowledge.

We collected sEMG data from 5 participants with unilateral congenital below elbow deficiency ages 8-19 years as they attempted to perform a set of 10 hand and grasping movements with their missing limb. A Delsys Trigno Research System was used to collect sEMG data with 7 electrodes adhered circumferentially around both the participant's residual and typical limbs. We used conventional root mean squared analyses on the data collected from the sEMG electrodes. We found that each time a participant attempted to move their missing hand to achieve a specified movement, distinct muscle activation patterns were detected across the sEMG electrodes. Our results showed that to varying degrees participants were able to perform consistent within-grasp contractions of their affected limbs when compared to their typical limb. Furthermore, leveraging conventional pattern recognition algorithms we found the participants were able to achieve average classification accuracies ranging from about 78%-95% for their affected limbs when compared to their typical limbs which reached 90%-99%. Additionally, for the affected limb, two of the participants were able to achieve accuracies greater than 80% across all hand grasp configurations including the rest state (11 movements in total) while the remaining three achieved 2, 6, and 8 hand grasps with accuracies greater than 80%. These lower classification accuracies are presumably associated with factors such as age and residual limb length. In the typical limb, the accuracies of all grasp configurations across all participants were greater than 80%. This work begins to address the extent to which children born with upper limb deficiency can actuate their affected muscles and how state-of-the-art prosthetic control technologies may be leveraged for intuitive operation of advanced dexterous prostheses.