CHARACTERISATION OF MYOELECTRIC ARTEFACTS IN CLINICAL SOCKETS

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ABSTRACT

A significant disparity exists between the functionality promised by modern multi-grip myoelectric prostheses and the reality of myoelectric control using clinical-standard sockets and electrodes. Unpredictable prosthesis behaviour means users will often choose not to use their prosthesis for certain tasks. One source of unpredictability in upper-limb prostheses are unintended device activations, that is to say prostheses opening or closing when the user did not intend for the action to occur. Unintended device activations occur when the output of electromyography sensors reach a given threshold. During closed-loop control it is usually not possible to determine whether sensors reach threshold due to mechanical disturbances inducing motion artefacts or because of genuine, but unintended, muscle activity. We present preliminary data from experiments which use arrays of sensors to characterise how and why artefacts may occur in clinical-standard upper-limb prosthesis sockets. Current data show early trends in physical positions which lead to unintended activation and shows some artefacts are concurrent with intended muscle activity.

INTRODUCTION

Myoelectric upper-limb prostheses suffer from high rejection rates [1]. Lack of functionality, or commonly a lack of functional gain in wearing a device, remain key factors in upper-limb prosthesis rejection [1,2,3]. Modern multi-function devices offer a range of grasp patterns; however, users of myoelectric devices typically find them difficult to control [4]. This lack of control, or lack of ability to predict how a prosthesis will move, has been posited as a reason for passive use of active devices and for device rejection [4]. A source of unpredictability in modern myoelectric devices is the myoelectric interface with the skin [6]. While experimental electromyography (EMG) research typically uses EMG sensors adhered to the skin, upper-limb prosthesis users control their devices via sensors housed in custom built sockets. This leads to mechanical coupling of the sensors, which can produce artefactual EMG as sensors move relative to the skin [5]. These artefacts are likely to contribute to unintended device activation, a key factor limiting the degree to which users can be confident in device behaviour.

In this paper we present preliminary results from a set of closed-loop experiments which aim to characterise and label artefactual EMG obtained using clinical grade sensors. To achieve this, we fitted clinical bypass sockets or prosthesis simulators with a range of sensors and compared the data acquired to create ground truth labels for artefactual EMG.

METHODS

Participants

Three participants (1 male, 2 female) who are anatomically intact and free from neurological or motor disorders were recruited. The study was approved by the Local Ethics Committee at Newcastle University (ref: 20-DYS-050). All participants provided written informed consent prior to the start of the experiment.

Experimental setup

Limb-intact participants performed a simple closed-loop myoelectric control experiment while wearing an instrumented clinical bypass socket. The bypass socket of one participant was made using the traditional casting, rectification and lamination approach, and two were created using a hybrid approach combining digital scanning with traditional clinical techniques [5]. An example bypass socket is shown in Figure 1a; the sockets are designed to simulate a hybrid supracondylar design. Sockets were fitted with two clinical standard surface electrodes (RSL Steeper SEA200). A two axis soft flex sensor (Bendlabs) was mounted on the posterior part of the socket and connected to

participants' upper arm to capture elbow flexion and extension. The clinical standard electrodes and the soft flex sensor were connected to an Arduino Nano sampling at 500 Hz. Eight EMG sensors (Delsys Quattro) were positioned in a band around the forearm distal to the clinical electrodes and fixed in place with a bandage. The Delsys Quattro units were placed on the exposed part of the. Data from the Delsys sensors and the Arduino Nano were synchronised and sampled on a PC using the AxoPy experimental library for human-computer interfacing [6].

Experimental Calibration

Participants performed a flex sensor calibration routine which involved moving their elbow through five positions. Two arm orientations were assessed, referred to as vertical and horizontal. In the vertical condition, participants performed a calibration with the shoulder relaxed such that flexion and extension of the elbow moved the forearm in the vertical plane. In the horizontal condition, participants performed the same calibration with the arm abducted to 90° such that flexion and extension of the elbow moved the forearm in the horizontal plane. Within each condition, the five elbow positions attempted to capture participants' range of movement on one axis, with targets one and five capturing top and bottom in the vertical condition and left and right in the horizontal condition. The arm position for target three aimed to be perpendicular to the display providing visual feedback in both cases.

Electromyography data from the clinical electrodes were calibrated to provide normalized muscle activity for use in the closed-loop experiment. Participants performed a calibration during which they were asked to perform activity representative of rest, y_r, and comfortable contraction, y_c. Normalized muscle activity, $\hat{y}$, was calculated according to $\hat{y} = (y - yr) / (yc - yr)$ and used throughout the experiment.

Experimental protocol

Participants performed four experimental blocks comprised of 40 trials under two conditions. A visual depiction of the experimental protocol is shown in Figure 1b.

