Bi-manual Skin Stretch Feedback Embedded within a Game Controller

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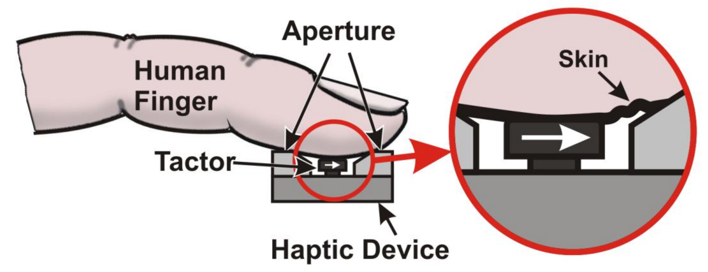
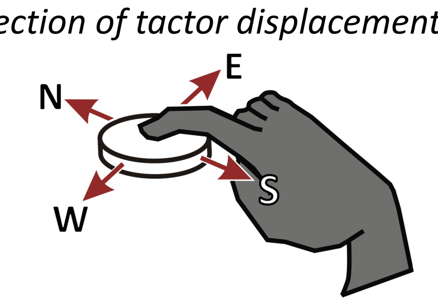
Introduction

Background: Tactile skin stretch can be used to communicate directional information. When users place their finger on the tactor, the force between the tactor and the finger stretches the skin laterally in the direction of displacement. Previous work has shown that with as little as 1 mm of displacement, users can accurately determine the direction of the tactor's motion [1].



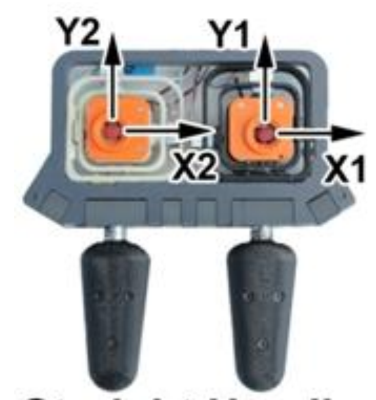
As the tactor moves, the skin is stretched in the direction of tactor displacement.



Skin stretch feedback can effectively communicate directional feedback.

Motivation: We believe that embedding skin stretch feedback into the thumb joysticks of a game controller will greatly enhance a user's gaming experience. This will allow new feedback to be presented to the user, which can present directional information through the sense of touch.

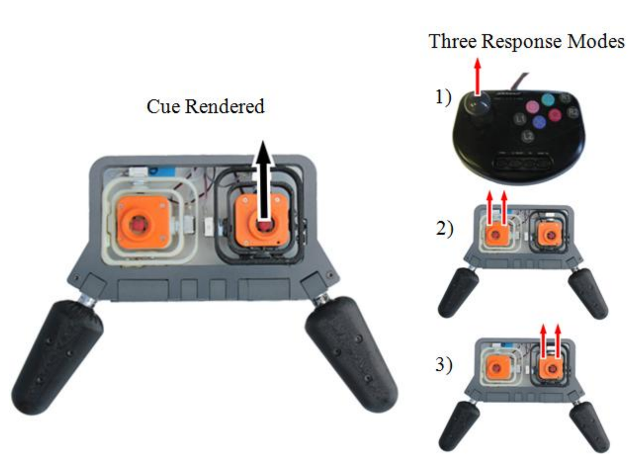
Previous studies have been performed with the fingers aligned with one axis of the directional cues applied by the tactor. However, game controllers typically orient users' thumbs in an angled orientation, rather than pointed straight forward. Because of this difference, we wanted to investigate possible cognitive and ergonomic trade-offs between different thumb orientations, so we developed a prototype game controller with adjustable handle positions. Slower and less accurate responses were expected in the angled handle design due to the cognitive process, known in the field of psychology as "mental rotation," required by users to interpret direction cues when the thumbs are angled. However, we suspected this may be balanced out by better ergonomics in the angled configuration.



