Chapter 7 – TACTILE DISPLAYS IN MILITARY ENVIRONMENTS: CURRENT STATUS AND FUTURE DIRECTIONS

by

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7.1 INTRODUCTION

The challenging environments encountered by military personnel require the Human Factors community to constantly search for innovative concepts to improve the interaction between soldiers, equipment, and information. The last 15 years, several groups within NATO started researching the use of tactile displays – displays that use the skin to present information. The primary motivation behind this research is the threat of overloading the eyes, ears and minds of soldiers (whether trained pilots or inexperienced dismounted soldiers) through the ever increasing need to communicate data from information systems. Several theoretical models substantiate the claim that tactile displays can potentially lessen the threat of sensory and cognitive overload. By using the skin as an information channel, a tactile display can reduce the overload of other sensory modalities such as ears and eyes. For example, a localised vibration on the torso can serve as a 'tap-on-the-shoulder' to provide local guidance information. Such information is processed intuitively, which reduces the risk of cognitive overload.

Given the current progress of technological developments and operational concepts regarding the use of tactile displays in military environments, a strong and combined effort of NATO countries was considered important. The NATO RTO HFM Task Group 122 therefore focused on the unique human-system issues associated with effective applications of tactile displays in military environments. Some of the issues included in this report are hardware/actuator technology, perception and psychophysics of touch, interface and coding standardisation, operating concepts, and integration issues.

The often combined efforts of the research groups involved in tactile displays have resulted in a growing body of evidence that tactile displays can indeed be a valuable addition to existing interfaces. Lab studies and several field studies have shown that tactile displays can improve performance and lessen workload. In general, favorable effects were found in the following tasks:

- Navigation;
- Vehicle control;
- Orientation;
- Detecting unexpected events;
- Time critical tasks; and
- Directional warning and attention allocation tasks.

These favourable effects have been noted in the following environments and situations:

- Rotary and fixed wing aircraft, armored vehicles and high speed boats;
- Under Spatial Disorientation evoking conditions;
- Under high G loads and in microgravity;
- During night operations;
- Under high workload conditions;
- In high vibration environments;

- Under water and airborne; and
- During remotely piloted operations (e.g., UAVs).

The successful applications mentioned above are only with regard to military applications – many other tactile displays have been used with automobile driving, gaming and virtual reality, and aids to people with visual impairments. These applications all confirm that tactile displays can be used to greatly improve spatial orientation, navigation, and even communication. The growing interest in other application areas may result in an interesting spin-off and spin-in of knowledge and technology. Recently, several new application domains were added, including sports, gaming, and team coordination.

7.2 FUTURE AREAS OF RESEARCH

Most of the current data on tactile displays have been gathered in controlled lab experiments and relatively simple field studies. The promising results from these trials warrant large scale testing under operational circumstance during prolonged periods. The shared opinion of experts is that the technology is on the verge of introduction into operational environments. Despite this observation, there is also a need to continue work on more fundamental issues that have not been solved yet. Introducing tactile displays into operational environments requires investigating a number of issues.

7.2.1 Coding and Standardization

The algorithm used to code information on the tactile display must be intuitive to the user. Different codings have been used in helicopter hover displays to display virtual corridors and to display self motion. This brings up the question that has been discussed in the visual display community for years – should we use an inside-out or an outside-in display? Although no one has systematically investigated this issue, anecdotal evidence indicates that there is no population preference for one algorithm over the other in the helicopter hover task. The preference is about 50 – 50, which also means that the chosen coding will not be the most intuitive for half of the population. Also, switching between different coding algorithms may result in problems (such as those experienced by pilots that transferred from an outside-in to an inside-out coding of the artificial horizon). This suggests that we should develop a coding that can either be adjusted to user profiles or preferences, or that is standardised across applications, countries and manufacturers.

