Vibrotactile Targeting in Multimodal Systems: Accuracy and Interaction

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Abstract

Tactile displays can enhance virtual and real environments. Extending previous studies [2,3], we explored spatial localization of individual sites on a dense tactile array worn on the trunk, and their interaction with simultaneously-presented visual stimuli in an isomorphic display. Stimuli were individual vibratory sites on the tactile array or projected flashes of light. In all cases, the task was to identify the location of the target. In the multimodal experiment, observers were also required to identify the quality of a stimulus presented in the other modality (the "distractor"). Overall performance was affected by the location of the target within the array. Having to identify the quality of a simultaneous stimulus in the other modality reduced both target accuracy and response time, but systematic response biases were a function of the relative location of only visual distractors with tactile targets.

Introduction

This work examines the integration of tactile display targeting information with visual displays. Tactile arrays allow aircraft pilots to maintain attitude without visual cues [9], for navigation and orientation when vision is reduced and vestibular sensory signals are misleading, to hold stable rotary-wing hover [8], and to pilot high-speed rescue watercraft in conditions of reduced visibility [4].

Tactile technologies augment spatial awareness by enabling operators to appreciate information through non-visual sensory inputs, potentially decreasing perceptual and cognitive loads. Such displays do not have to be "looked at" - the provided information is always available regardless of gaze direction [7]. However, how such stimuli interact with those from other sensory modalities is still open to discussion [5,6]. This research evaluates targeting of tactile stimuli representing environmental events under conditions requiring the user to integrate tactile data with information from vision.

Procedures (Observers' Tasks)

Unimodal baseline and Bimodal test conditions:

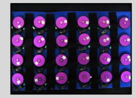
Unimodal: localize 200 msec 80 or 250 Hz bursts of vibration, or flashes of white, red, or orange lights at one of the 24 sites on their respective arrays

Bimodal: localize either bursts of vibration or flashes of light on one of the 24 sites AND identify the quality of a stimulus in the other modality presented at one of the 4 corners of the array

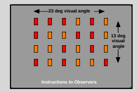
Apparatus

Two 4X6 element stimulus arrays: vibratory tactors and light flashes and an isometric response keyboard:

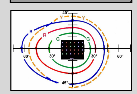
24 Engineering Acoustics Inc. C2 electromechanical vibrators on 50-mm centers on a Velcro belt



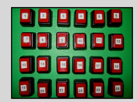
24 projected locations on a screen 200 cm in front of the observer in a dimmed room



The visual array was sized to fit comfortably within the visual fields of the retina for color [1]



24-button keypad for localization responses to stimuli presented in either sensory modality



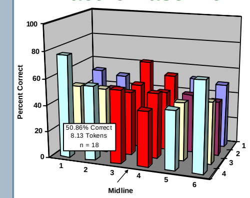
Results and Discussion

Eighteen student pilots from the Naval Air Station were tested in this bimodal study, in which either 1) the location of a vibratory stimulus in the array had to be reported, as well as the quality (color) of a visual (distractor) stimulus in one of the four corners of the visual array, or 2) the location of a visual stimulus was to be reported along with the frequency of a similar tactile distractor, also in one of the 4 corners of that array. Baseline unimodal localization was measured in each session, blocked by modality.

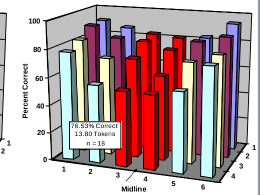
Baseline localization for tactile stimuli averaged 51% correct, while that for visual stimuli was 77% (next column). **When the locations of these target stimuli were identified in the presence of distractors in the other modality, performance dropped to 36% and 75%, respectively.** More interesting was the possibility that mislocalization might occur. Indeed, analyses of the response confusion matrixes for each target location showed interesting patterns, both in the unimodal baseline as well as in the bimodal test conditions, as shown to the right. First, the **response bias (how responses were distributed over possible loci) showed a body-referenced effect**, particularly with vibrotactile stimuli, in which errors almost never crossed the body midline, rather occurring in a direction to each side. When target loci were judged in the presence of a distractor, **tactile targets at the midline on the side closest to the distractor, were mislocalized towards the extraneous visual stimulus.** This effect did not occur for visual targets. These results indicate that visual capture of tactile locations occurs with dense tactile arrays.

Dense Array Localization Performance

Tactile Baseline



Visual Baseline



Localization of individual 200-msec bursts of 80 or 250-Hz vibration or red or orange flashes of light randomly presented to sites on the tactile or visual arrays.

Summary and Conclusions

Localization of brief static vibrotactile and visual targets was studied with dense arrays. When tested in the presence of simultaneous "distractor" events in the other modality, asymmetric effects were found. To insure attention to the distractor, subjects identified its quality while reporting the target locus in the other modality. Results show that overall tactile localization is impaired relative to unimodal baseline performance, although localization of visual stimuli is unaffected. Analyses of response biases showed a body-referenced effect, particularly with vibrotactile stimuli. First, errors rarely crossed the body midline. Furthermore, in the presence of a distractor, vibrotactile targets at ipsilateral midline sites were mislocalized towards the extraneous visual stimuli. This effect did not occur for visual targets. These results indicate that visual capture of tactile locations occurs within dense tactile arrays.

Literature Cited

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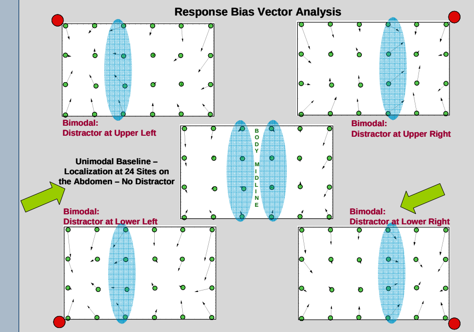
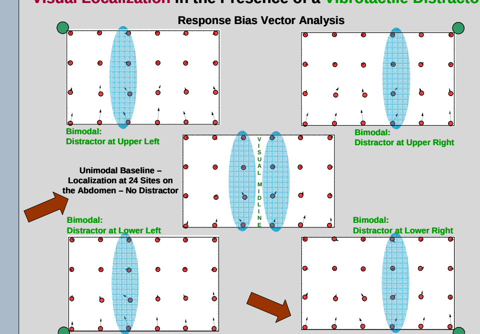
Responses Biases in Bimodal Localization

Vibrotactile Localization in the Presence of a **Visual Distractor**:



Visual Localization in the Presence of a **Vibrotactile Distractor**:



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