Straight Handle Configuration

Angled Handle Configuration

Methods



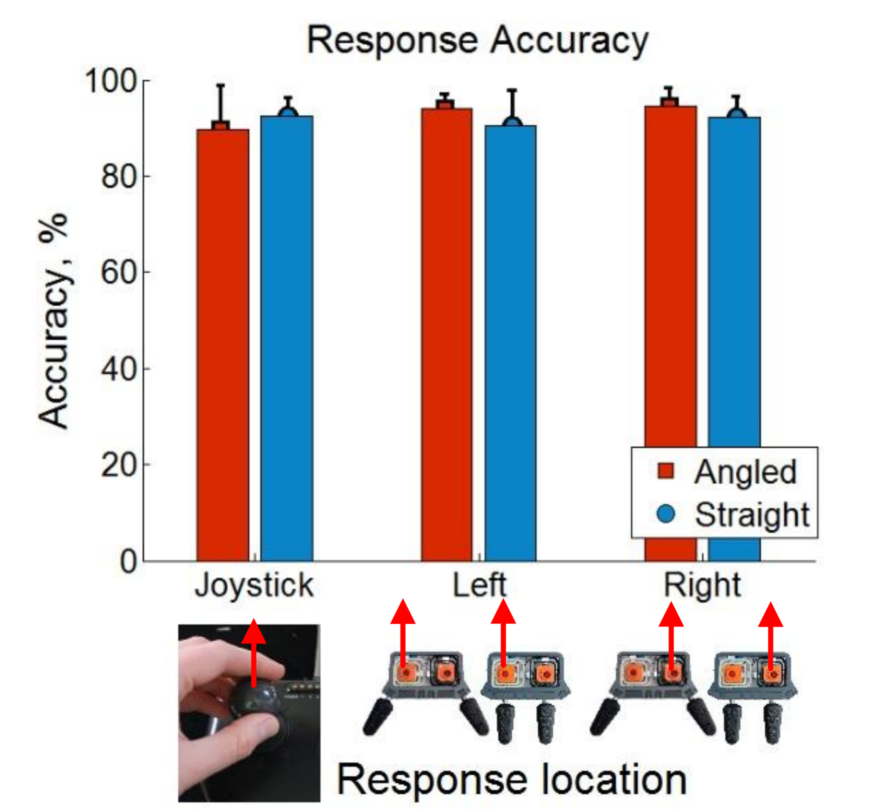
Cues were always rendered through the right thumb joystick, and there were three response modes.

For this experiment, direction cues were always applied through the tactor embedded into the right thumb joystick. Participants responded with their perceived direction using three response modes. In one response mode, participants responded with their left hand using a PlayStation joystick, which allowed us to compare our results to previous experiments, and provided a baseline for comparison for the other response modes.

