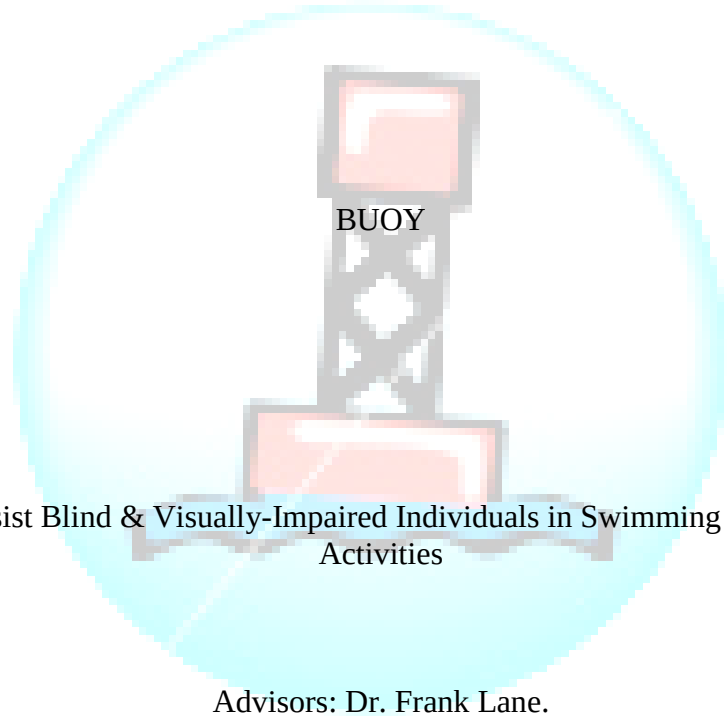
IPRO 310 Final Report

Spring 2010



BUOY

Devices that Assist Blind & Visually-Impaired Individuals in Swimming and Other Exercise Activities

Advisors: Dr. Frank Lane.

1. Executive Summary

This IPRO is working on the problem of creating an assistive device that will help blind and visually impaired (BVI) individuals exercise in a swimming pool and elsewhere with increased independence and also to present this technology to the community in a way that is usable to them. In the interest of achieving both of these goals the team has organized its structure into a technology team and a communication team, so that once the device has been created the methodology for teaching the community to use it will already be tested and approved.

The technology team took information from surveys of the community conducted in previous semesters and determined that it could best serve the community by developing a device geared towards use in recreational swimming. In the interest of this goal, the team focused on the radio frequency (RF) technology devised in previous semesters as the basis of their device.

Although a working circuit was designed, a fully functional device was never successfully constructed in previous semesters, so subject matter experts were consulted. After reviewing our specifications the subject matter expert brought up many relevant points that led to a review of the other available technologies. Sonar and radar were among the top choices of the subject matter expert. However, upon intense investigation of these technologies, it was decided that they were not feasible without the direct assistance of a team of experts.

Once it was decided that RF technology would be most viable for our purposes, the previous semester's circuit diagram was reviewed and improved. Operating parameters were calculated and initial testing was conducted. These initial circuits were assembled and tested. Then the parts necessary to build a higher frequency device were ordered.

The communication team's effort began with researching how BVI individuals are normally taught to navigate in their everyday environments. Based on what was learned, an initial protocol was developed and tested on members of the team. From there the protocol was further refined and then tested on members of the IIT community. Building on the progress made last semester, the protocol was further refined to increase both safety and acquisition of a cognitive mental map. Student participants from IIT were tested using the new protocol. This testing showed improvements in both the efficiency and mental mapping of the subjects. If the IPRO continues next semester, testing will be continued and the protocol has been deemed ready to include BVI individuals in the coming tests.

2. Purposes and Objectives

Our mission is to develop, test and implement an assistive technology in collaboration with the blind and visually impaired (BVI) community that promotes safety and improves independence of BVI individuals while swimming. In attempting to achieve that mission our primary goal has been to design and develop a cost-effective, assistive technology prototype using radio frequency technology. In the design of this prototype, the main concerns were the discreet incorporation of the device in the pool environment and the identification of an effective method of communicating information between the device and the swimmer. Through surveys and interviews, the team established a set of device specifications that met the needs and desires of the BVI community as the team currently understands them, and to leave room to incorporate further input from the community. The team also worked diligently to enhance the continuity between the semesters by being thorough and clear in our documentation. The team hopes that this will expedite the process of creating a product that can be developed for the BVI community and fulfill the IPRO's mission.

