Design and characterization of a novel screen-printed textile electrode for HD-EMG recording

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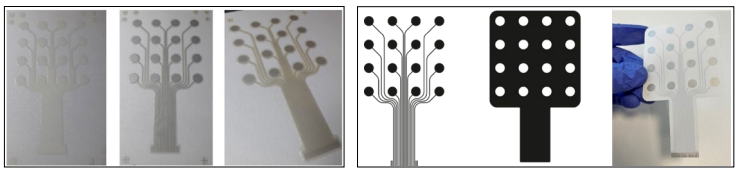
1. Introduction

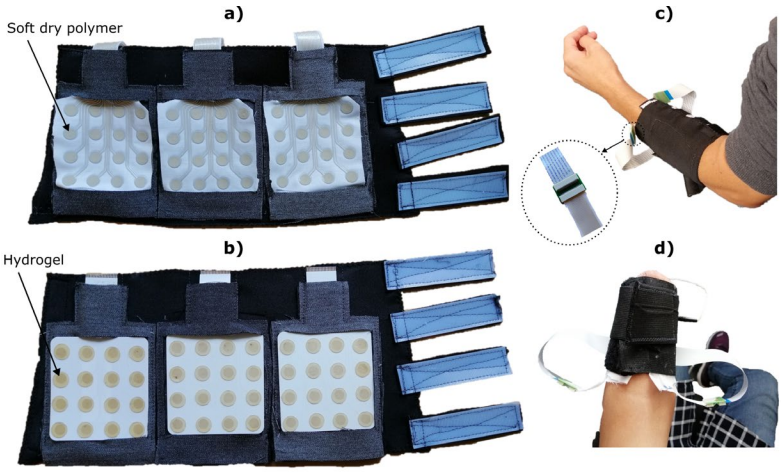
Recording electrical muscle activity using a dense matrix of detection points (high-density EMG) is of interest in a range of different applications, from human-machine interfacing to re-habilitation and clinical assessment. The wider application of high-density EMG is however limited as the clinical interfaces are not convenient for practical use (e.g., require conductive gel/cream). Dry electrodes are applied directly on the skin without conductive gel or cream, and this simplifies the setup. In the present study, we describe a novel dry electrode (TEX) in which the matrix of sensing pads is screen-printed on textile and then coated with a soft polymer to ensure good skin-electrode contact. To benchmark the novel solution, an identical electrode was produced using state of the art technology (PET with hydrogel).

2. Electrode design



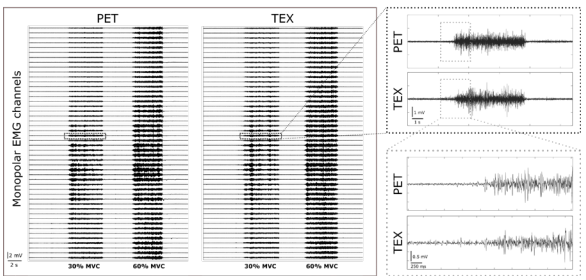
Two identically configured matrix electrodes were produced using screen-printing technology: A textile-based dry electrode (TEX) and a polyethylene terephthalate substrate electrode with hydrogel (PET). The TEX electrode was printed in three stages: Primer layer, conductive layer and encapsulation layer (left). The electrode pads remain exposed so that the subsequent skin-electrode interface material can be applied. Similarly the PET electrode was printed in two stages: silver-based ink electrode pads and dielectric protective layer (right).

3. Experimental protocol

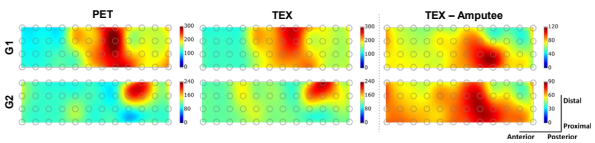


A custom-made garment (a,b) was designed to facilitate the application of the electrodes. Seven able-bodied subjects (c) and one transradial amputee (d) participated in the experiment. The experimental protocol included two phases: the recording of EMG data for offline analysis and classifier training, and the online control task. Firstly, to collect the EMG data for classifier training and offline analysis, the Maximum Voluntary Contraction (MVC) was measured for each gesture. Afterwards, the participants performed two consecutive isometric contractions for each gesture at two intensity levels (30% and 60% MVC). The online task consisted in recognizing 7 hand gestures, while receiving visual feedback about the gesture predicted by the classifier.

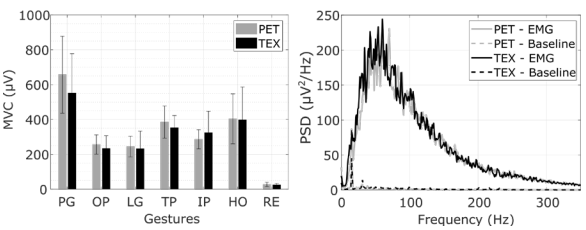
4. HD-EMG signal detection



Both recordings are characterized with a flat baseline (no motion artifacts), clear EMG bursts, and a similar signal magnitude and activity pattern across the channels and within single bursts.



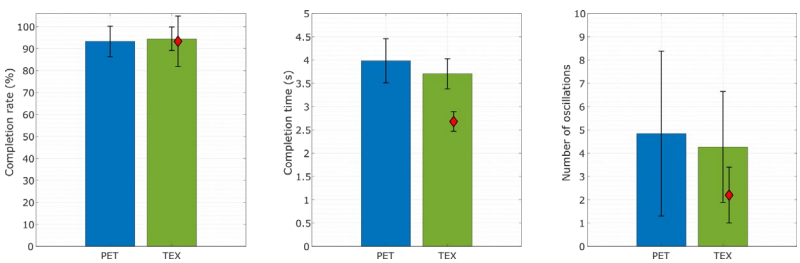
The overall correlation coefficient (mean ± std) calculated between muscle patterns obtained using PET and TEX across gestures and able-bodied participants was 0.78 ± 0.19.



The obtained MVC values were similar for the two interfaces consistently across the gestures. The average SNR was 53.2 ± 9.6 dB using PET and 52.7 ± 7.2 dB using TEX. Additionally, the PSD profiles were similar, with a baseline noise at least 2 orders of magnitude lower compared to that of the EMG signal.

5. Online assessment

The participants achieved a similarly high completion rates with both electrode types (94.4 ± 5.33% using TEX and 93.25 ± 6.95% with PET). Moreover, there was no statistically significant difference between TEX and PET in completion time (3.7 ± 0.32s vs 3.98 ± 0.97s) or the number of oscillations (4.2 ± 2.3 vs 4.8 ± 3.5). The amputee participant (annotated with a diamond) achieved a completion rate (mean ± std across trials) of 93.3% ± 11% and a completion time of 2.68 ± 0.2 s.



6. Conclusion

The tests showed that the signals collected using TEX and PET were characterized with similar spectra, magnitude, spatial distribution and signal to noise ratio. The electrodes were used to recognize 7 hand gestures, leading to similar performance during offline analysis and online control. The comprehensive assessment demonstrated that the proposed textile interface is an attractive solution for the practical applications.

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