BIMANUAL MOTOR CONTROL: BIOLOGICAL AND ROBOTIC SYSTEM LEARNING VIA SIMULTANEOUS MOVEMENT REQUIREMENTS

Pete B. Shull and Roger V. Gonzalez
LeTourneau University; email: RogerGonzalez@letu.edu, web: http://www.letu.edu/people/rogergonzalez/

INTRODUCTION

Bimanual human motor control learning studies have demonstrated that adaptation occurs while using both biological arms to conduct tasks of varying difficulty [1]. Unimanual learning has also been shown to occur when using a robotic system [2]. Though humans can perform tasks of varying complexity, bimanual learning using two contrasting input/output (I/O) systems simultaneously is not well understood. This study tested our hypothesis that humans can adapt spatially and temporally to a bimanual tracing task using both their biological arm and a robotic system simultaneously.

METHODS

Four female and six male subjects (ages 19-29) voluntarily participated in this experiment. All subjects were right-handed by self-report and were tested during the same time each day (±2 hrs) for four consecutive days. Each subject was given the task of tracing 15 cm circle(s) clockwise at 3.2 second intervals using their biological and/or a robotic arm (Figure 1). XY digitizing tablets recorded two-dimensional spatial position every 100ms, and each trial lasted approximately 50 seconds. Subjects traced two circles using both biological arms for the first and last five trials of the experiment to examine normal bimanual performance before and after testing. During stage one of testing, subjects traced one circle with a robotic arm by applying forces and torques to a rigid joystick with their dominant arm. During stage two, subjects used the robotic arm and their non-dominant biological arm to trace both circles simultaneously. The control strategy for the actuation of the robotic arm was intentionally designed to be difficult and non-intuitive so that possible learning could be observed over time.

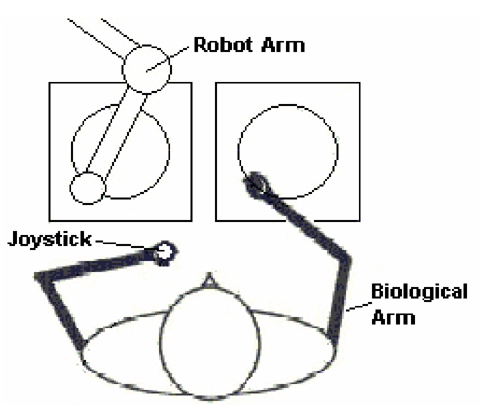

Figure 1: Experimental setup. Subjects traced 15 cm circles on digitizing tablets with the robotic arm by applying forces and torques to the joystick and/or with their biological arm.

RESULTS AND DISCUSSION

Data was analyzed in blocks of five trials. Performance was based on spatial and temporal accuracy in tracing the circle(s).

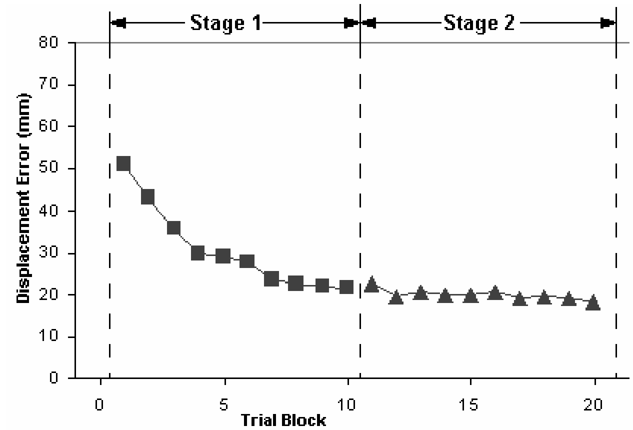

Figure 2: Subject spatial performance using the robotic arm. During stage 1 subjects used only the robotic arm. Stage 2 required using both robotic and biological arms simultaneously.

Spatial accuracy was calculated by averaging the distance from the circle (in millimeters) at each point during the trial. Temporal accuracy was the average of the differences in desired and actual angle (in degrees) at each point of the trial. Compiled results of all subjects show that subjects learned to control the robotic arm by demonstrating spatial learning curves (Figure 2) and temporal exponential learning curves. Biological arm spatial and temporal scores were constant throughout testing and were statistically lower than robotic arm scores since controlling the biological arm was more natural than controlling the robotic arm.

It would seem that moving from stage 1 of testing to stage 2 would be a difficult task because the subject would be controlling two distinct I/O systems simultaneously and that the initial performance of stage 2 would be worse than the final performance of stage 1. However, neither the spatial nor the temporal learning curves were adversely affected when subjects moved from stage 1 to stage 2 of testing.

CONCLUSIONS

Testing indicates that humans can learn to use two distinct parallel I/O systems simultaneously to conduct two-dimensional tracing tasks. It also appears that humans can transition from using one I/O system to using two distinct I/O systems without a decrease in performance in either system.

REFERENCES

1. Walter CB, Swinnen SP, Dounskaia NV. *Journal of Motor Behavior* **34** (2), 183-195, 2002.
2. Shull PB, Gonzalez RV. *J of Applied Biomech*, 2004 (sub.)

ACKNOWLEDGEMENTS

This work was funded in part by NSF-BES Grant (RUI-0201889