The Use of Tactile Navigation Displays for the Reduction of Disorientation in Maritime Environments

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Summary
The maritime environment can be difficult to navigate in, due to poor visual cues, leading to disorientation and the potential for operational failure. The sense of touch is often overlooked as a mode of information display, but is ideally suited to providing intuitive navigation cues. Tactile cues provide a potential method to overcome these visual limitations and provide an alternative mode of displaying information from the more common visual and audio mediums. The QinetiQ Centre for Human Sciences have developed a Navigation Tactile Interface System (NTIS) that displays navigation cues through the highly intuitive sense of touch. This has been demonstrated in high-speed boats by the setting of the blind world water speed record with the use of the QinetiQ NTIS, and underwater by the US NAMRL Tactile Situation Awareness System which allowed divers to successfully complete a navigation exercises using only tactile cues. Therefore, tactile navigation displays have the potential to reduce disorientation in maritime environments and improve operational performance.

INTRODUCTION

The maritime environment (both on and underwater) can be a harsh location for humans to function. Maritime military operations are often conducted in conditions of poor visibility (e.g. at night, in fog, and in turbid water), or poor sea conditions (e.g. sea state 4/5). This can make accurate navigation difficult, lead to disorientation and ultimately failed operations. Traditionally, navigation is a visual task, although cues may be provided through spoken instructions. Recently, the effective presentation of navigation cues via the sense of touch have been developed. Tactile cues have the potential to overcome the limitations of visual and aural cues, which are compromised by poor visibility and noisy environments. Covert operations require minimal visual and aural signatures and therefore further reduce the use of visual and audio cues. This paper discusses two military maritime scenarios requiring accurate navigation; the use of High-Speed Insertion Craft (HSIC) and Very Shallow Water (VSW) Mine Counter Measures (MCM) diving, and how tactile navigation cues may enhance orientation.

MARITIME HIGH SPEED INSERTION CRAFT

Operational issues

The potential for becoming disorientated during clear daytime navigational exercises in calm conditions, with access to modern electronic navigation aids, would appear to be difficult to comprehend. Military HSIC are required to operate at night and in poor sea conditions (>SS5) and weather conditions/visibility (e.g. fog and mist). Coxswains are therefore required to navigate accurately and maintain effective control of the craft in all conditions. Craft motion, including high levels of shock and vibration, reduces the crews ability to operate the boat, e.g. high force impacts of over 20g. Also, boat vibration in the 3 – 12 Hz range will elicit vibration within the human body further reducing the ability of the coxswain to navigate the required course.

Tactile navigation cues

The provision of non-visual navigation cues can overcome the limitations of visual cues. These cues may be obscured, and difficult to interpret and comprehend when operating in poor sea conditions. Navigation cues

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provided via the sense of touch are a highly intuitive alternative to visual and aural cues. The QinetiQ Centre for Human Sciences has developed a Navigation Tactile Interface System (NTIS) that has been used to navigate a range of craft at speeds of up to ~ 70 knots. The most effective demonstration being the establishment of the blind world water speed record.

Navigation concepts

The NTIS interprets Global Positioning System (GPS) output data to provide the navigation cues. From this data two navigation concepts have been developed.

Concept 1: *Virtual corridor*

The NTIS constructs a virtual corridor, around the direct line between predetermined way-points. The perpendicular distance that the craft is away from this direct line is known as the cross track error. The width of the virtual corridor is therefore the maximum acceptable cross track error. The corridor width is predeterminable for specific applications, e.g. long distance transits may use a relatively wide corridor, whilst the blind world water speed record used a very narrow corridor. The NTIS initiates a tactile cue (analogous to a tap on the shoulder) when the crafts crosses the virtual corridor boundary (i.e. the cross track error exceeds the predetermined criterion), analogous to driving off the side of a road and onto a rumble strip. The tactile cue is active until the operator returns to within the confines of the virtual corridor. This concept is outlined graphically in figure 1. The tactile cue can be transmitted in one of two ways, either to the side of the body that crosses the corridor wall (analogous to bumping into the corridor wall), or the cue is initiated to indicate the direction of the course correction required (i.e. if the right shoulder was tapped the individual would turn to the right).

