Hit The Road, Jack

P2: Design Alternatives

Amit Garg
Rachel LeRoy
Sahib Singh
John Crisp
Bryan Bennett

Table of Contents

Problem Space

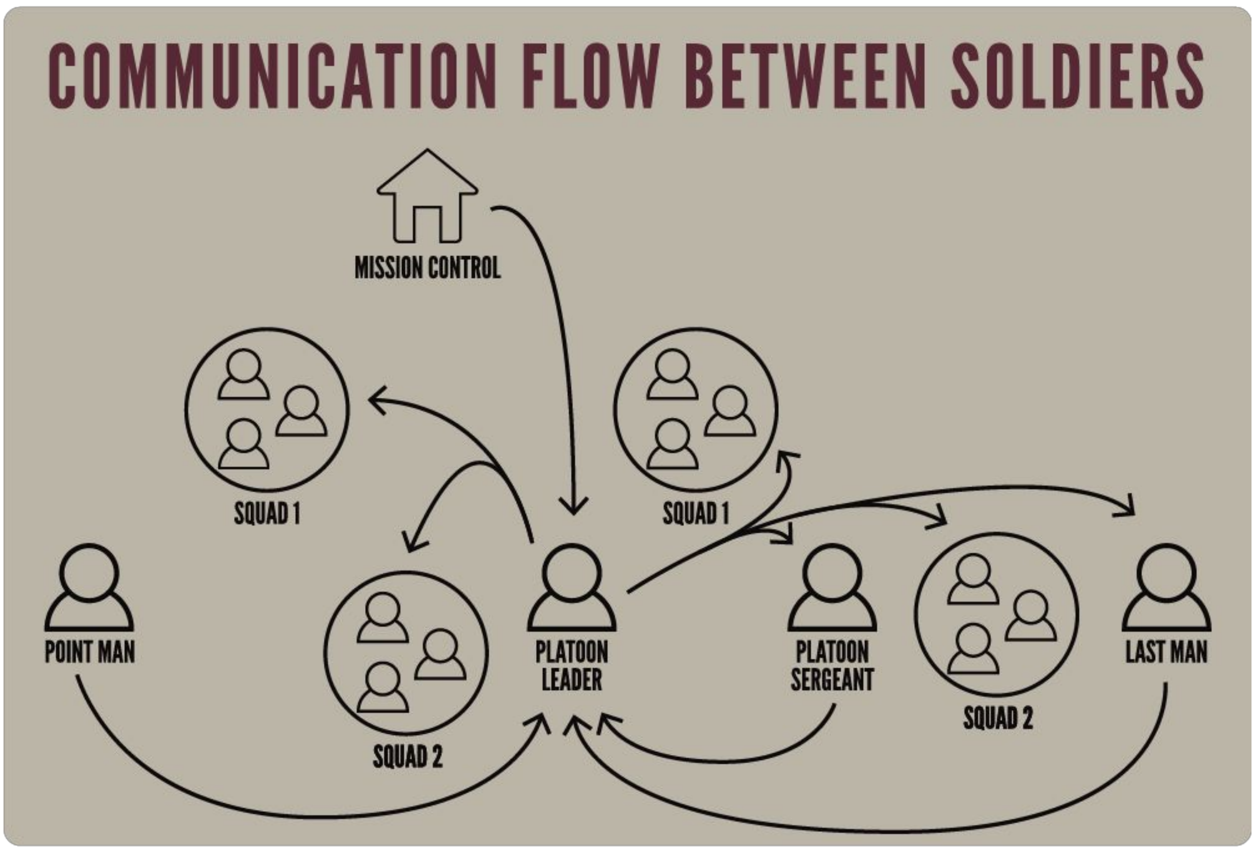
Our team is targeting ROTC cadets, both male and female. All ROTC cadets are young (aged 17-26). The purpose of the ROTC program is to expose cadets to US Army procedures and culture. Cadets are expected to be in good physical health and in constant communication with their peers and higher-ups. During the ROTC program, cadets engage in several training activities that teach them how missions are led and run. They rotate through leadership roles and get to practice running missions, and are expected to apply the knowledge they gain during each semester through discussion-based Military Science courses and leadership labs. This knowledge usually gets applied in an end-of-semester Leadership Development Experience (LDX) where cadets simulate different missions over the course of a weekend.

