Altered Muscle Activation Patterns during Training with an End-effector Robot Reflects an Embodiment Challenge to Users

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Summary

What effect does short-term physical connection to a cobot have on us during robot-assisted tasks? Previous studies addressing proximate human-robot interaction (HRI), where an end-effector robot offers various degrees of support, provide evidence that often both increased muscular activation and cocontraction occur. Such outcomes can lead to undesired biomechanical and cognitive effects in users. In this study, a preceding familiarization phase allowed users to acclimate to training with an end-effector robot to mitigate against its effect as an unusual exteroceptive stimulus. However, in spite of familiarization, muscular activation and coactivation still increased during task performance once subjects were connected to the robot. This may reflect subjects' difficulty to embody the robot-assistive system and infers a modified motor control strategy employed during such proximate HRI. This result has implications for our understanding of motor control and for effective motor learning.

Introduction

In the case of training with robotic assistance where the human is coupled to a robotic arm or system and both work together to attain a specific goal, the effect of such proximate human-robot interaction (HRI) on human motor control and learning increases in importance. A previous study reported that the use of an end-effector robot-based assistive system while performing the activities of daily living (ADLs) with varying degrees of robotic support had a marked effect on the muscular activation of healthy subjects (1). This study investigated if the aforementioned effects of HRI arises due to users' 'safety reaction' to the end-effector robot-assistive system and if a preceding dedicated familiarization phase can restore muscular activation patterns during ADLs.

Methods

22 healthy subjects (avg. age: 25.3 ± 2.6 yrs.) were recruited to exclude the effects of pathology. Subjects performed a simulated ADL: Cup to Box, Cup to Mouth (CBCM). The robot-assistive system centered on an Iiwa 14 robotic arm (KUKA Robotics). Subjects were seated before the robot-assistive system and connected to the robotic arm via a wrist splint (BORT Medical). The measurement protocol had 3 phases: (i) simulated free-handed ADL (ADL-F), (ii) a familiarization phase with robot consisting of 4 reach-to-touch test sequences (RTT) and (iii) simulated ADL with robot (ADL-R). In phases (ii) and (iii) the robot is connected to the subject but offers no support. Movements were recorded using a 3D motion analysis system (Vicon). Surface electromyography (sEMG) was recorded according to SENIAM recommendations from M biceps brachii, M triceps lateralis and M. brachioradialis. The sEMG data was sampled at 2000 Hz and bandpass filtered (range: 1 - 500 Hz). The data was rectified, smoothed and a normalized sEMG envelope was determined. The root mean square (RMS) value of each muscle was determined for each scenario of the ADL.

Results and Discussion

Figure 1 indicates that subjects adapted quickly to the robot-assistive system and that any existing 'safety reaction' was indeed nullified by a familiarization phase.

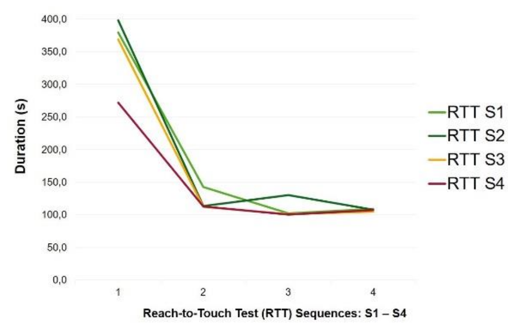

Figure 1: Figure 1: Duration of RTT sequences.

Yet, the ratio of the RMS of ADL-R to ADL-F for all 3 muscles showed that physical connection to the robotic system increased muscular activation of the elbow flexors and extensors and coactivation, especially for M. brachioradialis. This reveals that the effects of proximate HRI cannot be attributed to a 'safety reaction' to the robotic system but instead represents an embodiment challenge and prompts modified neuromechanical control during motor learning even in healthy subjects.

Conclusions

A preceding familiarization did not minimize the effect on muscular activation and coactivation during task performance. This may reflect subjects' difficulty to embody the robotic arm when performing ADLs with robotic support. It infers a modified motor control strategy during proximate human-robot interaction. This result has implications for robot-assisted training, our understanding of motor control and for effective motor learning.

References

[1] Becker, S. et al. (2019). *IEEE Trans Neural Syst Rehabil Eng*. **27**: 43-50.