As previously mentioned, this IPRO is serving the BVI community. According to U.S. Census Bureau News published in December 2008, there are approximately 7.8 million people, age 15 and older, who had difficulty seeing words and letters in ordinary newspaper print, including 1.8 million who are totally blind. According to this same census, 609,000 children in the United States live with some degree of visual impairment and over 50,000 of them are legally blind. This population is vulnerable both in the psychological context and from of the lack of assistive technology created with the direct input from the community. Most assistive technologies currently available to blind individuals for exercising do not meet their needs or are

too expensive. According to our research, a large portion of the BVI community lives beneath the poverty line, so making products for them affordable is crucial. It is an important part of the design process, to include the intended user – the BVI community. Assistive technologies exist to aid BVI swimmers in competitive or lane swimming but there are no current technologies that are practical for recreational swimming. Because there is a need for technology to aid in recreational swimming, this is the focus this IPRO has decided to take.

3. Organization and Approach

Our research began with a review of all the progress and data acquired in the history of this IPRO. According to the survey data from previous semesters, the current assistive technology does not allow BVI swimmers to swim as independently as they desired. The data also shows the BVI community's preference for tactile feedback from a device that would be economical for them to own. Also, as discussed above, this IPRO has focused on recreational swimming because this area lacks assistive devices whereas there have been numerous devices created for the arena of lane swimming. From the progress made in previous semesters, it was discovered that if all of the team's energy was focused on the creation of the prototype, the final prototype would not be able to move smoothly into a testing phase. This is why our IPRO team has divided into two developmental teams – Communication and Technology Team.

The Communication team this semester is geared toward refining and proving the validity of the protocol set in place by the previous semester for teaching BVI swimmers to use our assistive technology to form a strong cognitive spatial map of the pool. The research done the previous semester examined existing methods of mobility training. The team then used this information to write an initial testing protocol, which the team tested on members of the BUOY team wearing blacked out goggles to simulate blindness. Based on the results and feedback from last semester's pool testing, modifications were made to the procedure in order to improve the quality of the data gathered, clarify instructions given to the subject, and provide the most accurate facsimile of the conditions anticipated in the finished device. The script and exact protocol used during the current semester's research are located in Appendix 2.

The Technology team researched and analyzed the technological aspects of the prospective prototype device. At the start of the semester, all previously explored technologies were re-considered and notes from past semesters were thoroughly evaluated. The IPRO team decided to move beyond lane swimming to focus on recreational applications of the device and investigated various solutions, most notably sonar, radar, magnetic fields, and radio frequency. Further research was also conducted to specify the necessary components for the prototype such as batteries, resistors, capacitors, operational amplifiers, rectifiers, and other components. After designs were created based on this research, calculations were executed to ensure that the final circuit would run on a reasonable amount of energy and within the desired specifications. A magnetic design was also investigated and considered but was found to be impractical as it would require a dangerous amount of current and carried serious risk for those with pacemakers. At this point, a radio frequency transmitter designed last semester was reviewed. This design was built, and initial testing was conducted.

4. Analysis and Findings

We have thus far determined that the new protocol we developed ensures a stronger mental map without sacrificing the swimmer's sense of safety. This was achieved through splitting the training into two sections: one based entirely on walking, and one based entirely on swimming. Previously the testing had consisted of training being done solely with the participant walking and only a single swimming test, whereas the new protocol involves the participant going through every step of training both while walking and while swimming. Furthermore, we changed the focus of the protocol from establishing that the swimmer was comfortable to establishing that the swimmer had formed a strong cognitive-spatial map. In the interest of improving cognitive-spatial mapping a scale model of Keating Pool was constructed for use in future training to incorporate depth. Finally, we added new safety precautions such as a brief review of what the device can and cannot do as well as increasing the number of sighted individuals accompanying the participant in the pool.