During these simulations, cadets often find themselves in scenarios where their vision is situationally impaired. This is not a biological impairment, but rather is a challenge brought on by different scenarios such as during night time missions. We refer to these environments as 'low-visibility' situations. In these environments, cadets avoid using vocal communication in order to avoid compromising their position to the simulated enemy. The default communication strategy in these situations is to use Army Hand and Arm signals (H&A signals) in which a communicator will perform a simple movement of the hand and arms to communicate a specific message to his/her peers. There are standardized H&A signals, but mission leaders often modify them, or create their own, before a mission. This information is disseminated to peers during a mission brief. However, H&A signals are largely inefficient during low-visibility situations. In our user research, we learned that the communication of information to an entire platoon (approx. 36 members) takes almost 10 minutes (n.b. this was for cadets, and is closer to 1 minute and 30 seconds for active soldiers). Moreover, in low-visibility situations, H&A signals are often never received to an entire platoon or are misunderstood due to lack of full visibility. Thus, *we are attempting to make the conveyance of information between leaders and platoon members more effective in low-visibility situations, while also remaining natural and intuitive.*

Information Flow Model

In order to more effectively design a solution, we decided to create a graphic representation of the way information flows at the platoon level. We gathered this information during our user research. Although the diagram is titled for information flow between soldiers, the model applies to flow between cadets as well since cadets are soldiers in training. The information flow happens as follows.

Before the mission begins, Mission Control communicates facts about a mission to the Platoon Leader (PL). Facts include weather conditions, terrain information, and specifics about the enemy. The PL is the central communication point within the platoon. Upon receiving this information, the PL's job is to analyze it and create a mission plan based on the facts from Mission Control. Then, the PL communicates this to the rest of the platoon when it is at rest at home base. Each platoon is made up of four squads, each approximately eight cadets and a Squad Leader (SL). Each squad has three teams of three, each with leaders. Each platoon has a Point Man (PM) and a Last Man (LM) which leads and trails the platoon direction, respectively, as well as a Platoon Sergeant (PS, highest enlisted officer) whose job is to ensure that the PL's mission plan is carried out accordingly. Our problem space is not during the time before the mission has begun. Rather, we are focusing on communication flow when the platoon is in movement during a mission.



During platoon movement, communication is comprised of information related to any sort of on-the-fly change. For example, formation changes, enemy contact or intel, injuries, and personnel count are all types of info communicated while on the move. Communication falls under two categories: 1) from PL outwards, or 2) from squad members to PL:

1) When the PL needs to communicate information, such as a formation change, s/he will directly communicate that to the PS, SLs, and either PM or LM depending on the change.
2) PM, LM, and PS all report directly to PL, for example if enemy contact is made from the front or the back. Communication between PL and PS always exists, as the PS is supposed to ensure the execution of the PL's mission plan.

Major modes of communication include H&A signals as well as radio communication (depending on availability of radios, radio battery, and terrain features). As mentioned earlier, the current communication process is largely inefficient and uses modes that are unfit for low-visibility situations. In our design process, we set out to assess the qualitative data gathered during interviews with cadets and officers, assign important characteristics of our users and their task, and create designs that met certain criteria.

Design Process

In summary, our design process consisted of:

- conducting interviews
- reviewing interview notes and perform affinity mapping
- structuring the problem into send-transmit-receive
- preparing three alternative solutions.

Following is a more detailed description of our design process.

Conduct Interviews

Our team began collecting input from our targeted population, ROTC cadets (Georgia Tech students in the ROTC program) and faculty (with years of active service experience), regarding their goals and pain points when communicating in low-light situations while avoiding detection. We did this by conducting six 2-on-1 interviews; each ROTC cadet or faculty was interviewed individually by two team members (one conducting the interview, the other taking notes). All interviews were recorded with permission from the interviewee. Within 24 hours after each interview was completed (to avoid memory decay), the team member who took notes drafted and published a written summary of the interview on Google Drive.

