Same-side Hand Interactions with Arm-placed Devices Using EMG

Figure 1: Typical interaction setting with smartwatch and EMG armband

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Abstract
We present a preliminary evaluation of an approach utilizing eyes-free, same-side hand interactions with arm-placed devices based on electromyography (EMG). We hypothesize that the approach is well-suited for situations that do not allow for opposite-side hand interactions, e.g. while carrying something. In contrast to other methods such as speech input, it does not depend on external factors such as surrounding noise. In our pilot study in a laboratory setting, we compared same-side hand interactions using EMG against traditional opposite-side hand touch interactions to control a music player on a smartwatch. The results indicate that the same-side hand interaction approach is in general feasible for the envisaged type of interactions.

Author Keywords
Same-side hand interaction; eyes-free interaction; arm-placed devices; electromyography

ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies.

Introduction & Related Work
The latest advancements in mobile computing bring to a wide audience a new generation of wearable devices that are directly attached to a user's body, for example glasses

Figure 2: LG G Watch R

Figure 3: Electromyography armband by Thalmic Labs

or smartwatches. Due to the position of these wearables, problems can arise on the input side. If we consider, for example, devices placed on a user's arm, i.e. in the area from the shoulder to the wrist as well as on the back of the hand, interactions generally cannot be executed by the same-side hand (SSH), but require the use of the opposite-side hand (OSH), or another modality such as speech, to interact. Depending on the situation, other modalities may not be feasible for reasons such as surrounding noise. There also exist other interaction concepts for wearables like back-of-device input [1], approaches that utilize sensors such as a camera [11] or magnetometer [4] or approaches specifically designed for smartwatches focusing on augmenting the wristband [3, 9].

However, none of these approaches targets the problem of requiring the OSH for interaction as the SSH cannot reach the device. In certain situations, especially on the go, this could be problematic, e.g. when carrying luggage or purchases (see Figure 1). To be able to interact with an arm-placed device in a comfortable way, the arm has to be held in a position that normally does not allow carrying large or heavy items conveniently. As a consequence, such items are carried in the OSH, preventing it from being instantly usable for touch interaction. Summarizing the points above, arm-placed wearables seem to be suitable for interactions on the go, but touch or speech input may not be the best solution, depending on the situation. In this paper, we investigate an input possibility that enables SSH-based and eyes-free interactions with an arm-placed device, i.e. the interactions we focus on are conducted with the hand and arm wearing the device, making it possible to freely utilize the OSH for things not related to the interaction, e.g. carrying luggage.

As the sensing technology, we use surface electromyography (EMG) which is already established in areas such as muscular rehabilitation [8] or the control of prosthetics [5]. With the help of EMG, electrical muscle activity can be measured, among other things providing a possibility for gestural interactions. In this sense, EMG has also been explored as input modality in the context of human-computer interaction [10]. Based on our review of prior work (e.g. [2, 6]), we expect robust recognition rates around 95%, providing a reliable sensing technology.

To the best of our knowledge, no investigations have been done focusing on SSH interactions on the go.

In this paper, we provide a preliminary evaluation of surface electromyography as an eyes-free, SSH-based interaction method enabling gestural input. We validate our concept by utilizing an EMG sensing armband and conducting a user study in a laboratory setting showing that the proposed interaction technique is feasible, and we compare it to a standard baseline, i.e. OSH touch interaction.

Surface Electromyography

The technique of recording and interpreting electrical skeletal muscle activity is known as electromyography. EMG measures the electrical activity during muscle contraction between a ground electrode and a sensor electrode, either within the muscle or non-intrusively from the skin above the muscle (surface EMG). The expressiveness of the latter is comparatively limited, but in return, the approach is more easily applicable and does not need special preparation of the skin nor special medical training of the operator. With the recently available Myo armband by Thalmic Labs[1], an off-the-shelf commercial

[1] `http://www.myo.com`, retrieved 09/02/2015

Figure 4: Access to the music player controls via the smartwatch interface.

device is provided that is designed to be used by everyone. Through its Bluetooth connection, no interfering cables are required, which further eases the application in everyday situations, especially when on the go.

Experiment

For the rest of this paper, we consider a smartwatch as a typical representative of an arm-placed wearable device. In our preliminary evaluation, we compared OSH touch interactions to control a music player via a smartwatch with Android Wear as operating system against SSH, eyes-free gestural interactions sensed via an EMG armband.