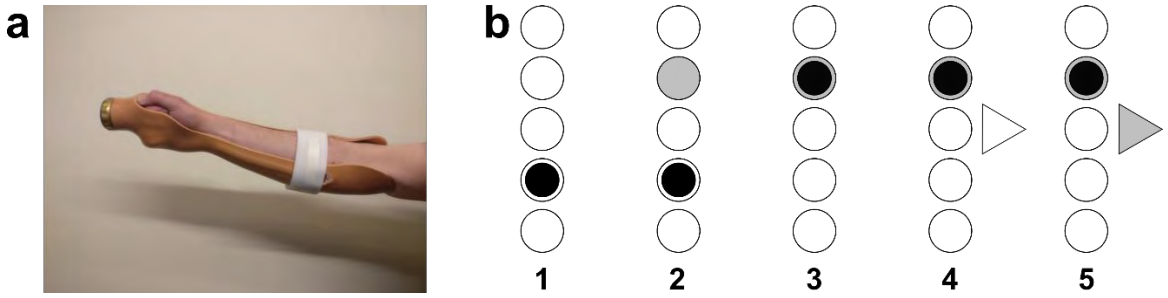

Figure 1: (a) Example bypass socket. (b) Visual prompts used in vertical arm position experimental protocol. 1: Participant views five vertical positions with current position highlighted. 2: Target position is presented. 3: Participant moves arm to target position. 4: Prompt indicates to activate the flexor (left arrow) or extensor (right arrow). 5: Feedback may be presented if muscle activity reaches threshold value.

At the start of a trial participants were presented with five circles. In the vertical condition, the five circles were aligned vertically (Figure 1b1). A target was presented (Figure 1b2) to prompt participants to move their arm to the correct position. Once in position (Figure 1b3), an arrow was presented to indicate which muscle group to activate (Figure 1b4). In the vertical condition a right arrow prompted activation of the extensors and a left arrow indicated activation of the flexors. In the horizontal condition an up arrow indicated activation of the extensor and a down arrow activation of the flexor. In the second block of each condition, participants received feedback if they reached normalised activation level $\hat{y} = 1$ (Figure 1b5). Participants used a single left-handed joystick (FragFX FragChuck, SplitFish Gameware) to pause the experiment to avoid fatigue. The first two blocks were performed in the vertical condition and the second two in the horizontal condition.

RESULTS

Two analyses are ongoing. The first is intended to probe the degree to which limb and socket position and orientation influence unintended myoelectric activations. The second is a manual data labelling exercise to

differentiate different forms of myoelectric artefacts. Due to the limited number of participants tested no statistical analyses were performed.

Arm position

Trial data were differentiated into correct and incorrect activations according to whether or not normalised activation level $\hat{y} \geq 1$ was reached on the prompted clinical electrode channel prior to any unintended activation of the other clinical electrode. Classification results for the five limb positions in the horizontal and vertical conditions are shown in Figure 2a and 2b respectively. In the horizontal condition, Figure 2a, results trend lower as the elbow is flexed and the forearm moves across the body. In the vertical condition, Figure 2b, lower classification results are observed as the arm is fully extended. Figures 2c and 2d show a breakdown of misclassification results for two participants. In both participants, misclassification distributions in the horizontal condition are distinct from those in the vertical condition.