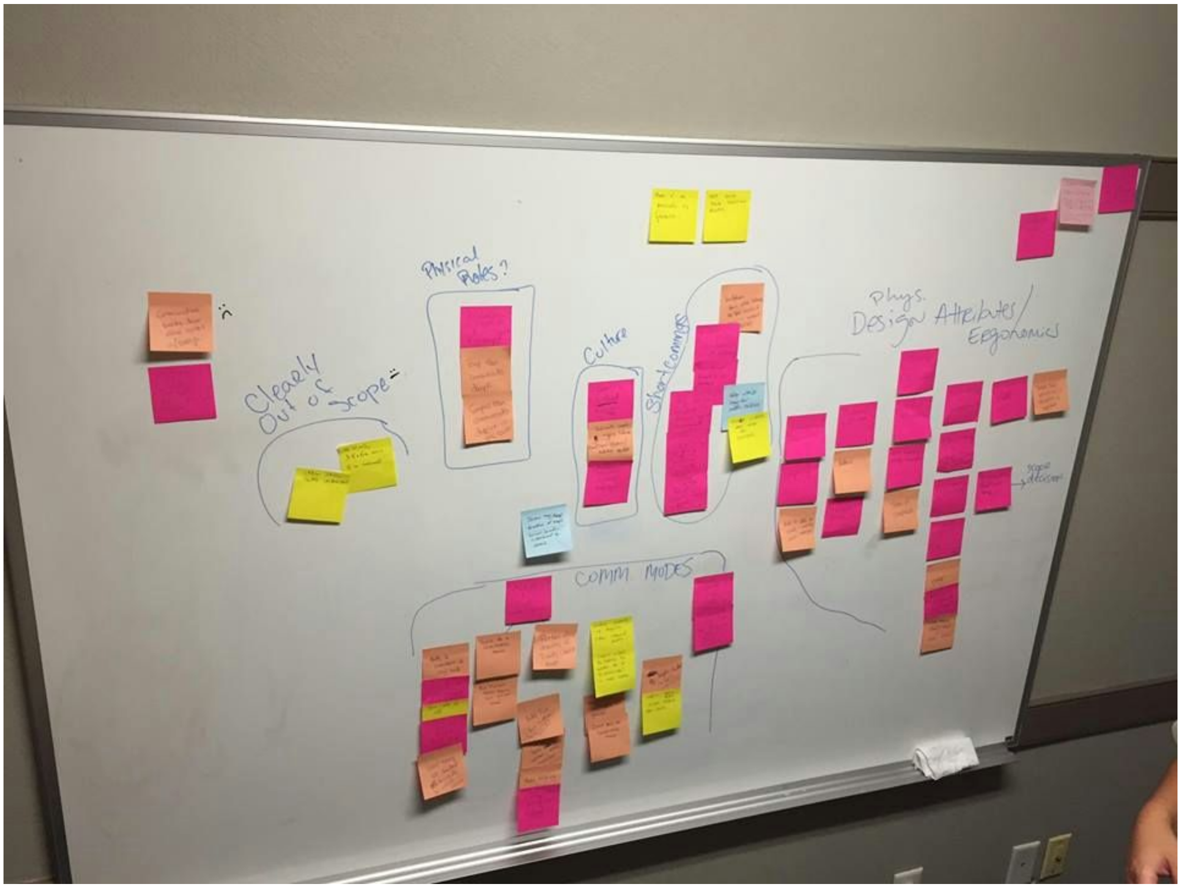
Interview with Sgt. Gary Benslay

Interview with ROTC Cadet

Perform Affinity Mapping

After interviews were complete, we conducted a team meeting where team members read aloud the meeting summaries they had written. This was done primarily to familiarize all team members with the content of all interviews, but it also allowed us to identify some common themes.

At a following team meeting, all meeting summaries/notes were read aloud a second time, during which team members identified key qualitative statements and captured them on Post-It notes for use in affinity mapping. We then conducted an affinity mapping exercise.



Final Affinity Diagram

In addition, to help us discuss the communication needs more effectively, we created a diagram which showed the communication flow among Platoon Leader, Platoon Sergeant, Point Man, and Last Man, as shown in the previous section.

Structure Problem into Send-Transmit-Receive

The affinity mapping process helped identify an overall structure to the problem space and possible solutions. Our data was classified into the following categories: communication modes, ROTC culture, physical roles, physical design attributes, and current strategy shortcomings. However, we quickly realized that every aspect of this communication process can be broken down into sending, transmitting, and receiving messages, and that each point of the process can be rejuvenated. As a team, we brainstormed different ways of sending, transmitting, and receiving messages in low-light situations while avoiding detection, and created a chart that contained this list. We recognized that not every possible means of sending could be used with every possible means of transmitting or receiving, but we also realized that there were many feasible combinations, more than we could possibly prototype.

This insight led us to recognize that the three alternative solutions we propose should represent different methods of sending, transmitting, and receiving. Not only would this ensure we created three very different solutions, it also addressed the possibility that we could ultimately propose yet a (fourth) different solution, which could include different aspects of several of our initial solutions. We felt confident that we would receive more and better feedback on each of these sending, transmitting, and receiving methods when presented in the context of an end-to-end solution.

