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Vibrotactor-belt on the Thigh – Directions in the Vertical Plane

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Introduction

Tactile displays introduce solutions to limitations in visual data processing, or malfunction in visual data perception [1].

Vibrotactile displays have been examined as:

- means to communicate spatial data, e.g., directional waypoint [2]
- guidance cues for target acquisition [3]
- threat marking areas to avoid or convey distance from a conceptual boundary (e.g., in helicopter or UAV landing) [4]
- alert for collision [5]

The most common locus for vibrotactile displays is the torso which maintains a good notion of direction in the horizontal plane [6]. The torso was also utilized to convey vertical spatial orienting [5] by applying vibrotactors on the shoulders and buttocks of the pilot.

Objectives

Our aim was to examine the thigh, as a potential locus for directional orienting, within the vertical plane when the operator is seated (Figure 1). Specifically:

(a) Examine the ability to locate a vibrotactile stimulation embracing the thigh.
(b) Determine which region along the thigh provided more accurate localization.
(c) Compare different burst durations and pulse repetitions which could later be utilized to encode information

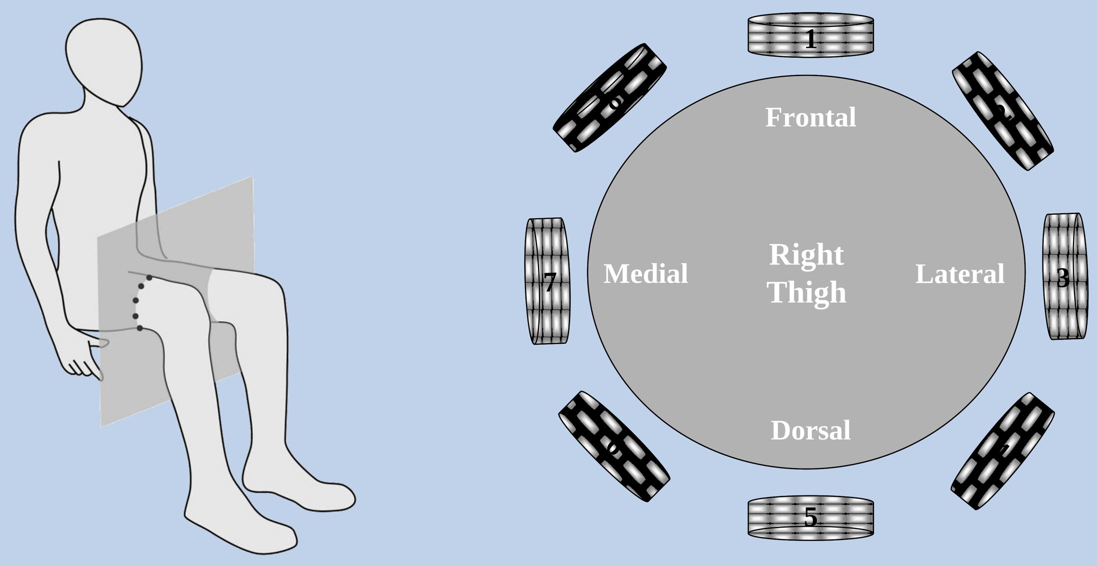

Figure 1. Left: Tactors on thigh convey orientation in the vertical plane.
Right: Mid-sagittal cross section of thigh (gray ellipse) and relative location of tactors (gray disks)

Method

Participants. Sixteen female and 25 male undergraduate students (age 22 to 30, mean 26.7).

Apparatus. Vibrotactor-belt* of eight C2 tactors stitched to an elastic fiber strip, 6 cm apart, regulated by the Eval2.0 controller (Engineering Acoustics Inc.). A touch screen was used as the response pointing device. E-prime2.0 was used for experimental design, execution and data collection (Figure 2).

*Prototype developed by a joint venture of Israel Aircraft Industries (IAI), Lahav Division and Ben Gurion University of the Negev (patent pending 11/968,405).

Design. A within-participants setup with three factors: Location of vibrotactor-belt on the thigh (close to the knee, middle of the thigh, and closer to the groins), Signal duration (200ms, 400ms, 600ms or 800ms), and Signal type (continuous at 250Hz, pulsed at 250Hz with 5Hz or 10Hz modulations).

Procedure. Once a tactor was activated. The participant pressed the matching virtual button on the touch screen based on her directional judgment. Each of the three thigh locations was stimulated in a separate block of 120 trials.

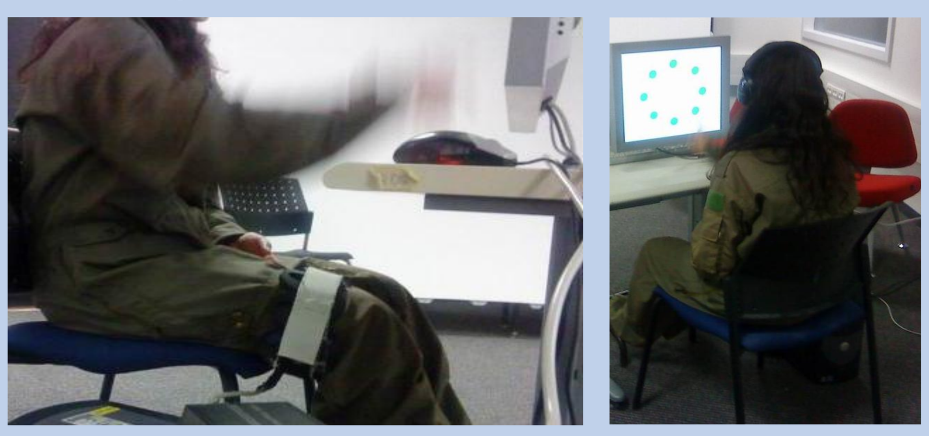

Figure 2. Left: Positioning of the participant and apparatus. Elastic tactile belt mounted on right thigh. Right: Virtual buttons (circles) displayed on the touch screen.

