Providing Directional Information with Tactile Torso Displays

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Abstract. Tactile torso displays convey information by presenting localised vibrations to the torso. Since these stimuli are directly mapped to body coordinates, tactile displays are able to present 3D spatial information in an intuitive way. This paper (1) provides a short description of the tactile torso display that we developed, and (2) gives a brief overview of a simulator study on the usefulness of tactile torso displays in maintaining a stable hover with a helicopter. The results prove the potential of intuitive tactile torso displays in reducing drift during hover, and – more generally – prove that tactile displays can be applied in fast man-in-the-loop tasks. The demonstration during Eurohaptics 2003 will consist of our tactile torso display connected to a helicopter flight simulator.

1 Introduction

Tactile torso displays consist of numerous vibrating elements attached to the torso in a matrix arrangement. Such displays are showing great potential for application in man-in-the-loop tasks. Of particular importance is the finding that these displays are able to communicate directional information to the wearer in a very intuitive way [1-5]. For instance, [4] showed that consistency of perceived direction varies with the location on the vibrating element on the torso and can be as good as 4° or better in the frontal directions.

Applications of tactile torso displays in aircraft cockpits have received a lot of attention recently. [5] examined the possibilities of tactile information presentation in the cockpit, including the possibility of a tactile directional threat display. They also supplied data showing that vibro-tactile perception is not substantially impaired during high G-load conditions, such as experienced in fighter jets. [6-7] showed that tactile torso displays can be used to support helicopter hover operations. [8], and more recently [9], proved the potential of such displays as a countermeasure for pilot spatial disorientation (also see [10]). Other studies are projecting these results onto other domains, such as countering diver disorientation, and providing a reference orientation to astronauts performing missions in microgravity environments [11,12].

In this paper we describe the Tactile Torso Display that we have used in several of the above mentioned studies. We also provide a short glance at part of a helicopter hover study that was reported in more detail in [7].

2 Method

Fig. 1. Tactile Torso Display. The subject is showing the inside of the vest.

Fig. 2. View at part-task helicopter simulator showing NVG imagery.

Tactile Torso Display

We have developed a tactile display consisting of up to 128 vibrating elements (tactors) attached to a fleece vest (see **Fig. 1**). The custom build tactors are based on DC pager motors that are housed in a PVC contactor with a contact area of 1.5 by 2.0 cm. They vibrate at a frequency of 160Hz, stimulating mainly the Pacinian Corpuscles in the skin. An electronics unit attached to the back of the vest connects the tactors with the parallel port of a standard PC. Special purpose software allows for individual on/off control of each tactor at up to 250 Hz update rate, but in practice the DC motors take a finite time to start and stop and the effective update rate is down to roughly 50Hz. The tactors can be arranged in different ways; in the experiment described below there were 12 columns and 5 rows (equally distributed between the navel and the nipples), plus a tactor on each shoulder and between the seat of the chair and each thigh. The vest can be used in two modes: (1) stand-alone, in which pre-programmed stimulation patterns can be played to the vest, and (2) in-the-loop, in which the pattern of stimulation depends dynamically on external parameters.

Helicopter Hover Support Study

The degraded visual information when hovering with Night Vision Goggles (NVGs) may induce drift that is not noticed by the pilot. To investigate whether a tactile torso display can help to compensate for such degraded visual information, we tested the possibility of counteracting these effects by using a tactile torso display in-the-loop.

The display presented information on the desired direction of motion only (simple version), or also included information on the current motion direction (complex version). Desired direction of motion in the horizontal plane was indicated by activating a single tactor on the middle row; desired direction of motion in the vertical direction was indicated by activating either both shoulder tactors or both seat tactors. Tactors were activated in a 100ms ON – 200ms OFF pattern for position errors between 1 and 5m, and 50ms ON – 100ms OFF for errors larger than 5m. Current motion direction was indicated by a five-step movement stimulus along two sides of the body in the direction of the motion. Tactors were activated in a 100ms ON – 200ms OFF pattern for speeds between 0.1 and 1m/s, and 50ms ON – 100ms OFF for speeds higher than

1m/s. All three type of activation could be presented in parallel, when the situation required such.
Twelve paid participants (students of the Royal Dutch Airlines Flight Academy KLS) flew scenarios in a fixed-base helicopter simulator consisting of three phases: hovering, low level flight, and hovering again. During a scenario they either had full vision or flew with simulated night vision goggles (NVG condition, see **Fig. 2**). We manipulated the (cognitive) workload by adding a secondary task (auditory continuous memory task, CMT) during the second half of each phase. This was done to investigate the claim that tactile displays are 'intuitive', which implies low level information processing. The experimental design, therefore, can be described as a combination of three independent variables: vision (full / NVG) x tactile display (none / simple / complex) x CMT Phase (before / during). We calculated the position error during the hovering phases separately for the horizontal and vertical directions. Performance on CMT was measured by the reaction time and the percentage correct.
Participants came in pairs for a full day. The morning was spent on training and familiarization. In the afternoon they both flew three blocks of two 13-minute runs each.

3 Main Results

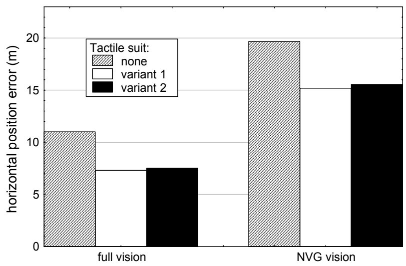

Fig. 3. horizontal position error for full vision and reduced (night) vision conditions.

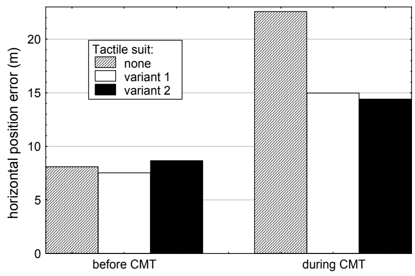

Fig. 4. horizontal position error as a function of the presence of the CMT task.

The results showed performance improvement for both tactile display variants [variant 1 = simple; variant 2 =complex] compared to hovering without a tactile display (see Fig. 3; main effect of tactile display type on horizontal position error; $F(2,22)=5.88$; $p=0.009$). This improvement was present in the NVG conditions (mean reduction of the position error of 22% in the horizontal direction and of 41% in the vertical direction [vertical data not shown in graphs]), but also in the full vision condition (mean reductions of 32 and 63%, respectively). Also, performance with a tactile display is less affected by the introduction of a secondary (cognitive) task than performance without a tactile display (see **Fig. 4**; interaction effect of tactile display with CMT on horizontal position error; $F(2,22)=45.67$; $p=0.001$). Performance on the CMT task was independent of condition.

3 Conclusions

The simulator study proves the potential of intuitive tactile torso displays in reducing drift during hover. The display is so effective that it even results in performance improvement in full vision conditions, apparently without increased cognitive load. Furthermore, the results prove that tactile displays can be applied in fast man-in-the-loop tasks.

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