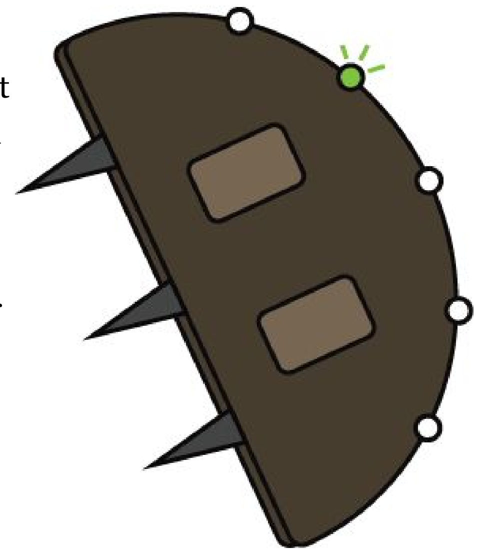
Prepare Three Alternative Solutions

As a team, we brainstormed three alternative solutions that represented different combinations of send-transmit-receive. We then as a team briefly discussed how each solution would work. One team member drafted a brief writeup of the three alternative solutions, and posted it for each team member to review electronically and provide feedback. A different team member was assigned to “flesh out” each of the three alternative solutions, including producing a sketch and modifying the brief write-up as needed to fit their vision. This material was provided to the graphic designer, who created digitally shareable versions of each of the possible solutions. Each team member reviewed the digital versions electronically and provided feedback.

This process allowed each team member to participate in the brainstorming approach to develop the three potential solutions, but also allowed us to develop a “champion” for each of the fleshed-out alternatives.

Design Alternatives

1) Physical LED Breadcrumb



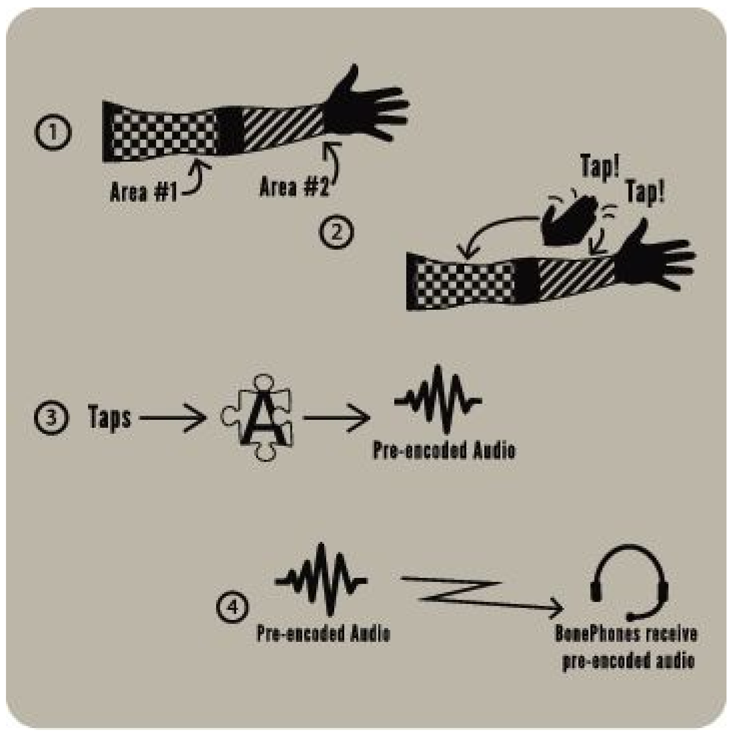
The Physical LED Breadcrumb is a small 1-2” tall object with a number of signaling lights on one face. Based on user feedback, each LED may emit either infrared or visual light. If visual, the light may be one of many colors. This allows the device to display different classes of information based on the color of the LED. If infrared, night vision goggles would be required to see the LEDs. At any point, only one LED may be lit. This limits the number of signals that the device may convey, but keeps interaction with the device simple.

Upon encountering an obstacle in their path, the point man (or another designated cadet) will select a color of LED and an LED position to indicate information about the obstacle to his platoon leader and the other cadets. The breadcrumb will attach to nearby trees via a retractable set of spikes, controlled by a small switch on the attaching face of the device. The person placing the device would simply attach the device to a tree and continue moving. This alerts those behind him of the presence of an obstacle in the path and its relative position, depending on the position of the LED. The platoon leader or last man in the march may then retrieve the device whenever the message has been adequately conveyed to the group.

This approach has a number of virtues. Firstly, it's an extremely simple solution. The electronics used to power it are minimal, helping reduce failure through repeated use or abuse. Secondly, the solution's simplicity affords to a rugged solution. If the correct components are selected, the case could easily be water and weatherproofed. Lastly, the device is somewhat dynamic. The means of communication gives the cadets the ability to build messages around its capabilities rather than enforcing that specific messages be communicated through specific means. Furthermore, since the actual light emitted may be either visual or infrared light, the possible usage expands beyond cadets, who don't have access to night vision goggles, and into military space beyond ROTC.

