



Changing perceived assistive force using visual feedback

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Abstract: This work is about examining the effects of a visual display notifying the assistive force provided through a wearable suit. We observed that subjects always underestimate the assistive force. This underestimation can be reduced by notifying about the force visually.

Keywords: Perception, visual assistive force feedback, pneumatic artificial muscle (PAM), therapeutic training

1. Introduction

Physical activity has significantly reduced due to the recent circumstances of pandemic and social distancing [1]. The motivation to perform physical training or even therapeutic exercises is low when we continuously stay indoors. Studies have shown that rich sensory and functional settings can increase subject attention and motivation to engage in therapeutic exercises [2]. That is, performing exercises can be more stimulating if we include sensory augmentation.

In this work, we introduce an assistive setting for performing exercises. However, an assistive force of constant magnitude would progressively depress the subject's voluntary control rather than promoting its increase. [3]. Therefore, if we can create deception of the magnitude of assistive forces while performing the physical activity, it may positively motivate individuals to achieve the target level of physical activity with a reduced psychological load.

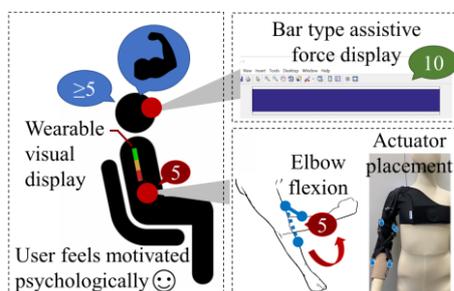


Fig. 1: Assistive force is usually underestimated. The challenge in this work is, can we change perceived assistive force through visual feedback?

In this report, we examine the effects of introducing a visual display to show the magnitude of assistive force provided through an assistive wearable pneumatic artificial muscle (PAM) prototype. In the first study, we use three conditions of correct, incorrect and no visual feedback for elbow joint

assistance. We recorded the level of assistive force perceived by the participants for all three states. It was observed that the subjects tend to underestimate the assistive force at all conditions. However, this underestimation can be reduced by introducing the visual information of the assistive force magnitude. Secondly, we compared two types of visual display to observe the differences in assistive force perception. In the second study, visual feedback always illustrated a higher value than the actual force magnitude. One was a colour-based display, and the other was a circular display with varying diameter. Fig. 1 shows the concept of the visual assistive force feedback in the form of bar display and prospective wearable LED display.

2. Related work

There is minimal research to identify the effects of visual assistive force feedback on physical and mental interpretation of exercises. Biofeedback has been used as an intervention tool in balance rehabilitation [4], pelvic floor muscle training [5], speech therapy [6], gait training [7], and posture control [8]. Other pieces of research focusing on the effects of visual feedback include a golf skill training exercise [9], assessment of motivation to perform squat [10] and a stationary cycling exercise [11]. Sound or audio feedback also have an effect on body perception during exertion exercise [12].

It can be said that additional feedback providing information on the performed task has positive impacts on motivation and competitiveness levels of the subject. However, the effects of assistive force feedback have not yet been studied explicitly.

3. System description

In this section, we briefly describe our prototype for providing assistive forces and the types of visual display used.

3.1 Pneumatic gel muscle (PGM)

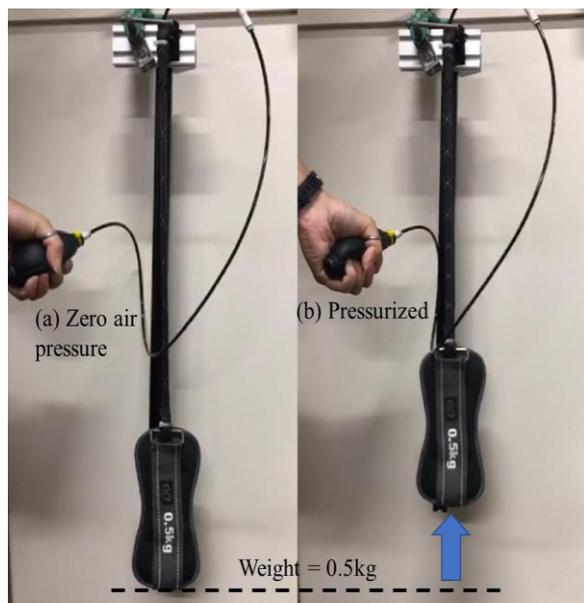


Fig. 2: Behavior of pneumatic gel muscle (PGM) under (a) non-pressurized and (b) pressurized conditions (simple hand-sized rubber pump used as a source of compressed air in this case)

We used a low-pressure PAM called pneumatic gel muscle (PGM) in our study as an actuator that provides assistive forces. The speciality of this actuator is that it can induce higher magnitudes of force compared to commercially available counterparts at low values of air pressure [13]. The composition of this actuator is completely soft that makes it eligible for developing a soft and wearable assistive suit. Besides, the low air pressure requirement enables the actuators to be used with small CO₂ canisters, thereby making the entire system portable.

