Combat Coordination Using Peripheral Tactile Display

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ABSTRACT
The purpose of this paper is to perfect a wearable tactile display that can provide rapid response and group coordination for infantrymen-foot soldiers. Vibro-Tactile displays are devices that convey information to a person through the sensation of touch. This is achieved by using electromechanical actuators such as vibrators that are mounted in clothing or belts that hug the body. By activating the actuators in different patterns, the user can recognize these patterns as commands. This paper proposes an extremity worn tactile display concept that provides information regarding gunshot localization to the user in a prompt manner to enable rapid response to a threat.

Keywords
Tactile Display, Group Coordination, Gunshot Localization, Rapid Response

1. INTRODUCTION
Tactile displays are devices that convey information to a person using the sensation of touch. This can be achieved through vibrations, heat, or pressure. Vibrotactile actuators, similar to those used in cell phones, are commonly used for a variety of applications [1]. Tactile displays can help substitute primary senses such as sight with touch for intricate tasks such as navigation. Tactile displays may also be used in a peripheral sense where the tactile actuators provide hints or directions that do not require the wearer's complete attention to enacts an impulse reaction.

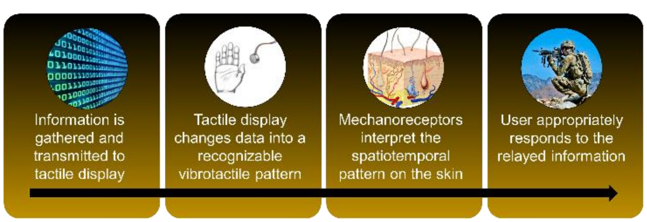

Figure 1. Data flow from raw information to tactile interpretation.

As shown in Figure 1, tactile displays translate raw data into a recognizable pattern on the skin for the wearer. Vibrotactile displays function by triggering the mechanoreceptors in the human skin by vibration. Depending on the application of the tactile display, some form of raw data will be transmitted to the tactile display by wired connection, wirelessly, or other means. The tactile display will then translate that data into a comprehendible pattern for the wearer. These patterns may change depending on the functionality of the display. An example of a spatiotemporal pattern is shown in Figure 2.

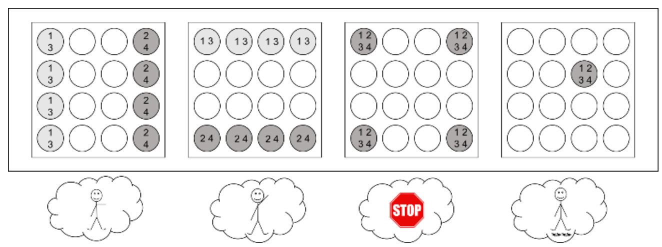

Figure 2. Example vibrotactile spatiotemporal pattern in a 4x4 array.

This represents patterns for a four-by-four tactile array. This kind of design has been used for many applications, including an MIT study where different spatiotemporal patterns like those above instructed the user to perform different navigational tasks [1]. The numbers in the tactors represent in what order the vibrations trigger as the time element in tactile displays is very important to how the wearer perceives the pattern. Some patterns may be much clearer or recognizable to the user if they pulsate left right such as in the first square, than if they were always both on.

Mechanoreceptors are sensory receptors embedded in the skin that give us the sensation of touch. Mechanoreceptors respond to mechanical pressure or distortions of these patterns on the skin. Certain areas of the body have a higher density of mechanoreceptors in the skin and are therefore more sensitive to smaller vibrations [2].

The more mechanoreceptors in a given area, the lower the two-point discrimination will be. Two-point discrimination is the minimum distance at which the body can identify two unique tactile stimuli. It is more difficult for the body to differentiate between two close stimuli in comparison to two spread apart stimuli [2]. Different parts of the body have different sensitivities to tactile stimulation and therefore have different two-point discrimination thresholds. For example, two-point discrimination is much smaller in the fingertips than on the torso. This is intuitive because our fingertips have a smaller surface area and are used constantly to determine characteristics of objects through touch [2].