There are some shortcomings with this approach as well. As the light is most usable when it's the visible spectrum, this would be preferable for increasing the semantic information shared with each message. However, this can give unit position away to any hostile forces in the area. One of our interviewees mentioned during an interview that "...light can be seen from a mile away [in low-viz situations]." This may be overcome by either reducing intensity of the visible light or introducing directionality to the emitted light. Furthermore, the small size will allow these to be easily lost, which could give away position information to hostile forces. This problem is inherent to the form factor and may not easily be solvable. Lastly, communication depends on line of sight of the device itself, which cannot always be guaranteed in large groups.

2) PRESSURE SENSITIVE SLEEVE

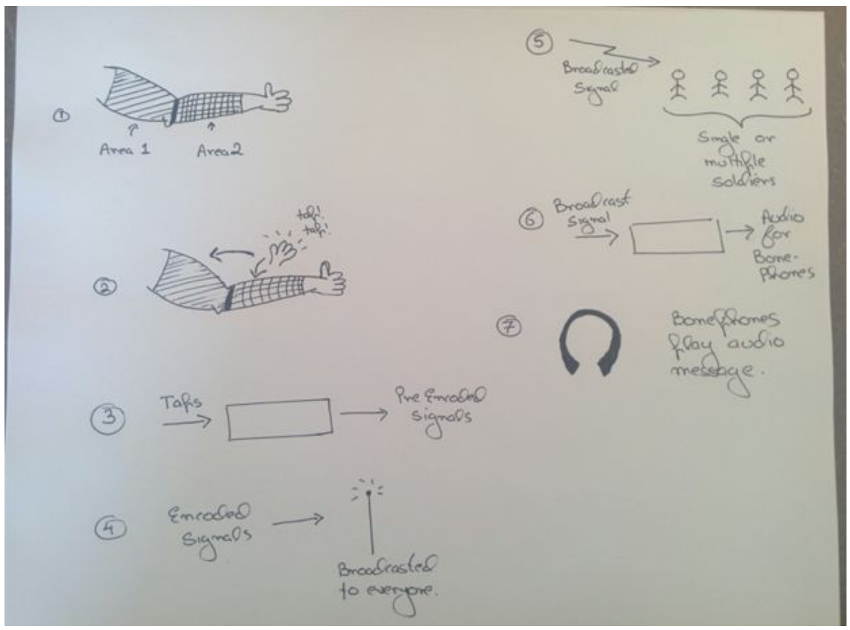


This model of communication works on the principle of reducing the amount of input that a communicator has to put in order to send a complete legible message across to either the whole of the platoon or the platoon leader. Instead of speaking out or signaling a message, a platoon would have pre-decided codes for each message in the form of tap sequences. The pressure sensitive sleeve recognizes these taps and automatically decodes the taps into legible messages. This is analogous to a simple vending machine where the buyer, instead of explicitly specifying what he wants to buy, inputs the code of the item and the vending machine decodes the code and presents the buyer with the item.

WORKING:

1) This design consists of a pressure sensitive sleeve, which has two different areas that denote two different components of a signal. The number of pressure sensitive areas can be varied depending on the situation and the number of commands that need to be sent.

2) The sender sends messages by tapping on the two pressure sensitive areas in a pre-decided pattern to create a signal. This is somewhat similar to Morse code, but instead of having a sequence of dash and dots to denote each alphabet, the platoon has a tap sequence for each message.



3) Each input tap sequence is encoded into a digital signal and is encrypted before being transmitted over a wireless medium. This ensures that the message to be transmitted is small in size and protected.

4) The encrypted digital message is transmitted to everyone in the platoon from the communicator. The message can also be sent to one particular person or just the key figures in the platoon, like the SLs or PL.

5) The transmitted signal is sent across the platoon via a private wireless area network, which can have a peer-to-peer connection or have one of the soldiers acting as a router for better efficiency of communication. All of the troops get the transmitted encrypted message at the same time and hence there is no delay in the delivery of the message to everyone.

6) The encrypted digital signal that is received is decrypted into a corresponding audio signal by a converter that each soldier has. This converter has all the audio messages pre recorded and stored, and it matches the incoming signal to the corresponding audio message.

7) Each soldier is equipped with bone conduction headphones or BonePhones, which lie on the bone just above the ear and conduct audio vibrations through the bones, rather than directly into the ear canal. This allows the soldiers to listen to ambient noises while also being able to receive audio messages simultaneously.

DESIGN JUSTIFICATION

This design consists of 2 main components, mainly the pressure sensitive sleeve and the BonePhones, which perform the vital roles of sending and receiving messages, respectively.

