



Rossiter, J., Knoop, E., & Nakamura, Y. (2017). Affective Touch and Low Power Artificial Muscles for Rehabilitative and Assistive Wearable Soft Robotics. In *Wearable Robotics: Challenges and Trends: Proceedings of the 2nd International Symposium on Wearable Robotics, WeRob2016, October 18-21, 2016, Segovia, Spain* (Vol. 3, pp. 101-106). (Biosystems & Biorobotics; Vol. 16). Springer.
https://doi.org/10.1007/978-3-319-46532-6_17

Peer reviewed version

Link to published version (if available):
[10.1007/978-3-319-46532-6_17](https://doi.org/10.1007/978-3-319-46532-6_17)

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Affective touch and low power artificial muscles for rehabilitative and assistive wearable soft robotics

Jonathan Rossiter, Espen Knoop and Yuichi Nakamura

Abstract—The goal in wearable rehabilitation is to restore the lost functionality of the body by rebuilding the sensory-motor link. This may be achieved through a replication, in an artificial or robotic system, of the physiotherapy methods employed by human experts. These methods are typically focused on physical manipulation. We suggest that a lower reliance on manipulation, combined with affective touch stimulation, has the potential to provide effective rehabilitation in lower power and lighter wearable devices. Here we consider affective touch driven by soft actuation and how this may be combined with low power artificial muscle actuators for physical rehabilitation.

I. INTRODUCTION

PEOPLE who have suffered from injury, disease and stroke often have reduced mobility. In order to maintain their independence, quality of life and mental health these people require rehabilitation and assistance. Rehabilitation is a short term program which aims to restore as much physical capability as possible. After rehabilitation has reached a plateau the patient may transition to a long term assisted lifestyle. Wearable robotics may be helpful in providing enhanced and automatic rehabilitation and assistance. Conventional rigid robotics, such as exoskeletons, have set the bar for ‘wearable’ physical rehab and assist devices [1][2]. Unfortunately the limitations of rigid robots and their underlying reliance on geared motors and rigid metals and plastics reduces the adaptability and comfort of these devices and elevates their cost and complexity. More recently soft robotic devices have come to the fore as an alternative to rigid robots [3][4]. Advantages to wearable soft robotics include inherent compliance (and associated increased safety), adaptability, lower cost and higher user acceptability. Although most approaches to soft robotic assist and rehab devices target the same high power range as their rigid robotic counterparts, there is great potential for lower power devices. A patient with movement deficit may not require a high power assist device that will restore 100% of their prior mobility. Rather a restoration of only a few percent may be sufficient to make a step change in their capabilities and quality of life.

In addition, the acceptability of the wearable device (be it orthotic or prosthetic) is a major stumbling block to adoption and use [5]. Acceptability includes subjective assessment of comfort, functionality and aesthetics. We suggest that affective touch, combined with low power soft artificial

muscle actuators can provide natural, comfortable and low-cognitive-load soft wearable assistive and rehabilitative devices.

II. AFFECTIVE TOUCH

The affective sense of touch is concerned with natural sensations which cover the spectrum from pleasant to unpleasant [6]. For example, smoothness and softness are often linked to pleasantness, whereas stiffness, roughness and coarseness are linked to unpleasantness. Affective haptics seeks to overcome the limitation of simple mechanical tactile stimulators by targeting the richer conceptual and emotional channel of communication that is encompassed by the affective sense of touch. This is in contrast to conventional electromechanical tactile stimulation, such as vibrations, which are convenient to generate with simple technologies, but which are not related to the natural sensations encountered in evolutionary history. The disconnect between conventional stimulation and human cognitive processes suggests that rehabilitation using the natural feelings afforded by affective touch may be more effective. Figure 1 illustrates how the low cognitive impedance of affective touch, in contrast to non-affective touch, can be combined with physical assistance to reinforce a rehabilitation activity such as bending the leg.

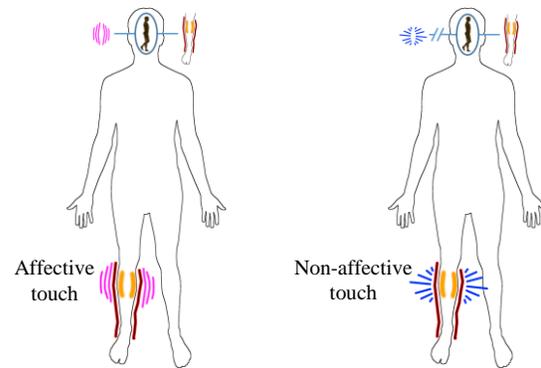


Fig. 1. Affective tactile stimulation (left) provides a natural context and channel for rehabilitation, in contrast with non-affective unnatural stimulation (right) such as vibration. Physical rehabilitation in red, muscles in orange

