VIBROTACTILE 'ON THIGH' ALERTING SYSTEM IN THE COCKPIT

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Introduction

•The visual and auditory modalities are exhausted in the cockpit.
•Tactile modality generally requires little to no cognitive effort to analyze spatial directionality (1)(2)(3).
•Tactile displays introduce solutions to impending limitations in visual perception and processing in the cockpit (2)(6)(7).
•Salzer, Oron-Gilad and Ronen (2011) proposed the thigh as a potential platform for orienting in the vertical plane (see Figure 1).

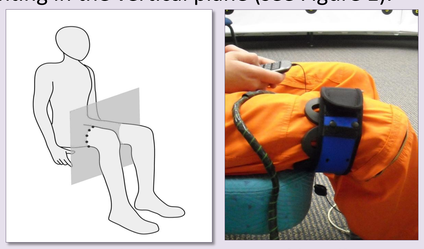

***Figure* 1**. Orientation in vertical plane created by vibrotactors mounted on the thigh (illustration and in-practice).

•Two contradicting tactile displays design approaches : a) compatible; the location of the tactile cue compatible with the response's direction, (i.e., aiming away from the source of hazard). b) inverse; the location of the tactile cue directs which direction to avoid.
•Tactile compatible cues were preferred (4). Yet, advantages for adding tactile alerting cues over the visual alerting alone were not found, probably because alerts were examined in a quiet environment with no additional cues or noise.

Objectives

To examine the utility of the vibrotactile cues in a loaded environment. Once the visual modality will be more loaded, it is hypothesized that advantages for the tactile alert display will emerge. It is also expected that the benefit of the compatible mode versus the inverse mode will remain.

Method

Participants. 5 female and 5 male undergraduate students (age 24 - 29).

Experimental system. Vibrotactor-belt* of eight C2 tactors stitched to an elastic fiber strip, regulated by the Eval2.0 controller (see Figure 2). The belt is worn on the right thigh over a pilot suit. A designated program in E-prime2.0 activated the experimental procedure and displayed the visual alerts on a screen. It controlled also a second PC used for playing the simulated flight path on a dome projection screen allowing a field of view of 60°. A 19" screen was placed on a table in front of the sitting participant, behind it, clearly visible was the dome projection screen. Responses were collected by a standard keyboard.

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

***Figure* 2**. The Vibrotactor belt and the Eval2.0 controller.

Tactile directional alert cues. Each of the vibrotactors represented one of the eight directions. The vibrotactile stimulus was a continuous 800ms pulse at 250Hz.

Visual directional alert cues . A compass rose was displayed on the 19" screen. The visual cue was a black arrow in the center of the compass rose pointing towards one of the eight directions; up, down, left, right and four diagonals (see Figure 3).

Flight movies and flying objects. Five movies of a flight path, accompanied by the sound of a helicopter, were allotted randomly to each block. Occasionally, red and yellow objects appeared flying toward the viewer, i.e. the flying aircraft (see Figure 4).

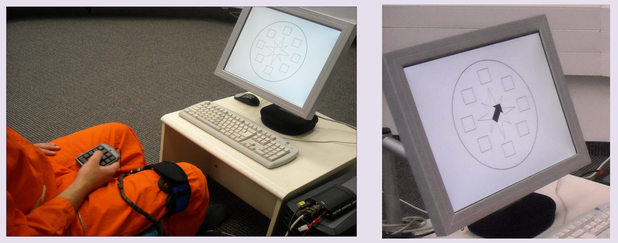

Figure 3. Left: The experimental system . Right: The visual directional alerts cues.

Design and Procedure

Two within-participant variables; visual cues (2; present or not), and tactile display mode (2; compatible or inverse). A visual-only block was used as a baseline. Participants performed two simultaneous tasks; 1) count and remember until asked the number of red objects in the movie. The question appeared at unexpected intervals within the block; 2) to respond accordingly to the spatial visual and/or tactile cues. Participants completed a practice blocks prior to each one of the five experimental blocks. Feedback was provided only in the practice trials. Upon completion of each block the SWAT was administered.

Figure 4. The projected environment of the flight path. The red object is marked for emphasis.

Results

Table 1- Response Time (RT) and Accuracy (ACC) by Modality and Tactile configuration.

		Tactile Blocks				Visual Block
N=10		CT	CTV	IT	ITV	V
RT(ms)	Mean	1367	872	1368	1085	864
	SD	158	61	122	134	197
ACC	CRR	.76	.98	.66	.96	.98
	SE	.027	.008	.080	.020	.009

T=compatible tactile, CTV=compatible tactile+visual, IT=inverse tactile, ITV=Inverse tactile +visual, V= visual only, CRR=correct recognition rate

Visual Loading Task

Performance was worse in the visual-only condition, 50% of the participants failed to identify the correct number of objects. Performance was perfect in the tactile-only condition (IT), implying perhaps on the toll of visual load to task performance when visual alerts were present.

Performance on the Spatial Alerts

Response Time. At the presence of visual cues, RT was significantly lower (visual present M=978 ms SD=322, not M=1367 ms, SD=158). No significant difference between compatible and inverse or between V and CTV (F<1).

Accuracy. Correct recognition rate (CRR) for compatible tactile mode was significantly higher than inverse (CRR=.93, SE=.02, CRR=.87, SE=.03). The presence of visual cue significantly improved CRR (CRR=.97, SE=.01, CRR=.71, SE=.05). CRR was equally good with/without tactile cues when the visual cue was present.

Workload (SWAT) [1-3]

An effect for experimental block was only found in the time dimension. Combined conditions, both CTV and ITV were perceived as most temporally demanding. Mean ratings; 1.4 for IT, 1.5 for CT & V, and 1.7 for CTV & ITV.

Discussion and Conclusions

- The advantages of adding tactile cues became apparent in the loading task where the worse performance was found in the visual only condition, indicating that participants had difficulties in attending to two visually displayed tasks simultaneously.
- The CTV condition generated the best performance on the alerts, but was not better than the CT or IT conditions in the loading task, indicating perhaps that the presence of visual alerting cues may have disrupted performance on the loading task, or vice versa. The benefits of the tactile cues with regard to the two tasks were most notable when compared with the visual only mode (V).
- The SWAT temporal scores confirmed that while the presence of visual and tactile cues combined was beneficial in the loaded environment in terms of overall mission performance, CTV and ITV conditions generated higher perceived temporal workload.
- Compared to the low-demanding environment where only the directional alerts existed (4), the loaded environment generated longer response times, as expected. Yet, accuracy ranges remained unchanged.

To conclude, the presence of tactile cues helped to maintain balance between the two tasks. Namely, the tactile cues contributed to improve situation awareness in the visually loaded environment.

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