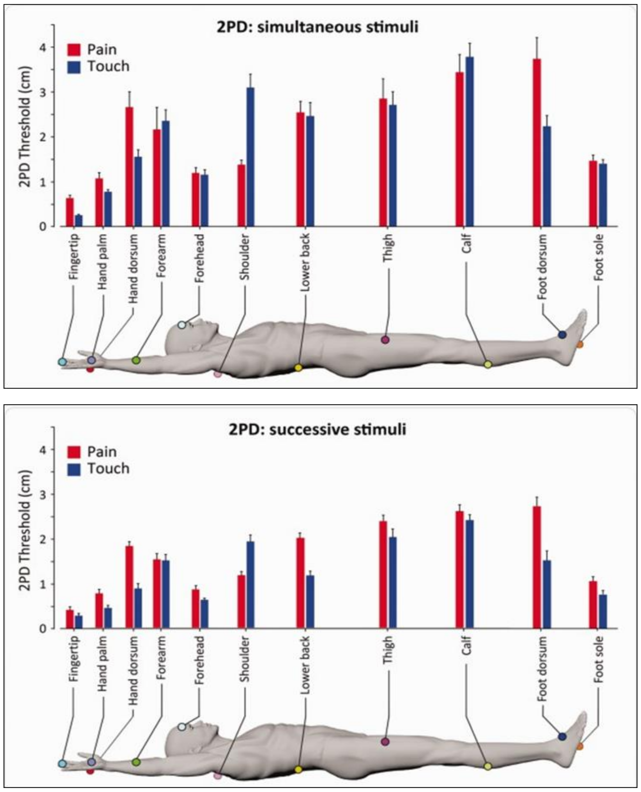

Figure 3. Two-point discrimination for successive vs. simultaneous stimuli in different regions of the body [2].

After the wearer of the tactile display feels the vibrotactile pattern on their skin, they will act accordingly depending on what the display is being used for. This result will vary greatly depending on application. For every tactile display however, the user must be trained to associate certain spatiotemporal patters with their respective commands. This can be seen in Figure 2 where the four corner tactors pulsating should indicate the wearer to stop moving.

Tactile displays must be in contact with the skin during data transmission for the wearer to receive the information; because of this limitation tactile displays are conventionally used in applications where the wearer is not drastically moving.

Tactile displays are used in many applications including assisting the blind and enhancing pilot's spatial awareness in limited visibility situations. The civilian use of tactile displays has shown that they can effectively supplement or partially replace another sense such as sight. Tactile displays have only been used in the military to assist pilots, however civilian uses are much more extensive. Furthermore, there are many areas of the body utilized by different tactile displays to achieve the same goals. Almost every area of the body has been used by tactile displays when guiding the blind including the fingers, torso, waist, feet and mouth. Below a few of these tactile display applications will be described.

Tang and Beebe used an oral mouthpiece tactile display to help the blind navigate outdoors. The device had an electro tactile display on the roof of the mouth and a tongue touch interface on the bottom for the user to operate. The tactile display could present four different arrow patterns representing left, right, forwards, or backwards [3].

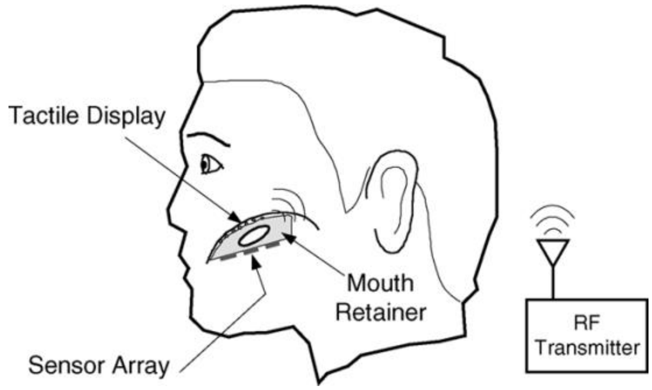

Figure 4. Tang and Beebe's oral microfabricated electro tactile display for the blind [3].

Velázquez et. al. designed a shoe integrated tactile display and evaluated the degree to which humans could interpret tactile information through this device [4]. The display consisted of a 16-point array of actuators on the bottom of the foot. The tactile display was integrated into the sole of a shoe. Some of the benefits of using the foot as the tactile receiver is the high density of mechanoreceptors and its continuous use by the body to maintain balance. The test subjects were successful at navigating the provided course given adequate time. These results were expected to improve were the subjects given more training with the device.