Apparatus

We decided to focus on the latest available off-the-shelf components that could easily be used in everyday life. We used an LG G Watch R (see Figure 2) running Android Wear 5.0.1 coupled to an LG Nexus 5 (Android 5.0). The smartwatch offers a round screen with a diameter of 1.3" and a resolution of 320 × 320 pixels. The Myo armband (see Figure 3) we used as the sensing device is directly connected to the smartphone via its Bluetooth Low Energy connection. For an example use case, we selected a music player, which represents a typical app often used on the go. On the software side, we employed the Spotify Music Android app[2] which could easily be controlled directly via the smartwatch interface. For the EMG application, we utilized the Myo Music app[3] which acts as a proxy between the Myo armband and various music applications.

[2] `https://play.google.com/store/apps/details?id=com.spotify.music`, retrieved 09/02/2015

[3] `https://play.google.com/store/apps/details?id=com.thalmic.myoconnect`, retrieved 09/02/2015

Supported Controls and Mapped Gestures

As depicted in Figure 4, the music player can directly be controlled via the smartwatch interface. To do so, the music activity has to be activated (steps 1 and 2), maximized (step 3, optional) and swiped to the control view (step 4). After activation (step 2), play/pause can be triggered, whereas other controls (track, volume) are only available after step 4.

The Myo armband currently supports five pre-defined gestures (see Figure 5) that are mapped to control a music player by the Myo Music app: (1) a double-tap of thumb and middle finger to unlock the armband, (2) spreading the fingers for play/pause, (3) wave left for jumping back to the previous track in a playlist, (4) wave right for jumping to the next track and (5) making a fist while rotating the arm left/right to decrease/increase volume.

Participants and Experimental Design

We recruited 9 participants (5 female), aged 21-41 (M=27.1, SD=4.1). Two participants did not have any smartphone experience, whereas the rest were daily smartphone users, but none of them had any experience with smartwatches. We split the experiment into two conditions: 5 participants (3 female) started to control the music player via touch interaction on the smartwatch, whereas the rest first completed the EMG condition.

After finishing the first condition, participants were required to take a five-minute break before they started with the second condition. After completing the tasks in each condition, all participants were requested to fill out a short post-session questionnaire consisting of a System Usability Scale (SUS), a NASA Task Load Index (NASA TLX), an ISO 9241-9 questionnaire and personal preference questions. Overall, the whole procedure took around 30 minutes.

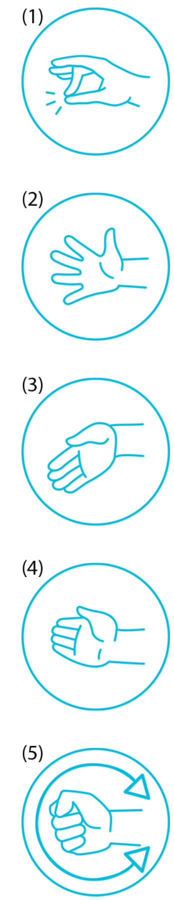

Figure 5: Gestures supported by the Myo armband (worn at right arm).

Preparations
For both conditions, the participants were first given the opportunity to select a music album based on the Spotify Premium catalog. None of the participants had a problem in selecting a suitable album. Afterwards, the instructor explained and presented the interaction technique to the participants before giving them about 2-3 minutes to try out the interaction technique to acquaint themselves with it. After the testing phase, the instructor prepared the actual experiment by selecting the previously chosen album so that the first song was playing.

Tasks
The scenario for both interaction methods was the same. The participants were standing as if they were on the go and had to control the music player on the instructor's requests. In each condition, the track had to be changed forward and backward, the volume adjusted (decreased by one step and increased by one step) and the playback paused (which requires the same interaction as restarting it) resulting in 5 control actions per set. We repeated the set 3 times per participant resulting in 15 interactions per condition. It was ensured that different interactions were always requested consecutively and that at least 15 seconds elapsed between them.

Measures
- *Task completion time*: Time between starting the task (after the instruction was given) and executing a recognized interaction (including trials with wrongly recognized interaction).
- *Error rate*: Percentage of interactions that were not executed according to the instructor's request over all performed trials.
- *False recognition rate*: Percentage of interactions that were correctly performed but falsely recognized over all performed trials.
- *Personal preference*: SUS, NASA TLX and ISO 9241-9 questionnaire assessing subjective information.

Hypotheses
We expect the EMG interaction technique to be significantly faster compared to direct touch interaction (H1). Regarding the error rate (H2) and the false recognition rate (H3), we do not expect any difference between the two interaction techniques.

Results
We used one-way repeated measures ANOVA tests for the task completion time, the error rate and the personal preference (SUS, Nasa TLX, ISO 9241-9) with the subject as random factor.