We thought the sleeve to be most suitable as a cadet's hands are always accessible no matter what the situation or position of the cadet. Also, by placing the sleeve on the arm, we can lower the chance of error inputs. To improve the accuracy and avoid erroneous input, we conceived an activation mechanism that engages when the sender clenches his/her fist. So, in order to start sending messages, the sender first clenches his/her fist, and holds the clench. Only taps made while the fist is clenched are recognized and then converted into signals. This ensures that the system can differentiate between intended and erroneous tap inputs.

During our interviews, we learned that the biggest concern that arises for cadets was to maintain situational awareness at all times, and they rely on their sensory organs heavily to do so. This makes the sensory system even more vital for them. Using conventional headphones makes it very difficult to hear other noises/voices, which practically makes them deaf; this is *beyond* the last situation a cadet or soldier wants to be in. To tackle this problem, we have introduced the use of bone conducting headphones, which allow the cadets to hear all external auditory stimuli as well as the audio messages being relayed to them. This ensures that cadets' senses are not compromised while being in constant communication with the platoon.

PROS & CONS

Cons

- The soldiers have to learn new codes in the form of taps, which makes their training, and the chance of error even high.
- The biggest problem is to undo a wrongly sent message. This will require acknowledgement from everyone stating that they nullify the previously received message.
- Since the sleeve shall be worn on the uniform, there are chances that it might breakdown, so the sleeve should be durable enough to withstand a cadet's routine activities.
- All cadets might not be comfortable with the use of bone conduction headphones over a large period of time. For some, they might seem uncomfortable.

Pros

- The design helps in sending crucial messages within seconds, without a lot of input from the sender's side.
- Everyone gets the message at the same time, so there's no possibility of delay in reception of the message.
- BonePhones do not let your hearing abilities to be sidetracked or hindered.

3) Accelerometer Enabled Gloves and Haptic Vest

This design utilizes a concept known as tactile communication, which is based on research into 'multi-modal' or 'multi-sensory' communication. The human brain extracts information from the different senses, and uses this combination of information to form an understanding. However, in our problem space where cadets' visual and auditory attention is highly occupied in order to maintain situational awareness, the tactile channel remains open for information to be sent and received. Additionally, tactile communication is silent and invisible which provides a huge advantage over other visual and auditory communication paradigms, especially for our users and the context of their tasks.

As mentioned earlier, the default communication strategy for ROTC cadets is with the army's Hand and Arm signals (H&A signals). This design attempts to avoid changing the the signal language itself, but provides alternative means for reception of the signals. There are two components to the design: 1) a glove (or gloves) that has an accelerometer, a transmitter, and a battery embedded within the fabric, and 2) a vest (or similar piece of clothing) with several vibrotactile actuators, a receiver, and a battery embedded within the fabric. Each sender is equipped with the glove(s) and each receiver is equipped with a vest.

Workings

When a sender needs to communicate an H&A signal, s/he performs the action while the accelerometer measures the movement. A custom machine learning algorithm classifies the accelerometer data into a pre-learned H&A signal and prepares to send the signal out to each haptic vest. Upon reception of the signal, the actuators on the haptic vest will vibrate in a predefined pattern corresponding to the H&A signal that was classified in the gloves. Each H&A signal's vibration pattern is mapped as closely as possible to each H&A signal such that learning of the vibration patterns are easy and intuitive. For example, the H&A signal for "Rally" is shown to the right. A corresponding vibration pattern would be sequential activation of actuators in a circular formation, signalling "Rally" in the vest of each receiver.

Design Justifications - Pros and Cons

This design has several advantages. First, it meets the criteria of being silent and invisible. Since low-visibility situations generally occur during covert operations, communication should be stealthy such that the group's location is not compromised. Tactile communication affords well to this situation since communication is mechanical and silent. Second, it features natural mapping between what the cadets already know (H&A signals) and they would have to learn (vibration patterns). Natural mapping results in a higher ease-of-use and reduces the workload of users to adopt the technology. Third, the design is completely hands-free, meaning that there no extra input required from senders or receivers during the communication process.