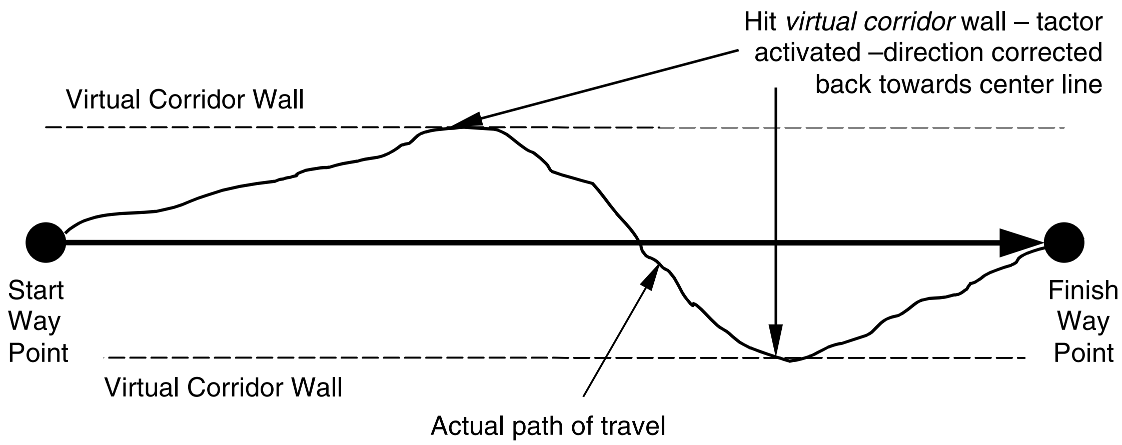

Figure 1. A graphical representation of the QinetiQ Navigation Tactile Interface System *virtual corridor* operating concept

Concept 2 : *Way-point direction indicator*

The NTIS determines the difference between the crafts heading and the direction of the target way-point. The magnitude of the tactile cue is then dependant on the magnitude of the difference between these. The greater the angle the greater the signal magnitude, i.e. if the craft is heading directly towards the way-point there will be no cue, whereas if the craft is travelling away from the way-point there will be maximum tactor activation. The magnitudes of the tactile cues are directly related to the magnitude of the angular difference. This concept has the advantage that the craft may detour from the anticipated track if required, whilst the coxswain knows in which direction the target way-point is. An example of how this concept operates is shown below in figure 2.

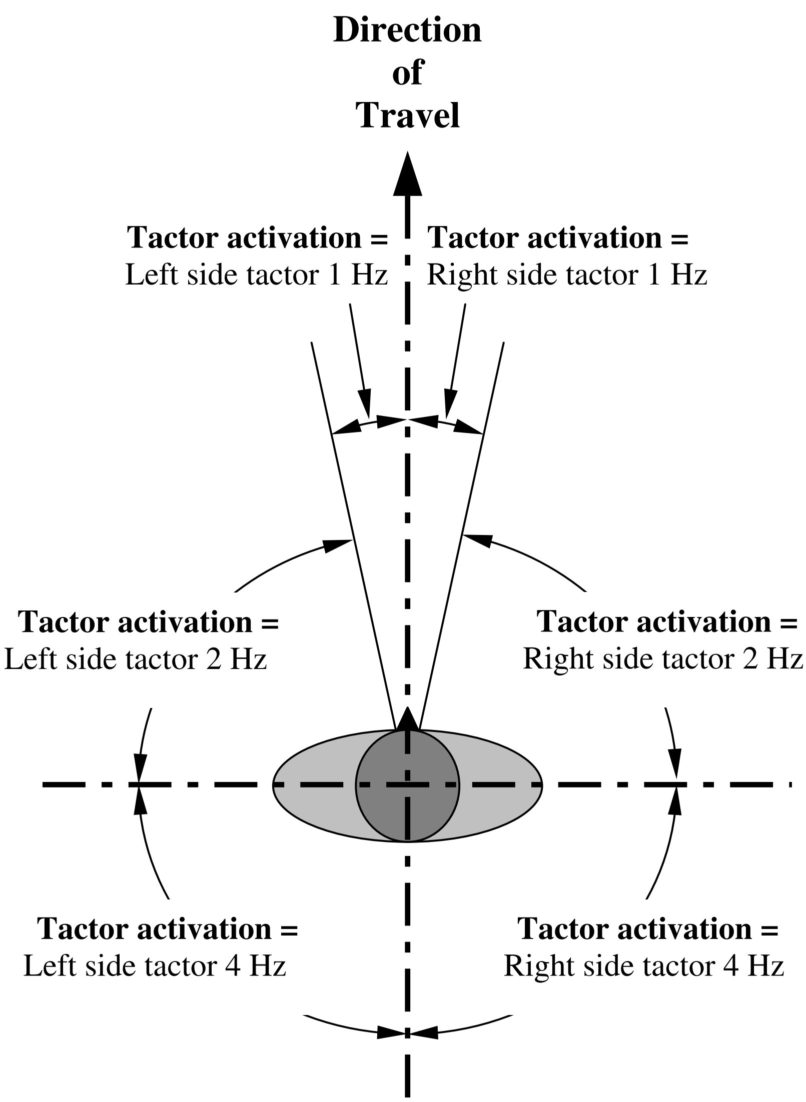

Figure 2. A graphical representation of the QinetiQ Navigation Tactile Interface System *way-point direction indicator* operating concept. Tactor activation occurring when the target way-point is not on the direct line of travel.

