INTRODUCTION
Robotic therapy, with its unique advantages over a human therapist, is an appealing option to minimize patients’ recovery time. *Massed practice* and means of amplifying its positive effects via a robotic interface (i.e., error augmentation of the patient’s reaching trajectory) has been extensively studied. However, even with utilizing such neuro-rehabilitation paradigms, therapy robots still have two major challenges: sustaining the patient’s motivation to continue therapy and the need for a therapist to set up the therapy session based on each patient’s physical and emotional states.

To overcome these limitations, we envision therapy robots that utilize a real-time decision-making algorithm to set the difficulty of the exercise based on emotional (psychological) state and motor performance. Such bio-cooperative systems will autonomously adjust the difficulty of the therapy task in order to reach a desired level of challenge, without causing stress or harm. We believe this approach will result in a longer engagement in the therapy regimen and a more intense workout. This paper presents the fundamentals of such a system.

METHODS
In [1,2] subjects were asked to reach for visually presented targets by moving a cursor to the target points via a haptic manipulandum (Figure 1). To study how subjects learn to reach, a rotation between the end-effector coordinates and the display coordinates was implemented, initially making it harder to reach for the targets. These studies showed that the learning will be faster if the initial reaching trajectory error was additionally augmented (visually or via haptics). This type of massed practice with trajectory error augmentation leads to persistent functional changes for hemispheral post-stroke subjects [3].

RESULTS
The top row of Figure 2 shows the trajectory-following performance over time: upon first exposure to the rotation, trajectory errors are large, followed by learning to reach in the distorted environment, and finally adaptation by the subject to the rotation (the errors grow large in the opposite direction when the rotation is turned off). Sudden changes in SCR data (bottom row of Figure 2) indicate a clear sign of the subject’s orienting response to a change in task challenge. This preliminary study indicates a correlation between the physiological signals (i.e., subject’s affective state), performance (i.e., trajectory error), and the rehabilitation task challenge (i.e., activation/deactivation of the rotation), and thus the possibility of designing a bio-cooperative rehabilitation robotic system.

DISCUSSION & CONCLUSION
In this paper, we present a future vision of robotic therapy: to shift from human-based to robotic-based therapy sessions, we need robotic therapist assistants that are more emotionally responsive. We believe that the first step toward autonomous robot therapists is to make the robots responsive to the patient’s affective state. Our proposed novel interface, which encompasses real-time use of the subject’s physiological data and performance, is aimed at reaching this vision.

REFERENCES