Although this design meets several design goals for our users' context, it does have many disadvantages. First, there are many factors that could result in communication errors. For example, the machine-learning algorithm requires a large data set to be trained on before it could function in the real context. Therefore, the algorithm is only as robust as the data set it is trained on. Errors during the classification process could be large number, and could have large impact on the feasibility of the design. Second, cadets (and soldiers) already have plenty of gear worn on their body; adding a potentially heavy vest might not be received well by the user. However, advancements in tactile actuator technology could mitigate this issue. Moreover, different form factors of the wearable could also be used. For example, an undershirt with actuators embedded in the fabric could be used instead of a full-on vest. This would also help protect the technology since cadets/soldiers wear protective vests with ceramic plates during missions. Lastly, the design fails to provide cadets with the ability to program their own vibration patterns for certain H&A signals. During our user research, we learned that many platoons will come up with their own H&A signals, or modify current ones, before a mission. A more robust design would allow the Platoon Leader to easily form new vibration patterns. This could be featured on a design iteration.

Poster Session

Our poster session was conducted on Monday 9-28, and afforded the opportunity to receive feedback from our fellow students, our TAs, our Professor, and Dr. Henneman, the Director of the MS-HCI program. Here is an image of the poster we presented:

TEAM HIT THE ROAD JACK

Rachel LeRoy · Sahib Singh · Amit Garg
Bryan Bennett · John Crisp

OUR PROBLEM

Our teams is targeting ROTC cadets, both male and female. All ROTC cadets are young (aged 17 through 26). On average they are largely inexperienced in the arduous hikes, training and activities they are undertaking as ROTC cadets.

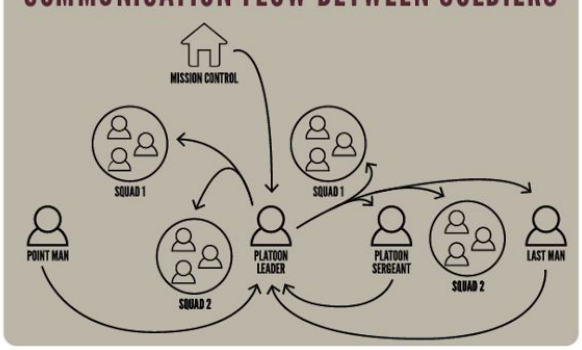
The cadets are expected to be in good physical health, so the worry of disability is low. Instead, these students often find themselves in situational visual impairment scenarios. These include vision impairment as it relates to low light or movement techniques during their field training activities and the inability to use vocal or audio communication methods in order to avoid detection by enemies. To ease their situation, *we are attempting to make the conveyance of informvation between the leader and the rest of the cadets more effective in low visibility situations, while also remaining natural and intuitive.*

OUR SOLUTIONS

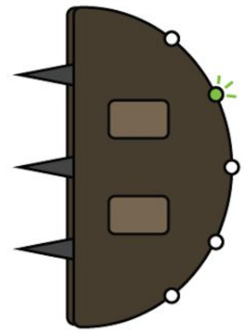
In order to effectively send a message, we have identified that a system must contain an input (or send) method, a transmission method, and an output (or receive) method. We are focusing on novel and effective components for each of these three categories, which is allowing us to effectively pick and choose an efficient and cost-effective solution.

SEND	TRANSMIT	RECEIVE
Hand/Arm Signals	WiFi	Visual
LED Housing	Line of Sight	BonePhone
Compression Glove	Bluetooth	Haptic Vest
Pressure-Sensitive Sleeve	iBeacon	Google Glass
Accelerometer-enabled glove	RFID	Night Vision Goggles
Conductive cards		
Wearable sock		

COMMUNICATION FLOW BETWEEN SOLDIERS



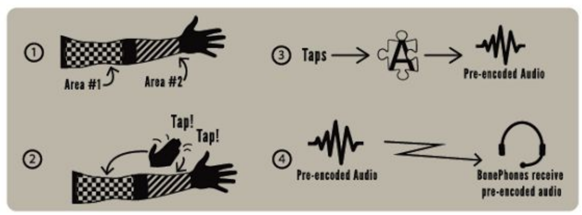
STICK-TO-TREE LED



BASIC PREMISE

· Point Man identifies obstacle(s).
· Point man selects appropriate LED in appropriate color.
· Point man attaches device to nearby object.
· Any member behind is warned of upcoming obstacle and may retrieve device

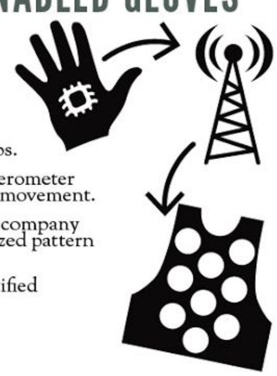
PRESSURE-SENSITIVE SLEEVE



BASIC PREMISE

· Line leader or Platoon Leader (the sender) must transfer a message.
· The sender touches two pressure-sensitive areas on a wearable sleeve. The order of taps encodes a message, much like morse code.
· The system recognizes a pre-registered sequence of taps as a specific message and sends that message out.
· Message is received by the rest of the company via a bone-conducting headset so each company members "hears" the order audibly.