World Blind Water Speed Record

As part of a programme of increasing the public's awareness of blind people's abilities, Steve Cunningham established a world blind water speed record in 2000. The QinetiQ Centre for Human Sciences provided assistance for this record by providing the NTIS to increase the driver's level of autonomy. The boat used for the record attempt was a V24 'bat boat' (Ocke Mannerfelt Design), see figure 3. The design is relatively stable for a high-speed powerboat, particularly in rough water conditions. It also allows the driver and co-driver to sit alongside one another, both of which were required for a blind speed record attempt. The tactor location used for the record attempt was under the leg straps of the 6-point restraint harness used in the boat. This location provided an effective tactile stimulus whilst allowing the occupant unrestricted egress from the cockpit in the case of an emergency. The weather for the 1st attempt was poor, with a sea state of 4/5 and winds gusting to force 6. This meant that the highest average speed was only 50 mph. A second attempt was made a month later where there was minimal wind and calm water. An average speed of 73 mph was recorded, approximately ½ mph less than the sighted speed record for the V24 boat design. The use of the NTIS in establishing the blind world water speed record demonstrated that tactile cues can effectively increase the level of autonomy that blind and visually impaired people can obtain using this technology. Similarly the effectiveness and safety of sighted people may also be enhanced by the use of tactile displays.

Figure 3. The V24 power boat used to establish the Blind World Water Speed Record during the 1st attempt in conditions of sea state 4/5.

Further research

Many current tactor designs rely on vibration to provide tactile cues. Most military platforms have inherent vibration and this is particularly true of HSIC. The influence of platform vibration on tactile perception is currently unknown although there is limited anecdotal evidence on which to work from. The QinetiQ Centre for Human Sciences is undertaking a programme of work to investigate this area.

VSW MCM Diving

Operational requirement

Divers conducting future VSW MCM operations will be required to simultaneously navigate, and monitor mine detection sensor displays (e.g. sonar), whilst operating in turbid water conditions. This may be achieved using equipment such as the QinetiQ Diver Reconnaissance System (DRS), see figure 4 below. The diver must be capable of operating in conditions of very low visibility, therefore visual information will need to be presented via a head mounted display. QinetiQ trials have indicated that divers may have difficulty in navigating and searching simultaneously using visually displayed information. Subjective feedback suggested that this was due to an overloading of cognitive work capacity, and non-optimal screen symbology. Therefore a reduction in the information displayed visually to the diver is likely to improve operational performance. The presentation of navigation cues by the sense of touch is a concept through which diver performance may be enhanced.

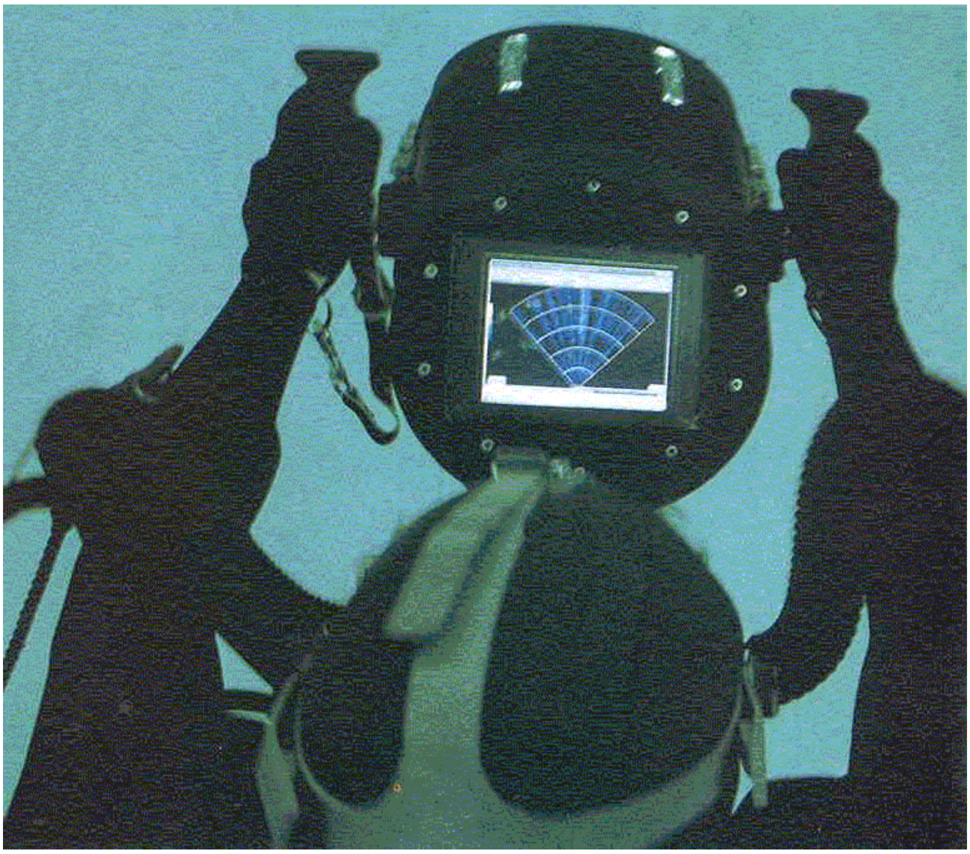

Figure 4. The QinetiQ Diver Reconnaissance System being used by a Royal Navy diver