Fig. 2 shows the operation of the PGM actuators used in our study. We used PGMs to support two different degrees of freedom (DOFs), namely, elbow flexion and wrist extension. On supplying zero air pressure, the actuator behaves like a spring with a maximum stretchable length of 20cm. We attached the actuators on the subject's arm at 93% stretching. Fig. 3 shows the attachment points of PGMs associated with elbow flexion and wrist extension. The actuated and non-actuated positions of the arm are illustrated for each DOF. This configuration was followed according to the previously developed prototype called ForceArm [14].

3.2 Visual display

Fig. 4 shows the visual display types used for the two user studies. The first is a simple bar-type display changing linearly with respect to the magnitude of the assistive force displayed for the subject. The second is a colour-changing circular display with a colour bar for reference on the right side. The third is also a circular display with changing diameter. We used discrete levels from 1 to 10 for all displays.

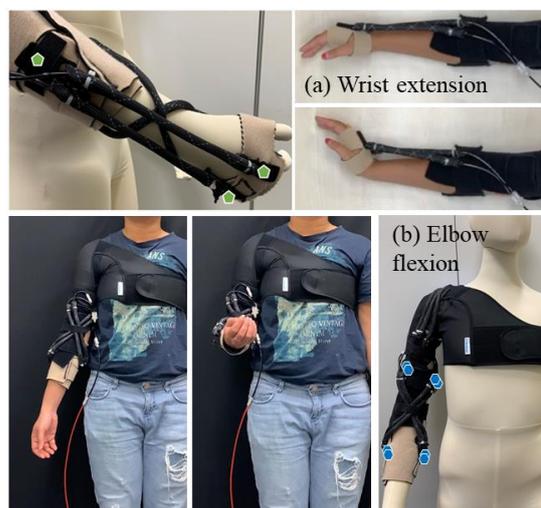


Fig. 3: Attachment points of the pneumatic gel muscles (PGMs) for (a) wrist extension and (b) elbow flexion

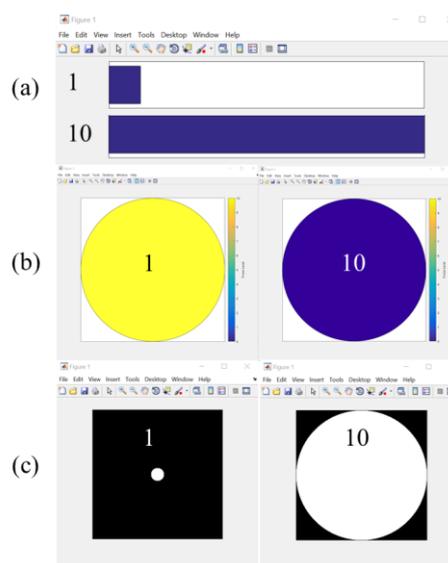


Fig. 4: Visual display types used with representative force levels of 1 and 10 (a) bar display (b) color display and (c) circle display

3.3 Control for air pressure

The PGMs induce variable force levels according to the magnitude of air pressure fed to them. We used a PWM type of valve called SMC ITV0031-2L for precise manipulation of the air pressure fed to the actuators. We varied the air pressure from 0.1 to 0.2MPa for levels from 1 to 10.

4. User studies

In this section, we describe the user studies conducted and the results obtained. A total of 12 participants consented for both user studies. They were all asked not to perform any physically demanding task before the experiments.

4.1 Experiment protocol for user study 1

This study comprised of three main sessions, namely, correct, incorrect and no visual feedback. For each session, 50 pairs of visual feedback and assistive force levels were chosen.