Analysis of the various technologies led to the conclusion that most were not feasible and in some cases impractical. There were too many technical hurdles that needed to be overcome for technologies such as sonar and radar to be implemented. There were major issues with the air-water medium boundary refraction and reflection of the signal, where the device would not function properly if the signal were to pass the surface boundary. Moreover, issues with signal reflection and noise generated by the walls within the relatively small confines of a pool make this an issue that still has not been solved in larger bodies of water. Magnetic field technologies were impractical as it required a dangerous amount of current and the resulting field, pose serious risks to individuals with pacemakers.

After the technology team designed the new transmitter and receiver, the team conducted tests on them to determine if further modifications were necessary. The transmitter worked as expected with the exception of a few set-backs but was successfully tested underwater. The receiver proved to be more difficult to perfect; additions to the design may have to be implemented as work continues.

5. Conclusions and Recommendations

The conclusions for the Communication team are that our current protocol not only teaches the swimmer to be comfortable and confident using the device, but gives them a strong mental map of the pool. While further testing is still required to fully validate the protocol we feel that within another semester of testing the protocol will be validated enough that BVI individuals could be incorporated into the pool of subjects. We have begun to consider a more advanced phase of training that would include a model for illustrating depths in the pool, and a practice round of swimming in a noisy environment with other swimmers to address concerns about public pools.

Our recommendation would be to continue pool testing with the protocol used during this semester. Once a larger dataset has been acquired and validity has been shown, we recommend that the participant selection be expanded to include visually impaired individuals if not both blind and visually impaired members of the community. We recommend that this expansion take place within members of the Chicago Lighthouse community, given our long involvement with the people there, through data collected in previous semesters.

The conclusions for the Technology team are that although a functioning transmitter, which was tested under water, was completed, the entire receiver still requires debugging and/or redesigning. The bridge rectifier which will actually take the final signal and power the motor is not functioning properly. Currently, a new magnetic switch system is being integrated into the circuit and testing is being conducted to rework the circuit to accommodate this change. The method of using radio frequency transmission of communicating proximity location has been well researched and has been established as the most efficient method for our project. As a recommendation for the next semester, establishing early communication with the EE

department head would be very helpful in generating interest for this IRO amoung people with knowledge and experience in circuitry. This semester has been plaqued by limited circuitry experience as there was not a single EE student in the class. A team with such experience and knowledge would be better equipped to troubleshoot any problems which may arise. Furthermore, upon completion of the working model, a prototype built to our particular design specifications would complete the circuit aspect of this project and designing of the actual device would commence.

6. Appendices

APPENDIX 1

Category	Requested	Approved	Explanation	Status
Supplies	**$175 2/1/10**	**Awaiting**	**General circuit building materials, and general pool test supplies**	**Pending**
Equipment	**$200 2/1/10**	**Awaiting**	**-Vibration Motors -Water resistant wristbands -Batteries (for motors)**	**Pending**
Services	**$25 2/1/10**	**Awaiting**	**Printing etc.**	**Pending**
Participant Support	**$50 2/1/10**	**Awaiting**	**Paying a Lifeguard (As needed)**	**Pending**
Misc.	**$100 2/1/10**	**Awaiting**	**Used for team building exercises to be determined**	**Pending**
TOTAL	**$550.00**	**$0**		

Faculty	Email	Specialization
Frank Lane	lane@iit.edu	Rehabilitation Psychology
Dr. Ken Schug	kschug@msn.com	Biology, Chemistry, Physics
Dr. Phillip Troyk	troyk@iit.edu	Biomedical Engineering

Name	Email	Phone #
Amine, Mukarram	mamine@iit.edu	708-539-6364
Antony, Claude	cantony@iit.edu	708-289-7009
Chipman, Aubrey	achipman@iit.edu	214-546-5911
Choi, Lien	lchoi@iit.edu	312-725-3610
Dykeman, Kimberly	kdykeman@iit.edu	410-322-5160
Healton, Michaela	mhealton@iit.edu	763-913-0524
Jayanthy, Ashika	ajayanth@iit.edu	312-533-9822
McKinley, Matthew	mmckinle@iit.edu	408-375-6925
Noorts, George	gnoorts@iit.edu	847-321-5860
Reilly, Jeffrey	jreilly2@iit.edu	440-371-5019
Schafer, Michael	mschafe1@iit.edu	815-341-9489
Taylor, Joseph	jtaylo8@iit.edu	319-558-8442