Figure 5. Velázquez 's Tactile display incorporated in a shoe [4].

The TNO Tactile Torso Display and the Naval Aeromedical Research Laboratory Tactile Situation Awareness System (TSAS), both provide intuitive three-dimensional spatial information [5].

The TNO Tactile Torso Display consists of small vibrating elements in array form. When activated they give a localized vibration that is similar to a tap on the shoulder. The TNO Tactile Torso Display is integrated into a vest. This display gives the pilot fast and intuitive spatial information. A tap on the left corresponds to an event on the pilot's left. The vest does not depend on visual information therefore giving the pilot redundancy when operating in IFR or limited visibility conditions [5].

Figure 6. A Helicopter Pilot Showing a TNO Tactile Torso Display (TTTD) [5].

The Tactile Situation Awareness System (TSAS1) is an advanced flight instrument that uses tactile displays integrated into the flight garments to provide situation awareness information to pilots. The TSAS system accepts data from various aircraft sensors and presents this information via tactors integrated into flight garments. TSAS has the capability of presenting a variety of flight parameter information, including attitude, altitude, velocity, navigation, acceleration, threat location, and/or target location [6].

The TSAS display uses an array of eight columns of two tactors to give spatial information to the pilot in 45° increments. This system, similar to the TNO display, supplements the pilot's other senses to add a layer of redundancy but does not replace them.

Figure 7. The Tactile Situation Awareness System (TSAS1) [6].

The benefits of tactile devices is that they reduce the risk of sensory overload in man-machine interfaces. Traditionally these activities addressed by the displays have a low demand on tactile information processing. In the pilot's scenario, it is extremely demanding on the pilot's sense of sight and hearing. By shifting some of the workload to the tactile sensory system, this device helps reduce the number of accidents due to a lack of spatial awareness resulting from sensory overload.

An important distinction to be made between the discussed tactile displays used for the blind and those used for the pilots is that the two displays designed for the blind completely substitute a lost sense whereas the two vests for military pilots give redundancy to the pilot's visual sensory system.

Current technology exists that can determine the origin of gunshots by analyzing soundwaves from the shot. One device that does this is the QinetiQ EARS Gunshot Localization System [7]. This device has been tested in Iraq and was popular with those soldiers that used it. The EARS system consistently and accurately determines the location of gunshots in a variety of environments. Another benefit of the EARS device is that it finds the location of the origin in under a quarter of a second.

Figure 8. QinetiQ EARS shoulder mounted sensor [7].

The EARS system comes in three variations: shoulder worn, fixed site, and vehicle mounted. When using the shoulder worn variation, which is what this proposal will pertain to, the user must carry the EARS sensor system as well as a separate display. The display gives the user audial and visual cues on an LCD screen regarding the location of the gunshot.

The disadvantages of this system are the extra equipment that must be managed in combat and the attention required from the overloaded audial and visual systems of the soldier. The display portion of the device does not quickly and concisely relay information to the soldier. This is because the device alerts the user through audial communication. It declares direction and distance of hostile gunfire through audio communication which could result in a couple second delay of information. In a battlefield environment one second can be the difference between life or death.

The objective of this paper is to adapt the tactile display as a peripheral device for soldiers and infantrymen to aid in gunshot localization in chaotic environments by assisting the wearer in taking cover and coordinating a retaliation. By doing so, military units would be more coordinated, and the chances of miscommunication would be greatly reduced by freeing their overloaded visual and audial senses. Tactile displays could provide soldiers with a wealth of information, including positions of allies and hostile gunfire.

When combined with a system such as the QinetiQ EARS shoulder mounted sensor, a tactile display could result in quicker response to hostile gunfire while simultaneously using a non-overloaded sensory system. The idea is that this system would enable split second decision making in critical situations for soldiers.

2. CONCEPT PROTOTYPE

To create a tactile display that can passively inform the wearer of a gunshot direction and to coordinate the group, the display must be supplementary to the wearer's other senses and not be a substitute for a sense. Because it takes more attention from the wearer to differentiate between two nearby vibrations, it makes sense that the vibrotactile actuators should be spread across the body's extremities as to make that determination easier. By spreading the actuators across the extremities, the wearer does not have to dedicate much thought to understand the instructions given by the tactile display.