7.2.2 Limitations of Intuitive Displays and Tactile Clutter

Although the skin is able to process large amounts of information (people who are trained in Braille can actually read with their fingertips), there is a trade-off between the amount of information and the intuitiveness of the tactile signals. Braille reading consumes a large amount of cognitive resources, as does reading with the eyes. That is, a high tactile information transfer rate usually yields codings that are not intuitive and require considerable training. Van Erp introduced the term tactile clutter to describe a situation where displaying multiple signals in parallel on a tactile display results in difficulties interpreting them. Apart from the possible spatiotemporal interaction of individual signals, some form of processing or (spatial) attention may be required to separate the different elements of information, or to track one signal and ignore a second. The limitations to present more complex messages with tactile displays become a relevant issue in, for example, presenting global awareness information. In these situations, it may be beneficial to limit the function of the tactile display to drawing the user's attention to a message or map displayed on a visual display.

7.2.3 Multimodal Integration

A tactile display will rarely be used in isolation, but instead in a combination with visual and/or auditory displays in a multimodal setting. This raises many issues, including how much information will cause

cognitive overload, how to calibrate touch with other modalities in space and time, and how to allocate information to the sensory modalities. In a simple multimodal interaction approach, information would be displayed redundantly via two or even three modalities. In general, this approach may result in faster reaction times and lower workload. A more complex approach than presenting information redundantly is to make the information from the different modalities complementary. In such an approach, there may be costs involved. For example, there are costs involved in switching attention between the different senses.

7.2.4 Hardware Development

Like in any new technology, tactile hardware will need to undergo many iterations before it is available for widespread operational use. Current hardware systems are mostly research oriented, and no hardware that has been field tested is available on a large scale. Developments are required in areas such as miniaturization, weight, cost, power consumption and methods to incorporate tactors into seats, harnesses, and other current equipment. Also, tactor measurement and evaluation protocols should be developed.

7.2.5 Miscellaneous Research Issues

In the previous sections we mentioned several issues (e.g., tactile clutter, multimodal integration, and coding standardization) that were discussed in this report but still require additional research. We can add the following important issues:

- Age-related effects. Most experiments described in this report were run with participants from a relatively young population. However, not all military personnel are below 30 years of age. Important aspects in the design for older users include: thresholds and spatial resolution (in general, the processing of tactile stimuli will degrade with age), learning skin-hand coordination, and trust in the system.
- Psychophysics under different stressors, including high workload and different environmental factors (e.g., extreme temperatures, G-load, vibration).
- Perceiving vibrotactile signals in a vibrating and other stressful environments. Real world applications are closely related to the psychophysical perception in different environmental conditions. There is no systematic knowledge available on tactile perception as a function of real world aspects such as vibrating environments, clothing, pressure, temperature, etc.
- Algorithms to aid the user in switching on the tactile information. Continuous stimulation may result in adaptation and habituation effects, and may even annoy the user. The decision when the display should be switched on then becomes relevant.
- The risk and effects of tunnelling in relation to sensory modality and prolonged use. The use of tactile displays has been suggested as a means to prevent attention tunnelling in the visual and auditory domains. A tactile signal can serve an alerting function to break attentional fixation. There is a risk that with prolonged use of tactile displays, there may also be attention tunnelling. Adaptation and habituation effects may contribute to this, which may cause the user to miss important tactile information.
- Multifunction tactile displays. Tactile displays are primarily designed and tested for one application in isolation. Visual displays are rarely designed for a single function – tactile displays will also usually need to serve more than one purpose. In a multifunction tactile display, the user must be able to discern which function is being displayed. Methods for separating functions in tactile displays (such as sequential separation, spatial separation, sensational separation, and the use of icons and multimodal cues) must be further developed.
- User acceptance. As with any system, user acceptance will ultimately determine the usefulness of tactile displays. The systems must be intuitive, accurate, reliable, and require a minimal amount of

training. Comfort is also a major requirement, particularly since some wearers report that certain tactors can feel ticklish or even annoying. Integration into current equipment is also important, as military members prefer not to don yet another piece of equipment.

7.3 CLOSING REMARKS

Overall, we conclude that data described in this report are important evidence that using the tactile modality in military environments can improve performance and lessen workload, thereby improving the quality and safety of the man-machine-interface and the operational effectiveness of military personnel.