APPENDIX 2

Communication Team Protocol and Script

Modified Experiment

1. Place tape at 9 locations (corners and midpoints) to indicate positions at which to vibrate the egg.
    a. "You will have a device on your wrist which will vibrate when it is within 4 feet of any wall within the pool (put the device on their wrist). We caution to use common sense throughout this experience. The device will only vibrate if it is within 4 feet of the wall, not if you are. Therefore, if your body within the range, but the device is not, you will not feel a vibration. If at any point the device vibrates indicating that you are near the wall but you are unsure of how close you might be, please use caution. Stop, take a moment to get your bearings, and proceed with caution. Our experiment is trying to help you create a mental map of the pool by doing various activities. If at any point, you feel uncomfortable, let us know and we will stop. There will also always be someone with you while you are wearing the blacked out goggles. Do you have questions before we proceed?"
2. Lead subject with blackout goggles on from locker room to pool (someone other than the guide)
    a. "You will now be led from the locker room to the testing area."
3. Describe vibration. (within 3 ft range)
    a. "When the device gets within 4 feet of the wall, the device will begin vibrating. Otherwise, there will be no vibration."
4. Have the subject walk to ladder with guidance from one person. The guide in the pool will describe the ladder to the subject. The subject will then use the ladder to enter the pool.
    a. "You are now in front of a ladder. There are 4 steps to enter the pool with handles on either side to help guide you."
5. Subject is led to nearest corner of the pool. Guide leads them around the pool once and only tells them midpoints and corners to turn at.
    a. "You are now in a corner of the pool and we are going to walk around the perimeter of the test area. I will be letting you know where the midpoints and corners are. Are you ready?"
    b. "This is the midpoint along the first wall, here is the first corner, we will be turning right"…etc.
6. The subject is led around a second time and told which quadrant they are in (pool will be divided into 4 quadrants). → only buzz within a 4 ft range
    a. "We will now proceed to go around the pool a second time, but this time I will tell you which quadrant number you are in. There are 4 quadrants. We are in quadrant 1 now…We are now at the midpoint passing into quadrant 2" …etc until back at the beginning.

7. Proceed based on acquisition of a mental map
    i. "Do you feel you have created a mental map of the pool?"
    b. If no
        1. "Since you did not pass, we will walk around again, this time giving you all of the information from the first two laps." repeat script from above
    ii. Taken around again – condense midpoints and quadrants into one revolution instead of two
    iii. Repeat this at any point they fail from "Do you feel you have created a mental map" portion
    c. If a mental map has been formed
        1. "Please find the midpoint along the first wall, and let me know when you think you are there"
    ii. Find midpoint along Wall 1
        1. "From your current location, can you find the midpoint along the second wall?"
    iii. Find midpoint along Wall 2
        1. "From your current location, can you find the center of the pool" – NO TIPS or HINTS
    iv. Find center of pool
        1. "Can you point in the direction of quadrant 2… 4… 3…. 1" (1-4 chosen at random)
    v. Point in direction of all the quadrants (at random)
        1. "You now have 5 minutes to walk around freely in whichever direction you wish. Please make sure to walk and not swim. I will be near you if you need anything. Do you have any questions? … Ok, you have 5 minutes starting now…"
    vi. Move around for 5 minutes freely, stop, tell us which quadrant you are in
        1. "Please stop. Can you tell us which quadrant you think you are in?" If correct, continue. "Can you locate the other quadrants?"
    vii. Subject is led to starting corner of the pool. Guide leads them around the pool once and only tells them midpoints and corners to turn at.
        1. "You are now in a corner of the pool and we are going to swim around the perimeter of the test area. I will be letting you know where the midpoints and corners are. Are you ready?"
        2. "This is the midpoint along the first wall, here is the first corner, we will be turning right"…etc.
    viii. The subject is led around a second time and told which quadrant they are in (pool will be divided into 4 quadrants). → only buzz within a 4 ft range
        1. "We will now proceed to go around the pool a second time, but this time I will tell you which quadrant number you are in. There are 4 quadrants. We are in quadrant 1 now…We are now at the midpoint passing into quadrant 2" …etc until back at the beginning.