A. Affective tactile stimulation

Affective touch can be communicated via a range of affective tactile stimulators, providing the foundation

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supported by the Dyson Foundation. Y. Nakamura is with the Academic Center for Computing and Media Studies, Graduate School of Electrical Engineering, Faculty of Engineering, Kyoto University

technologies for inclusion in wearable rehabilitation and assistance devices. These include the Tickler, a wearable soft robotic tactile stimulator that stokes or tickles the skin [7] (figure 2a). The Tickler is fabricated from a 3d printed compliant frame with integrated 3d printed rigid bars which hinge at their mid points within a soft membrane (Objet260 Connex, Stratasys Ltd.) The bars are actuated by shape memory alloy filaments at the ends away from the skin, causing the bars to pivot about their hinges and the ends in contact with the skin to move laterally. The relative lateral motion of the bar ends across the skin stimulates sensations described by test subjects variously as ‘a subtle tickling sensation’, ‘like a massage’, ‘comfortable’, ‘feels good’.

A smaller scale affective stimulator is achieved by replacing the bars of the Tickler with rounded pins. We can also reduce the size of the stimulation elements to achieve a higher resolution or lower profile (figure 3) [8]. To actuate the pin array stimulators we use a dielectric elastomer (DE) electroactive polymer actuator. This DE membrane is stretched across the base of the pins, and electrodes are applied to the regions between the pins. When these regions are electrically stimulated (electric field $\sim 1\text{MV/m}$) they expand, causing lateral motion at the tips of the pins in contact with the skin.

Larger laterotactile stimulation can be achieved using more conventional servo motors to push apart, or bring together, two patches attached to the skin (figure 2b,c). These ‘skin stretchers’ interact with the skin only and do not directly drive movement in the limbs. They impart a larger sensory stimulation and a higher degree of urgency than the smaller scale stimulators, providing an enhanced link between stretcher movement and limb movement.

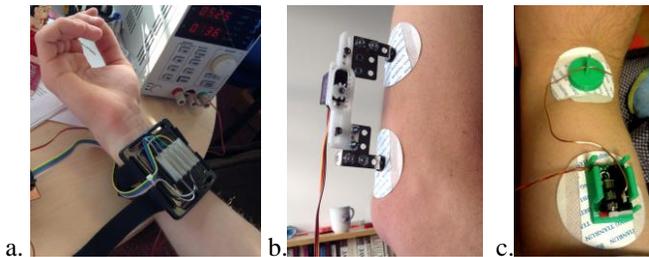


Fig. 2. Affective touch stimulators: (a) The Tickler laterotactile stimulator, (b),(c) large skin stretchers using servos.

III. ARTIFICIAL MUSCLE REHABILITATION

Electroactive polymer (EAP) artificial muscles, such as the DE actuators used above in the laterotactile stimulators, have power densities of the same order as biological muscle. This suggests their use in soft wearable assist devices. Unfortunately fabrication challenges, mismatches in natural frequencies, and reliability issues mean that high power electroactive polymer assist devices are not currently achievable. A better application of EAPs is as lower power assist devices, for example to regulate or boost level walking, or to assist with standing stability in those who would benefit from a small level of assistance. The inclusion of the above

presented affective tactile stimulators in these low power devices is expected to improve the acceptance, comfort and cognitive compatibility of these devices.

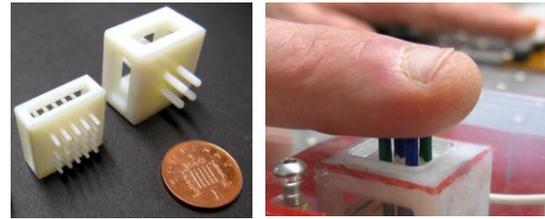


Fig. 3. Electroactive polymer driven laterotactile stimulators: (a) two different tactile arrays, (b) sensitivity and discrimination experiments.

Reducing the power output of the wearable rehabilitation device also means that it can be made smaller, lighter and with lower cost. These will improve user adoption if the wearable device can be worn discreetly and comfortably under conventional clothing. With the integration of affective touch, and its emphasis on natural tactile communication, the device will be minimally disruptive cognitively, with consequent benefits in rehabilitation and long-term assistance.

IV. CONCLUSIONS

We have presented affective touch as an important and overlooked channel of communication for integration in wearable soft robotic rehabilitation and assist devices. By integrating artificial muscle-driven affective touch, through natural laterotactile stimulation such as stoking and tickling, with low power EAP actuators we propose a new form of wearable device. These are expected to be comfortable, discrete and have wider acceptance and adoption in target patients undergoing neuro and physical rehabilitation or in need of long term assistance.

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