Results

Correct response rate across all tactors was 0.72. Correct response rate reached 0.985 when calculating the accuracy with a permitted error range of one distinct button to the left or right of the target button.

Location of vibrotactile-belt on the thigh affected response accuracy ($F(2, 78)=12.487$, $p=.00002$). Near the knee was found to be the most accurate location (correct response rate 0.78).

Signal duration affected response accuracy ($F(3, 117)=3.947$, $p=.01008$). The longer the signal - the more accurate the response (0.7 and 0.73 correct response rate for 200ms and 800ms, respectively).

The frontal (pointing up) and dorsal (pointing down) tactors (1 and 5) were significantly more accurate (mean correct response rate 0.860) than the diagonal tactors 2, 4 and 8 (mean correct response rate 0.775) ($p<0.001$). Tactors 2, 4 and 8 were significantly more accurate than tactors 3, 6 and 7 (mean correct response rate 0.627) ($p<0.001$), but insignificant within the group. (see Figure 3).

Subjective reports agreed that recognition of the orthogonal tactors (mainly frontal and dorsal) was easier than recognition of the diagonal tactors.

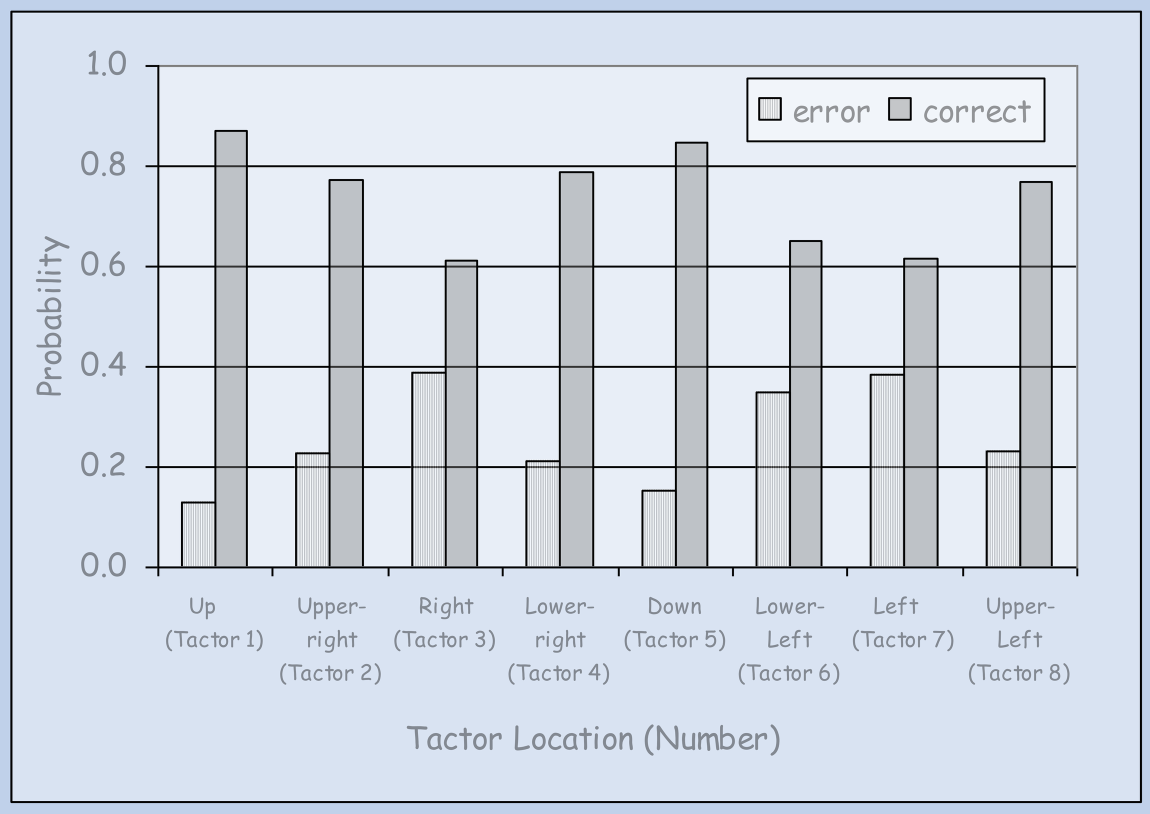

Figure 3. Correct and error response rate by tactor's position on the thigh.

Discussion

The thigh can be utilized for spatial orientation in the vertical plane, best perceived near the knee.

The frontal and dorsal tactors were perceived most accurately, medial and lateral tactors (3 and 7) were perceived least accurate, this resembled variation of accuracy found around the torso [6].

Tactile cues may provide benefits in enhancing general alertness and orienting attention toward the required direction, not necessarily in being highly punctual (overall correct response rate 0.985 if certain error tolerances are permitted)

Future directions

Examine whether vibrotactors' orienting signals are beneficial when accompanying the auditory and visual cues already assimilated in the cockpit, or when experiencing dynamic body posture and orientation changes which commonly occur during flight.

Examine the concept of a three dimensional orienting system for aviation and space vehicles.

Acknowledgement

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