ix. Proceed based on acquisition of a mental map
    1. "Do you feel you have created a mental map of the pool?"
x. If no
    1. "Since you did not pass, we will walk around again, this time giving you all of the information from the first two laps." repeat script from above
    2. Taken around again – condense midpoints and quadrants into one revolution instead of two
    3. Repeat this at any point they fail from "Do you feel you have created a mental map" portion
xi. If a mental map has been formed
    1. "Please find the midpoint along the first wall, and let me know when you think you are there"
xii. Find midpoint along Wall 1
    1. "From your current location, can you find the midpoint along the second wall?"
xiii. Find midpoint along Wall 2
    1. "From your current location, can you find the center of the pool" – NO TIPS or HINTS
xiv. Find center of pool
    1. "Can you point in the direction of quadrant 2… 4… 3…. 1" (1-4 chosen at random)
xv. Point in direction of all the quadrants (at random)
    1. "You now have 5 minutes to swim around freely in whichever direction you wish. Please make sure to swim and not walk. I will be near you if you need anything. Do you have any questions? … Ok, you have 5 minutes starting now…"
xvi. Move around for 5 minutes freely, stop, tell us which quadrant you are in
    1. "Please stop. Can you tell us which quadrant you think you are in?" If correct, continue. "Can you locate the other quadrants?"
xvii. Subject has to find ladder and get out of the pool
    1. "Can you make your way back to quadrant 1 and the ladder, and then exit once I tell you to proceed?" Once there "Thank you, you may now exit the pool and someone will guide you out."

Wet Pool Testing

Location: Keating Pool (shallow end)
Subject 1: Protocol modified to add mental map section
Subject 2-5: Protocol modified to add mental map section, safety measures, and separate walking and swimming sections

Total Laps: 9
Total Time: 52 minutes

Comments: Testing ended when subject hit his head on the wall

Subject	Mental Map?	Laps until mental map	Midpoints/Center	Walk/Swim	Adjacent/Quadrant 1 – Exit
1	N	5	P/P	P/F	
				P/F	
				P/P	F
					F

Additional Information:

Age: 19
Sex? M
Do you currently swim? No, once or twice a year at best.
Have you ever seen this pool before? Yes
Did you feel safe? At first yes, but not after the device began lagging
Was there an aspect of the training that was particularly helpful to you in forming a cognitive-mental map? Counting steps was helpful; while walking water level also helpful.
Did the vibrating device help you? Somewhat, not fool proof
If so, in what way was it helpful? Was good for telling where boundaries are.
Were there any parts of the test you found easy (specific tasks)? Yes
If so, describe which tasks you found easy and if possible, what made them easy for you? Moving between quadrants 1-4/2-3. Easy because of water level.
Which tasks did you find most challenging? Locating after free swim.
Any other thoughts or reactions to the training you want to share with us? Have a way to detect 2nd wall in corner; device good for boundaries, not good for specific location; not enough landmarks, safety, a way to not hit walls

Laps: 8
Total Time: 1 hour 8 minutes
Comments:

Subject	Mental Map?	Laps until mental map	Midpoints/Center	Walk/Swim	Adjacent/Quadrant 1 – Exit
2	Y	2	F		
			F		
			F		
			P/P	P	
swim	Y	2	F		
			P/P	P	P/P

Additional Information:

Age: 21
Sex? M
Do you currently swim? No (Swims recreationally, but hardly ever)

Have you ever seen this pool before? Yes
Did you feel safe? Yes
Was there an aspect of the training that was particularly helpful to you in forming a cognitive-mental map? Laps around the pool
Did the vibrating device help you? Yes
If so, in what way was it helpful? Protecting his noggin
Were there any parts of the test you found easy (specific tasks)? Yes
If so, describe which tasks you found easy and if possible, what made them easy for you? All about same difficulty once he figured out the device
Which tasks did you find most challenging? Finding pool center
Any other thoughts or reactions to the training you want to share with us? Safety more because of people than device, more precise vibrations

Laps: 7
Total Time: 37 minutes
Comments:

Subject	Mental Map?	Laps until mental map	Midpoints/Center	Walk/Swim	Adjacent/Quadrant 1 – Exit
3	Y	2	P/F		
			P/F		
			F		
			P/P	P	
swim	Y	2	P/P	P	P/P

Additional Information:

Age: 19
Sex? F
Do you currently swim? Yes, weekly swim laps to work out
Have you ever seen this pool before? Yes
Did you feel safe? Yes
Was there an aspect of the training that was particularly helpful to you in forming a cognitive-mental map? Crossing midpoints/turning
Did the vibrating device help you? Yes
If so, in what way was it helpful? Finding corners, swim parallel to wall
Were there any parts of the test you found easy (specific tasks)? Midpoints
If so, describe which tasks you found easy and if possible, what made them easy for you? Counting steps
Which tasks did you find most challenging? 5 minute free swim, finding center of pool

Laps: 7
Total Time: 35 minutes
Comments: Forced to change personal from this test onward, this test was with a former buoy member therefore potential biased, also was unable to finish due to time constraints

Subject	Mental Map?	Laps until mental map	Midpoints/Center	Walk/Swim	Adjacent/Quadrant 1 – Exit
4	Y	2	P/P/F		
			P/P/F		
			P/P/F		
			P/P/P	F	
				P	

Additional Information:

Age: 21
Sex? M
Do you currently swim? Yes, weekly for excercise
Have you ever seen this pool before? Yes
Did you feel safe? Yes
Was there an aspect of the training that was particularly helpful to you in forming a cognitive-mental map? Being guided
Did the vibrating device help you? Yeah, slow to start
If so, in what way was it helpful? Told when wall was close
Were there any parts of the test you found easy (specific tasks)? Midpoints
If so, describe which tasks you found easy and if possible, what made them easy for you? Counting steps
Which tasks did you find most challenging? Center of the Pool, failing and not knowing why
Any other thoughts or reactions to the training you want to share with us? Helped to know what when wrong when failing a step

Laps: 7
Total Time: 42 minutes
Comments: At least one failure may have been a result of an operator error of the person activating and deactivating the vibrating device

Subject	Mental Map?	Laps until mental map	Midpoints/Center	Walk/Swim	Adjacent/Quadrant 1 – Exit
5	Y	2	F		
			P/P/P	P	
swim	Y	2	P/F		
			P/P/P	P/P	P

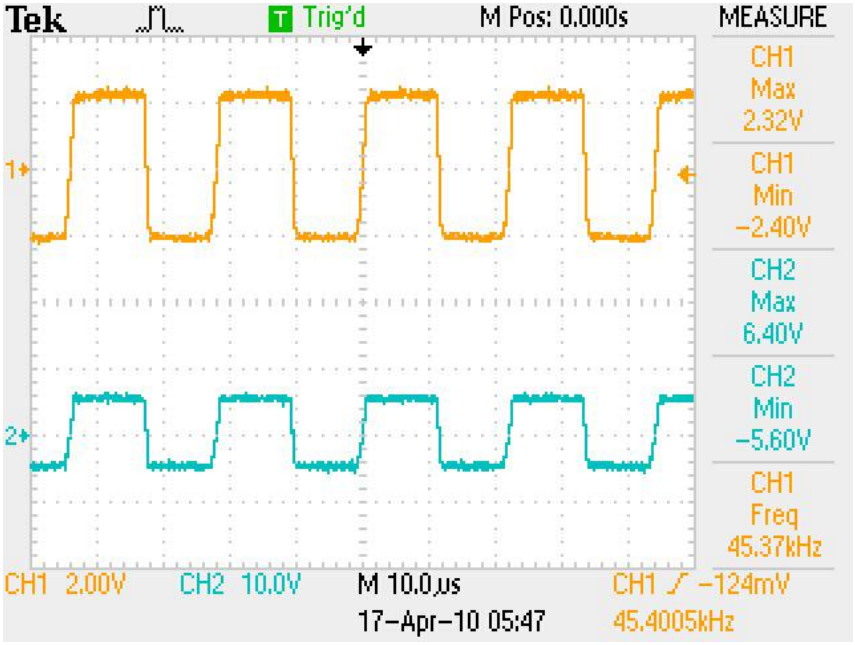
Additional Information:

Age: 21
Sex? M
Do you currently swim? No, but 16/17 years prior experience
Have you ever seen this pool before? Yes
Did you feel safe? Yes