If a four by four matrix of actuators is used, the actuators are at the limits of the skin's two-point discrimination thresholds. When the actuators are spread across the body as in Figure 9, they reside on different regions of the skin and therefor do not confuse the wearer with the instructions being conveyed. An extremity display can be accomplished by placing individual actuators on the shoulders, wrists, and legs.

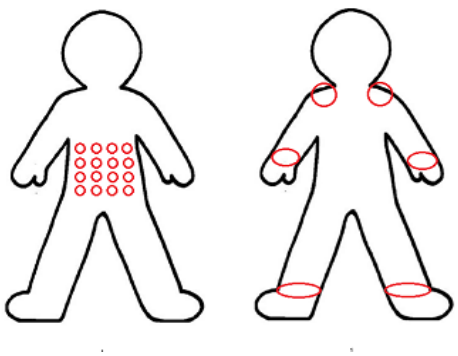

Figure 9. 4x4 matrix vs. extremity display

The benefit of this approach is that there is little chance the user will mistake a vibration on the left leg with, for example, a vibration on the right shoulder. By making the interpretation of the display more reliable and intuitive, information can be reacted to more naturally and as second nature to the wearer.

3. PROTOTYPE TESTING PLAN

To test the effectiveness of our tactile display, we would use a situation that could simulate a combat zone during hostile gunfire. The situation would represent a soldier in a hostile area who is approaching a barricade that provides cover when unexpectedly he is fired upon. The soldier must quickly decide which side of the barricade is opposite of the gunfire origination and get behind that side to avoid being injured.

To simulate gunfire, two speakers will be used; one speaker will be on the left of the barrier, and the other on the right. The speakers represent the origin of the gunshot, and one will be selected to play a gunshot sound to which the subject must react to.

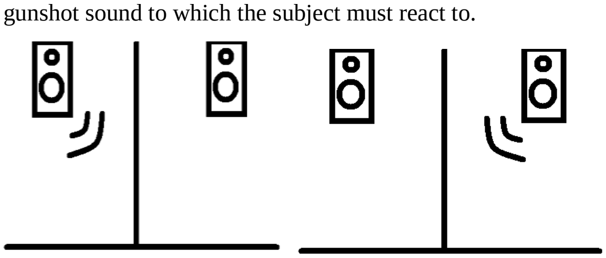

Figure 10. Test scenarios: left originating gunshot vs. right originating gunshot.

Two important factors in the results of these tests will be whether the subject chose the correct side for cover and how long the decision took to be made. The test subject's decisions will be compared to the true gunshot originations and the timer will begin as soon as the gunshot sound is played. By comparing control and test trials, we hope a trend can be discerned.

If no meaningful difference is found between the two methods, more speakers will be added in smaller radial intervals from the subject to test the limits of the human and device. For example, if results for the two-speaker test are identical, four speakers will be tested- two speakers on each side in 45 degree intervals.

3.1 Control Test

A control subject will react to the audial cues without the vest and decide to take cover on the side of the wall opposite to where they think the sound originated. Timing will begin as soon as the shot is fired.

3.2 Tactile Display Test

Similarly, the subject with the vest will make the same decision with the guidance of the tactile display. The tactile display will know the direction the gunshot originated and will try to convey this to the user using predetermined patterns that the subject will be trained to recognize. For these trials the subject should react based off the tactile cues and not the audial cues of the test.

By comparing the speed at which the subject takes cover, as well as how accurately they choose the safe position of cover, a relationship can be made to conclude whether an extremity tactile display could aid with supplementing decision making in critical situations.

4. CONCLUSION

In combat environments visual and auditory sensory systems are overloaded due to excessive stimulation. In civilian applications tactile displays have shown that they can transfer some of this bandwidth to the tactile sensory system which relieves stress on the overloaded systems. By making an intuitive tactile display that requires little attention in combat situations, military units can organically be coordinated to reduce casualties in hostile environments. Future work will include finding out the appropriate location of the display tactors on a soldier since they are heavily loaded with combat equipment which can compromise the sensation.

5. REFERENCES

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