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A Psychophysics-Derived Mapping Scheme for Translational Shape-Changing Haptic Interfaces

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***Abstract*—This demo showcases a method of applying the findings from the first (to our knowledge) in-depth psychophysical study on a Shape-Changing Haptic Interface (SCHI) to real-world HCI applications via a high-precision test rig and interactive 'paddle game'.**

I. Introduction

Shape-changing haptic interfaces (SCHIs) are an emerging area of HCI research that promises highly intuitive data communication with low cognitive load. However, compared to other haptic sensory modalities, such as vibration, there exists little literature that addresses how users perceive changing shapes. To encourage further SCHI development, we conducted a psychophysical experiment studying user perception of 'translational' shape change using a custom-built test rig (Figure 1) and evaluated the effect of different translation magnitudes, directions, and grasp types on stimulus perception. That work has been accepted as a regular paper for WHC 2025. In this demo, we wish to show how our findings can be applied to improve user interactions with SCHIs through a video game loosely based on the 1976 game *Breakout*. We demonstrate that compared to conventional linear mapping between the SCHI device position and its represented value, a non-linear mapping derived from our perceptual experiment outcomes is more effective, with improved error distribution.

II. Device and Psychophysics Findings

Our device (Figure 1) utilizes a high-precision lead-screw linear actuator to offset the top section (crown) of a 3D-printed cube from its main body. We conducted a series of psychophysics experiments using *Methods of Constant Stimulation – Difference Thresholds* [1] method. We found that, unlike other sensory modalities (e.g. vibration, weight, light intensity) that have predominantly constant Weber Fractions across stimulus levels, a large translation magnitude corresponds to a significantly heightened perception sensitivity. Moreover, having more fingers in contact with a shape-changing device does not effectively result in better perception. Finally, the perception of shape-changing devices is not symmetric and can have a directional bias, likely to differ from person to person.

III. Demo

In this 5-minute demo, we showcase how to apply our findings to real-world applications through a 'paddle game'

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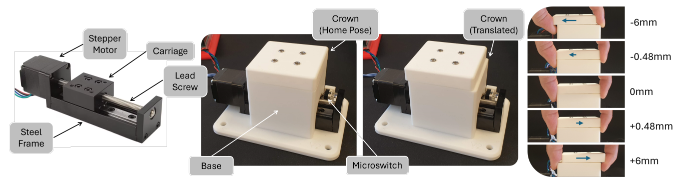

Fig. 1. Test rig and finger contact with the device when it moves to different magnitudes and directions.

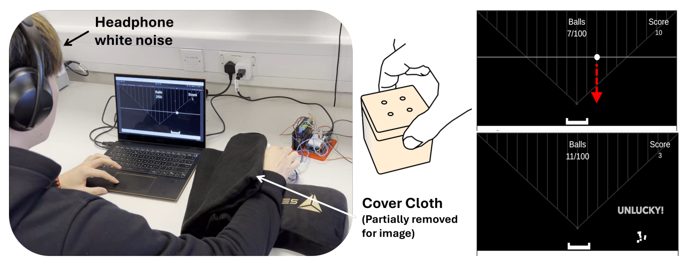

Fig. 2. Demo setup and screenshots from the paddle game. The red arrows, lines, and text are for annotation purposes only and are not visible to participants.

(Figure 2). The user pinch grasps the device with their dominant hand and controls the horizontal position of an on-screen paddle (using a laptop touchpad) to catch falling balls. The first 10 balls are visible to help the user calibrate their perception, and the remaining balls are invisible. The balls' vertical positions are represented via a falling horizontal line, and the balls' horizontal positions are only represented to the user through the pose of the haptic device. A ball falling in the middle of the screen is presented as the device in its home pose (0 mm in Figure 1). A ball falling in the left/right half of the screen is presented as the device translates from its home pose to the left/right to a certain magnitude (based on a mapping scheme), then back to its home pose. This game is a simple 1D analogy to real-world applications, such as screen reader cursor position representation for vision-impaired users.

The user will play the game twice with a linear mapping between the ball's horizontal position (x) and device position (translation magnitude (y)), and a non-linear mapping derived from our psychophysical results, where the gradient $\frac{dy}{dx}$ is significantly smaller near the screen center compared to the screen edges. Both schemes map -8 to 8 game units (ball position) to -6 mm to 6 mm device position.

References

[1] G. A. Gescheider, "Psychophysics: Method, theory, and application," *(No Title)*, 1985.