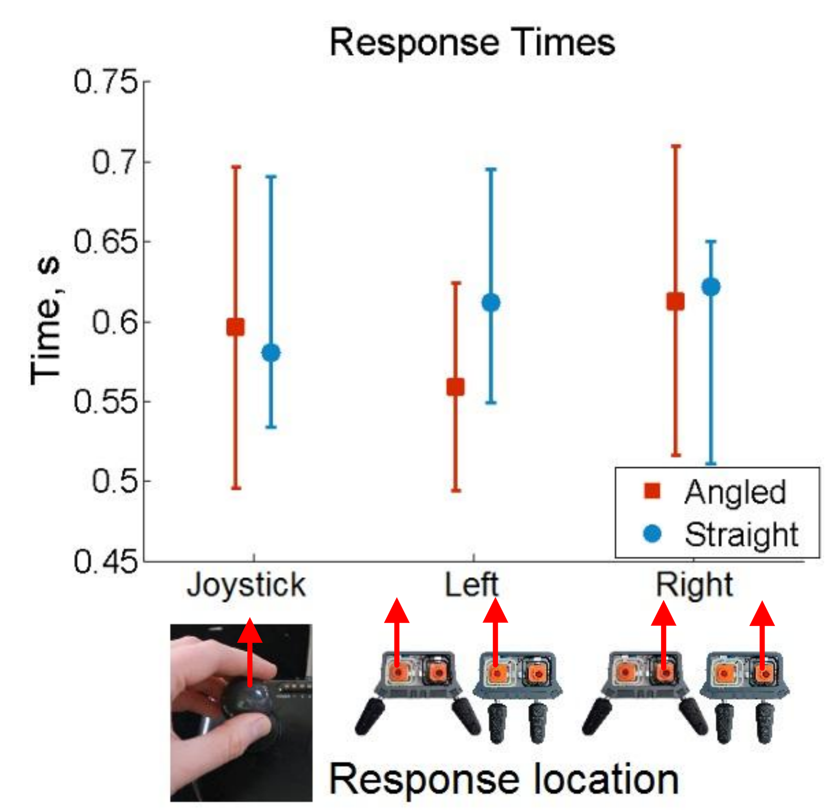
In another response mode, participants responded by tilting the left thumb joystick of the controller. A third response mode involved the participants responding by tilting the right thumb joystick, the same as where the cue was applied. Each participant responded in all three modes for each of the handle configurations (angled and straight), for a total of six test conditions.

Results

Response Accuracy: In all six test conditions, participants achieved high accuracy for their direction responses, with no test condition having an accuracy less than 89%. This percentage of correct direction responses is consistent with previous research [2], and indicates users are capable of accurately interpreting direction cues using our prototype game controller, regardless of handle configuration. There was no significant difference in accuracy performance for any of the six test conditions [F(5,66) = 0.53, p = 0.7537]. These results suggest that mental rotation of the tactile stimuli appears to have no significant affect on the participant's accuracy.



Percent accuracies exceed 89% in all six test conditions.



Mean response times for all six test conditions.

Response Times: The mean response time for the PlayStation joystick was 0.5767 s. This response time was similar to average times of 0.6049 s and 0.546 s found in previous experiments [3] and [4], which shows that user performance with the game controller is similar to that with prior skin stretch devices.

A one-way analysis of variance (ANOVA) shows no significant difference in participant response times between handle configurations [F(1,70) = 0.27, p > 0.60]. A direct comparison of the participants' PlayStation joystick responses for the angled and straight handles does show slightly faster responses when the handles are straight, but this difference is not significant. This indicates that mental rotation due to thumb orientation does not appear to impact response times (or accuracy), consistent with findings in [4]. Furthermore, faster responses with the thumbs in the angled handle configuration, while not statistically significant, suggests possible ergonomic advantages to the angled handle design. A one-way ANOVA with respect to response time shows no statistical difference between the participant response times for the three response modes within tests using the angled handles [F(2,33) = 0.46, p > 0.63] or within tests using the straight handles [F(2,33) = 0.41, p > 0.66].

Conclusions and Ongoing Work

Conclusions: The game controller that was designed and built is capable of providing tactile directional feedback to a user through its thumb joysticks. Response times and accuracies were similar to prior work which investigated multimodal direction cueing and mental rotation of skin stretch direction cues [2, 3, 4]. Our results indicate that thumb orientation does not influence a user's accuracy or reaction times (p > 0.60). These results suggest that future experiments should be conducted with a controller with angled handles, similar to current commercial game controllers. There appear to be possible ergonomic advantages to this design, observed in the slightly faster response times with angled handles, and there is no significant effect of mental rotation on response time or accuracy.

Ongoing Work: A new self-contained game controller has been created, which will permit further testing of effects such as stimulus masking. Experiments are in progress to determine if there are cognitive masking effects between stimuli rendered on the two tactile skin stretch displays, or between skin stretch and vibration feedback. We have also began to develop gaming environments to demonstrate the potential of this feedback in game controllers.

A self-contained game controller is used to demonstrate the full potential of skin stretch feedback in a game controller.

References

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