The pairs were divided into five sub-sessions so that users could rest. We used the elbow flexion assistance for this study. For the correct session, both visual and assistive force levels were the same throughout with force levels from one through ten repeated five times in random sequence. For the incorrect session, the visual error (= visual feedback level – actual assistive force level) was varied from -5 to 5 in steps of 1. For the no visual feedback session, force levels from 1 through 10 were repeated five times in a randomized sequence.

The three sessions were done on separate days for each participant. Counterbalancing between the incorrect display and no display was done for two groups of the participants.

4.2 Experiment protocol for user study 2

The second user study was to compare the effects of two different visual displays using wrist extension motion assistance. There was one session each for the two visual display types. Each subject participated in the two sessions on separate days. Although, both sessions had the same values and sequence of pairings of the visual and assistive force levels. For each session, the first sub-session comprised of training with correct visual displays for each force level from 1 through 10 and back to 1. The next three equally sized sub-sessions contained a total of 45 randomized pairings with visual errors varying from 0 to 5. These sub-sessions were repeated once again, making a total of 7 sub-sessions for each visual display.

For both user studies, the subjects responded with their perceived force level and were unaware of the incorrectness of the visual display. We calculated the perceived force error (= perceived force level – actual assistive force level) for all cases and compared the average values for different sessions.

4.3 Results

Fig. 5 illustrates the average perceived error values for correct, incorrect and no visual sessions during the first user study. The average perceived error values for three types of visual displays, namely, bar, colour and circle, are compared in Fig. 6. For this plot, we used all data with a visual error greater than 0 from user studies 1 and 2 both. Statistical differences were identified using repeated measures ANOVA for all data. The cross points represent the average values, and the horizontal lines in each box represent median values in the box and whiskers plots of Fig. 5 and 6.

5. Discussion

From user study 1, we could observe that during all conditions, the average perceived force is lesser than the actual assistive force values. In other words, subjects underestimate the assistive forces provided by the PGM-based actuation. However, this underestimation could be significantly reduced by using both correct and incorrect bar visual display types. The results from the second user study were also compared with

user study 1 data (visual error > 0). We can observe that we could successfully remove the tendency of underestimation of the assistive force. The average perceived force level was always higher than the actual force level. Comparing the visual display types, we found that, colour type display could most effectively create the illusion of higher than the real assistive force. The colour-based display could also have a significantly stronger effect as compared to the bar display as well as circle display. The results of this study can be extremely beneficial for designing training exercises with extra motivation provided with augmentation providing the limited magnitude of assistance. Such psychological effects, along with assistive technology, are particularly helpful for people with weak muscles who find it challenging to train themselves without any assistance.

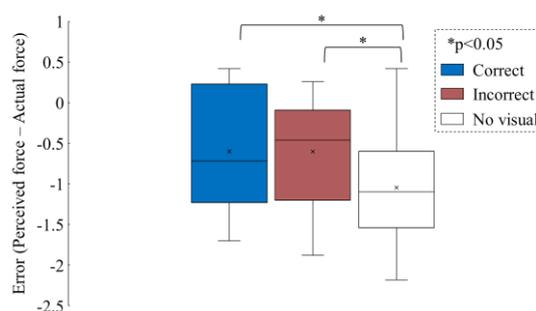


Fig. 5: Comparison of perceived force error for three sessions of user study 1 (using bar type display)

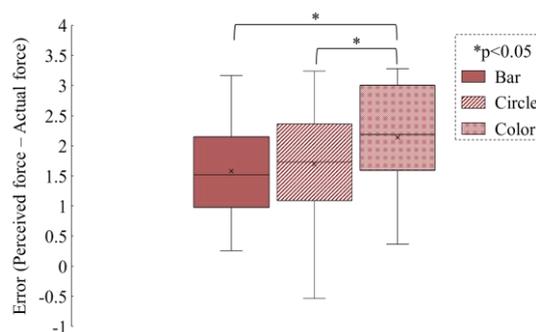


Fig. 6: Comparison of perceived force error for three different visual displays from user studies 1 and 2

6. Conclusion

This work evaluated the effects of introducing a visual display to show the assistive force level provided by a PGM-enable ForceArm glove on different parts of the arm. We observed that we could induce an illusion of higher than actual assistive force levels in the minds of the subjects through our visual display types. The most effective type of display was the colour type with varying colour and provided colour scale.

The results of this work can be beneficial to design healthy as well as rehabilitation training methods with gradually withdrawn assistive forces. The illusive assistive force perception due to the visual display can result in higher levels

of motivation in users.

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