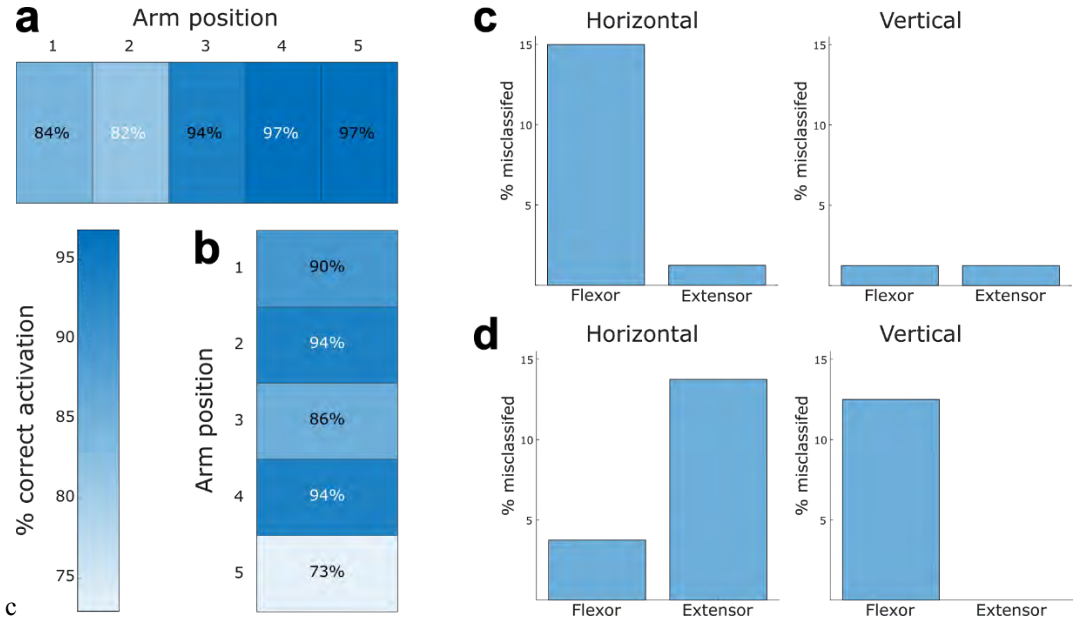

Figure 2: (a) Percent of correct activations in the horizontal condition. (b) Percent of correct activations in the vertical condition. (c) & (d) Misclassifications for two participants broken down into the horizontal and vertical experimental conditions.

Manual artefact analyses

Experimental data were manually analysed on a trial-by-trial basis. Electromyography sensor data obtained from clinical surface electrodes were compared to those obtained from the array of Delsys sensors. Trials in which the clinical data could not be explained by EMG activity observed in neighbouring Delsys electrodes were labelled as artefacts. Two common artefact types observed across participants are shown in Figure 3. Both Figure 3a and Figure 3b show artefactual EMG activity observed in the clinical electrode on the extensor side, during a flexor contraction. In both cases, artefacts occur concurrently with both the intended muscle activation and a degree of unintended co-activation. Our working hypothesis is that this activity represents unintended electrode shift caused by intentional muscle activation on the contralateral side of the bypass socket.

Figure 2b shows a change in baseline activity on the clinical electrode occurring at eight seconds, following an EMG artefact. During inspection it was observed that changes in baseline activity at the end of a trial period often led to the succeeding trial commencing with a similar shifted baseline.

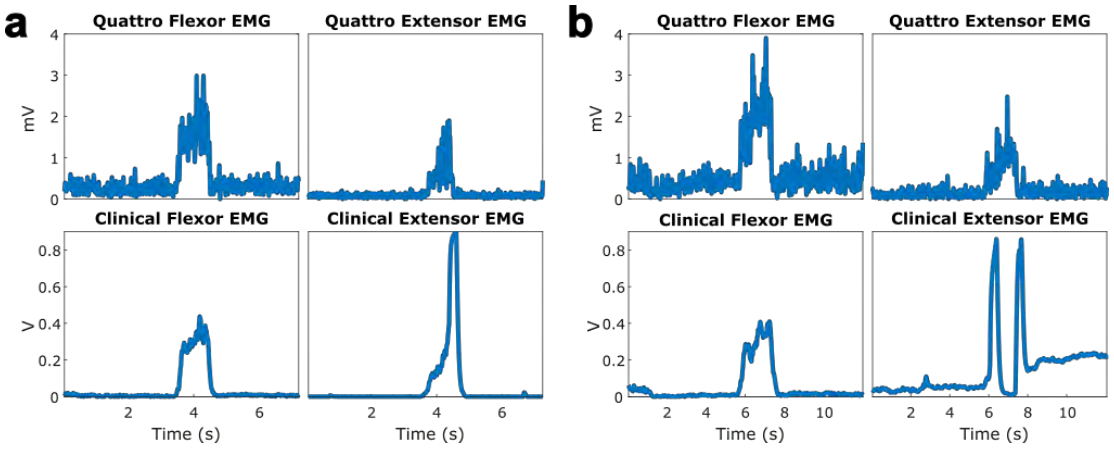

Figure 3: Sample artefactual EMG activity observed in clinical standard electrodes. Both figures show activity observed in the flexor and extensors via clinical standard electrodes on the bottom row. The upper row shows the nearest neighbour Delsys sensor. (a) Sample showing single peak artefact. (b) Sample showing double peak artefact.

CONCLUSION

We have demonstrated a proof of principle method whereby myoelectric artefacts can by observed and recorded in a clinical simulation socket. This work is being undertaken as part of a larger project which aims to develop a joint mechanical electrical method to ameliorate electrode artefacts in clinical standard upper-limb prosthesis sockets [7]. The primary goal of this phase is to characterise any consistency in arm positions contributing to the generation of artefactual EMG and create ground truth artefactual EMG data for analysis. Current results trend towards more EMG artefacts being generated at limb position extremities, and changes dependent on limb orientation. We aim to run complementary studies in participants with limb absence using a modified socket design and fewer probe electrodes.

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