Diver tactile navigation cues

Tactile navigation cues can be highly intuitive and in particular circumstances may be preferable to visual or audio cues. An example of this was the successful demonstration by the US Naval Aviation Medical Research Laboratory, Tactile Situation Awareness System (TSAS) programme of diver navigation in the VSW environment using a tactile navigation system interfaced to the Swimmer Inshore Navigation System (SINS). The divers navigated a triangular course, in good visibility, with position data being stored within the SINS and then downloaded after each trial. The navigation cues were provided visually or via tactors attached to the divers wrists. General observations indicated a similar cross-track error between using visual or tactile cues. Subjective feedback from the divers suggested that tactile cues may be more effective than visual cues. Example data is shown in below in figure 5 which compares the navigation tracks of diver using visual and tactile cues.

From the results of the SINS/TSAS trials and subjective evaluations it was concluded that:

- Tactile cues were an effective alternative, or enhancement to visual displays.
- Underwater navigation cross-track error (deviation from the baseline navigation course) was insignificant for both the visual only, and tactile displays.
- The majority of divers felt that the tactile display was easier to use, provided enhanced navigation, and preferred the tactile display over the visual only display.
- All divers indicated that operational navigation capabilities could be enhanced with tactile technology.

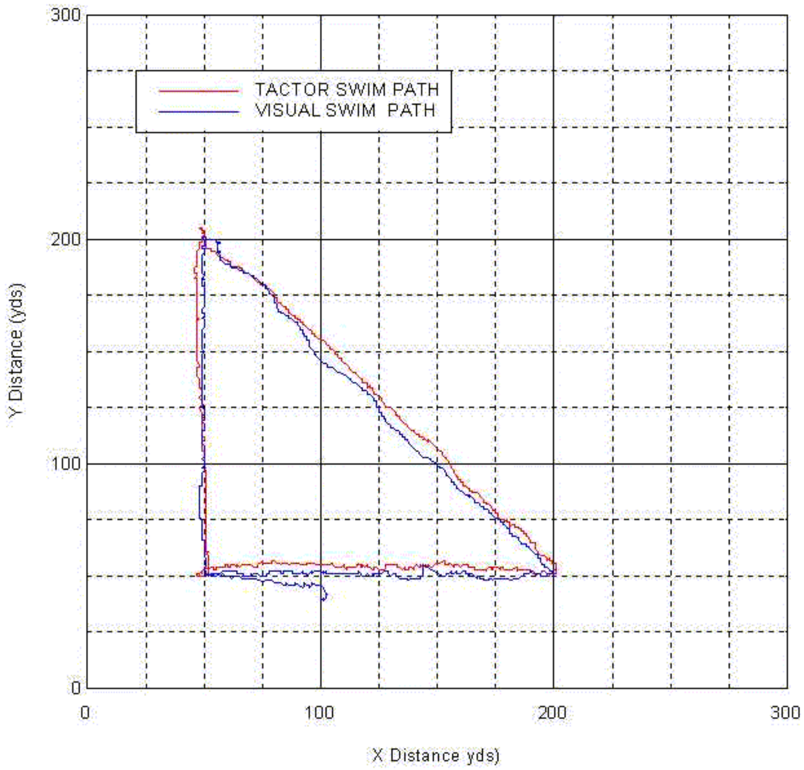

Figure 5: Example of diver navigation around a triangular course using either visual or tactile cues from the Swimmer Inshore Navigation System (SINS).

Further research

The concept of the QinetiQ DRS is a self-contained system, therefore tactile cues are presented through the DRS handles as opposed to independent tactors attached to the wrists as used on the SINS/TSAS system. Current research is establishing the optimum tactile presentation scheme, and particularly its integration with the visual sensor display to minimise cognitive workload. This may allow divers to effectively navigate and search simultaneously.

CONCLUSION

The trials conducted demonstrate that the concept of tactile navigation displays can be effective at improving navigational accuracy in hostile maritime environments. Further research is establishing the human factors that underpin the effective development of tactile interface systems such as the intuitive presentation concepts of navigational cues, the optimisation of the tactile communication devices (tactors), and the application specific requirements of individual platforms/vehicles.

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