ACCELEROMETER ENABLED GLOVES



BASIC PREMISE

· Line leader gives standard Army hand/arm signal to signal to troops.
· Line leader's glove contains accelerometer that recognizes and identifies the movement.
· Movement is transmitted to each company member and vibrates in a recognized pattern or region.
· Company member reacts to identified meaning of particular vibration.

Below is some of the general feedback received on the project:

- Try to reduce the possibility of accidentally sending an order, to ensure confidence in the system.
- During combat, there should be an easy way of locking the system from sending orders, to avoid accidental orders being generated in that chaotic time. Further, during actual battle, the system should not transmit orders that will distract soldiers.
- Survey users on the common orders to be communicated in low-light situations while avoiding detection. Determine the ability of our solution to handle all of those common orders.
- Realize the possibility that users of the system may forget how to trigger a specific message. How can the system remind/help them, in low-light situations while avoiding detection?
- The position of the leader may affect the ability to communicate.
- Get feedback from ROTC faculty and cadets.

Feedback specifically directed to one of the three alternative solutions:

- Consider a virtual "digital breadcrumb", as being discussed by another team, as a transmission alternative.
- Use of infrared (IR) technology reduces/eliminates the ability to discern color. As such, the possible communications using the Physical LED Breadcrumb would be reduced under IR; not as many possible combinations can be transmitted.
- Regarding the "glove" as a send method, not only would an accelerometer be needed, but also sensing of hand and wrist position (difference between fist and extended hand).
- Regarding the "sleeve" as a send method, how would single taps be treated? Ignored as possible inadvertent messages?
- Regarding the "haptic vest" as a receive method, concerns include weight, possible conflict with body armor, and the ability of the soldier to discern the vibrations (receive the message) considering their load of body armor and backpack.
- The Physical LED Breadcrumb has several problems, including the limited amount of information it can transmit, and the possibility that a found Physical LED Breadcrumb might allow an opposing force to "hijack" the message.
- Users would probably find the "accelerometer glove" to send, and "bone conduction headphones " to receive, a more natural solution.

- The Physical LED Breadcrumb would take time to pick up and put down. In some environments (sand, beach, water, desert) there may not be a good place to affix it, leading to the possibility that either the message, or the Physical LED Breadcrumb itself, may become lost.

Next Steps

As our team continues into P3, we need to prepare for creating our initial prototype, and the evaluation of the prototype. In summary, our next steps include:

- Schedule User Review
- Select Initial Prototype
- Conduct Research Necessary to Construct First Prototype
- Develop Initial Prototype Evaluation Plan

Following is a more detailed description of our Next Steps.

Schedule User Review

Our next step will be to schedule and conduct meetings with ROTC leadership, faculty, and students focusing on send and receive possibilities. The goal of those meetings will be to determine what users believe should be highest priority for our initial prototype.

With a different user population, we might ask to conduct a single meeting attended by representatives of leadership, faculty, and students. Given the military chain of command, it is possible that ROTC program leadership will us to meet with them initially, and then leadership will decide what follow-up meetings should be scheduled and with whom. We will need to respect whatever decision is made by ROTC program leadership.

Select Initial Prototype

For the first prototype, we will, in consultation with our users, select a “send” technology and a “transmit” technology. For this first prototype, “transmit” technology should be an internal team decision. We will select the most expedient transmit technology, with the goal of it not being the failure point in the prototype.

Conduct Research Necessary to Construct Initial Prototype

It is possible that the users will ask for the first prototype to include the accelerometer glove as the “send” technology. That would map more clearly to the current method of hand/arm signals that are well known among the user population, so it is likely that the users would believe that technology would involve the least training. If we prototype with the accelerometer glove as the “send” technology, the team realizes we must do substantial research into feasibility of that wearable product. Our team is already seeking assistance from resources outside our team that are experts in that area, specifically the assistance of IPDL.

It is possible that the users will ask for the first prototype to include the bone conduction headphones as the “receive” technology. it is likely that the users would believe that technology would involve the least training, as that would again involve the least training on their part. Use of bone conduction headphones as the “receive” technology will also require some research.

Develop Initial Prototype Evaluation Plan

Depending on the send and receive technologies selected, we will consult with the users and select the benchmark tasks that will help evaluate the prototype. This will help us determine how much of the interface we will need to develop for the initial prototype. We will select a subset of signals and orders that are normally used. For example, there are 30 standard hand and arm signals; if we are using the accelerometer glove as the “send” technology, we will select and support a limited number of those signals in the initial prototype.