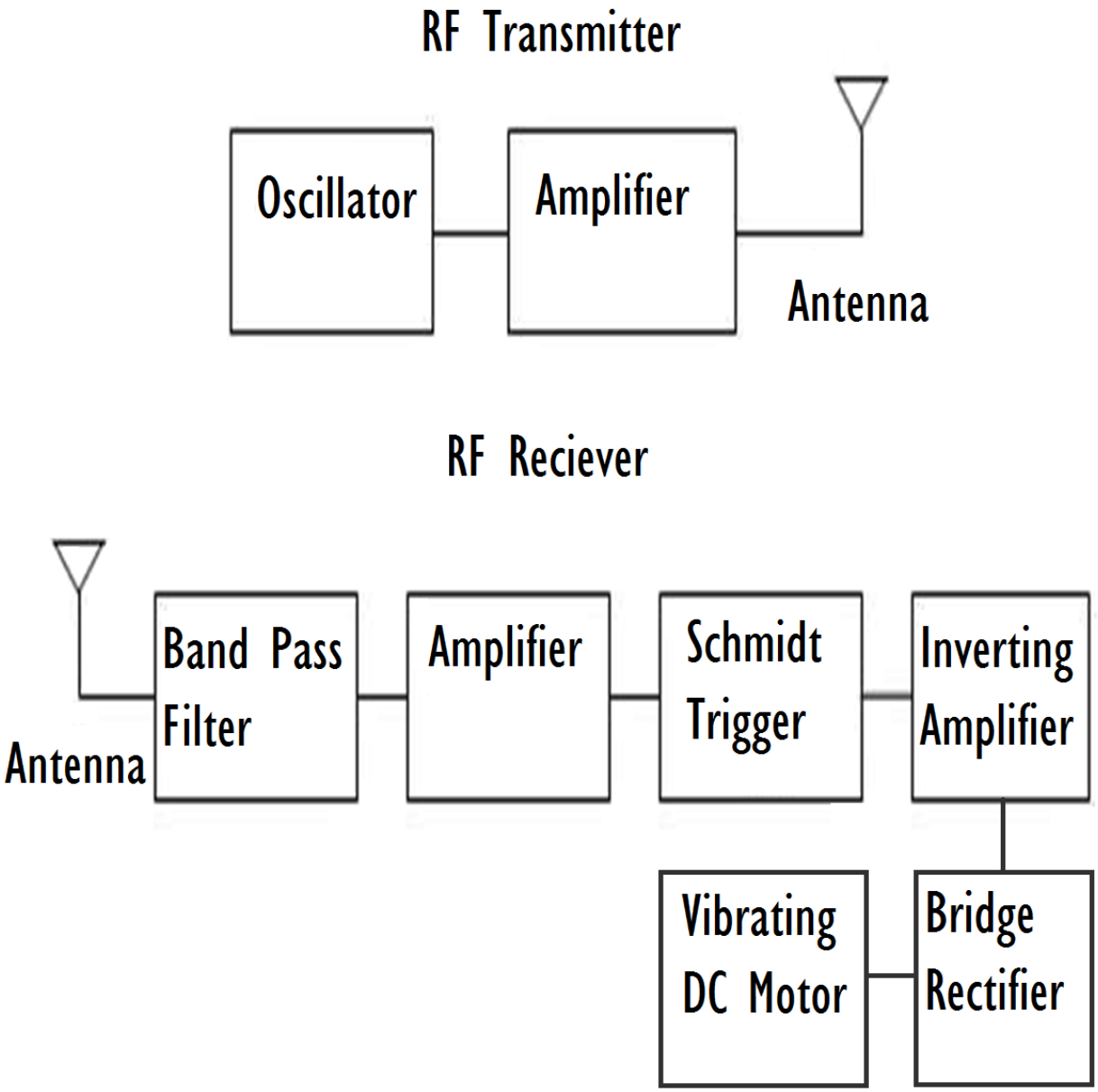
Was there an aspect of the training that was particularly helpful to you in forming a cognitive-mental map? The Buzzer, finding corners
Did the vibrating device help you? Yes
If so, in what way was it helpful? See Above
Were there any parts of the test you found easy (specific tasks)? Midpoints
If so, describe which tasks you found easy and if possible, what made them easy for you? Using blocks to direct as tactile help
Which tasks did you find most challenging? swimming
Any other thoughts or reactions to the training you want to share with us?
Used sound for orientation, different vibrations could mean different things like 2 buzzes for a corner and 1 for a midpoint.

APPENDIX 3

Technology team transmitter and receiver block diagrams.



Voltage output of transmitter.



Schematic of transmitter and receiver.