Task Completion Time: There was no significant effect of interaction technique considering all interactions. However, for pause / restart we found a significant difference ($F_{1,8} = 7.22, p < 0.05, \eta^2 = 0.31$): The EMG interaction was significantly slower (M=2.55 sec, SD=0.98 sec) compared to touch interaction (M=1.77 sec, SD=0.4 sec).

Error rate: The interaction technique had no significant effect on the error rate (M_{Touch}=3.0%, M_{EMG}=5.9%).

False recognition rate: The interaction technique had no significant effect on the rate of falsely recognized interactions (M_{Touch}=5.9%, M_{EMG}=17.8%).

Personal preference: We found no significant differences for the NASA TLX questions. However, for the general comfort question of the ISO 9241-9 questionnaire, we found a significant difference ($F_{1,8} = 12.0, p < 0.01$, $\eta^2 = 0.43$): Users rated the touch interaction technique as more comfortable (M=1.67, SD=1) compared to the EMG interaction technique (M=2.67, SD=1). For the System Usability Scale, we also found a significant difference ($F_{1,8} = 7.18, p < 0.05, \eta^2 = 0.31$) as the participants assigned a higher rating to the OHS touch interaction (M=87.5, SD=6.85 vs. M=76.1, SD=15.9). However, regarding learnability (considering item 4 and 10 of the SUS [7]), no significant difference between the interaction techniques could be found. When asked for their preferred interaction technique, six of the nine participants chose the OHS touch interaction.

Discussion

For task completion time, we found a significant difference when considering the time for pause / restart. As the task completion time is significantly higher in the EMG condition, we have to reject H1. One reason for this might be the fact that the touch interactions are similarly designed to those on smartphones so that the participants could benefit from prior experience. As we could not find any significant differences in error rate or false recognition rate, H2 and H3 can neither be confirmed nor rejected.

Regarding the outcome of the personal preference questionnaires, no clear picture can be drawn. Although the SUS revealed a significantly higher rating for the touch interaction, it has to be taken into account that the standard deviation for the EMG condition is rather high. From the users' feedback in the post-session questionnaire, the following statements are noticeable: Two participants mentioned the unlock gesture in the EMG condition as problematic and it could be seen that 33% of the falsely recognized gestures were intended as unlock gestures. Based on this, it might be reasonable to consider a different unlock pattern. Regarding the EMG interactions in general, we observed a false recognition rate of 17.8%, which is higher compared to what we expected from our review of related work. A possible reason for this could be the relatively simple calibration process working with one pre-defined calibration profile for all participants. It may be worthwhile to examine the individual calibration process recently made available for the Myo armband[4]. From the participants' perspective, it was reported twice that it seemed unusual to interact with the non-dominant hand (as a result of wearing the smartwatch on this hand), but both participants were confident that their perceived uncertainty could be reduced with further practicing. Two participants reported their concerns that it might look strange to gesticulate with the hand while walking in the city. In this context, it should further be examined how subtly the gestures can be executed while still being recognized, which could possibly reduce this problem. In three cases, properties of the EMG approach like eyes-free and one-handed interaction were explicitly mentioned as advantages by the participants.

Conclusion and Future Work

In this paper, we presented the results of a preliminary evaluation of one-handed, eyes-free smartwatch interactions with the help of an electromyography armband. In terms of task completion time, we could not show that SSH EMG interactions could outperform the well-established OSH touch interactions. In terms of user preference, touch interaction was favored by the majority of the participants. However, keeping in mind the

[4] `http://www.thalmic.com/blog/myo-sdk-beta-7`, retrieved 09/02/2015

advantages of SSH and eyes-free interaction, which were also mentioned by the participants, we would argue for further investigation. It should also be examined how the EMG interaction technique is perceived when used in the proposed context, i.e. when on the go—especially when only one hand is available for interaction or people are concentrating on other things like traffic. In this regard, the visual attention required, as well as social acceptance, should be also examined, especially in contrast to other interaction modalities such as speech. It may also be worthwhile to investigate possible effects of a longer-lasting training phase for the SSH condition.

As recently announced[5], the Myo armband now also provides access to the raw EMG readings. This gives the possibility to further extend the set of supported gestures by utilizing a self-written gesture recognizer. Based on this, we want to analyze the EMG interaction technique with a different and probably increased set of gestures. It might especially be worthwhile to consider a different unlock pattern, as it was the gesture most participants had problems with. Among others, an increased set would also provide the possibility to control different applications simultaneously without the need to explicitly select the target application beforehand.

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