IPRO 310 Final Report

Fall 2009

BUOY

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

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1. Executive Summary

This IPRO is working on the problem of creating an assistive device that will help blind and visually impaired (BVI) individuals to be able 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 reorganized 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, they focused on the electromagnetic field technology devised in previous semesters as the basis of their device. They quickly found that the existing device left over from the previous semester would not suit their needs so after a great deal of studying literature on circuit design a new transmitter and receiver were designed. These circuits were simulated, refined, simulated again, and then the parts necessary to their construction were ordered. There were several setbacks in getting the appropriate parts for the device but despite these problems the initial results are incredibly promising.

The communication team started with researching how BVI individuals are normally taught to navigate in their everyday environments. From this a prototype protocol was developed and tested on members of the team. These tests lead to a refined protocol tested on members of the IIT community. It was discovered during this testing that the method that was being used to approximate the tactile feedback that will be provided by the final device was insufficient. A

replacement remote controlled tactile feedback device was procured and used in several subsequent wet and dry tests. These tests showed that the protocol is sound but a much greater sample size is needed to generate statistically significant results. Testing will be continued next semester and the protocol has been deemed ready to include BVI individuals in the coming tests.

2. Purposes and Objectives

This IPRO's mission is to develop, test, and implement assistive technology with the community that promotes safety and improves independence of BVI swimmers. In attempting to achieve that mission our primary goal has been to design and develop a cost effective assistive technology prototype using radio technology. In the design of this prototype the main concerns were the incorporation of the device in the swimming environment with discretion, and the identification of effective means of communicating information from such a device to the swimmer. With the modification of the BUOY Website, and the use of surveys and interviews, the team has attempted to create a device that meets the needs of the BVI community as the team currently understand them, and leave room to incorporate further community input. The team has also worked diligently to enhance the continuity between the semesters by being thorough and clear in our documentation. The team hope that this will expedite the process of creating a product that can be marketed to the BVI community and fulfill the IPRO's mission.

The community that this IPRO is attempting to serve is as mentioned above the BVI community. According to U.S. Census Bureau News published in December 2008, there are nearly 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 completely unable to see. 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 not only a vulnerable

population in the psychological context, but also vulnerable in that due to lack of assistive technology created with the involvement of the community. Most assistive technologies currently available to allow blind individuals to exercise are insufficient or too expensive. According to our research and our survey data, a large portion of the BVI community lives beneath the poverty line, so making products for them affordable is pivotal. The BVI community is both an important part of the design process of this product and its intended end user.

Currently while there are a number of assistive technologies designed to aid BVI swimmers in the competitive or lane swimming arena there is no current technology for practical recreational swimming. Because of this gap in the available technology, this IPRO has decided to focus on recreationally applicable technologies rather than continuing to pursue lane swimming technologies in a market that has plenty of suitable technologies already in use. This being said, in the development of a protocol to teach blind swimmers to use this IPRO's prototype a number of existing technologies are being employed including, in the early stages of development, the passive device created at Notre Dame.

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. Also shown in this data was that the device would need to be economical to be marketable, and that the method of feedback preferred by the BVI community is tactile. In outside research the team found that technology in the field of lane swimming has come a long way since the start of this IPRO and therefore there is less need in this field for innovation as in the field of recreational swimming.

This is why the device the team is developing for this semester is geared toward recreational and general exercise applications. From the progress made in previous semesters, it was discovered that if all 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 is geared toward developing a prototype protocol for teaching blind swimmers to use our assistive technology to identify their location in a pool. The research started with studying existing methods of mobility training. The team used this information to write an initial prototype protocol, which the team tested on members of the BUOY team wearing blind goggles. Notes were kept and photographs were taken during each test, and modifications were made to the procedure throughout testing to improve the quality of the data gathered, to clarify instructions given to the subject, and to provide the most accurate facsimile of the conditions anticipated in the finished device. In the spirit of making the testing environment as close to the environment created by the finished device, the team have used tactile feedback throughout our testing using first a passive device that floated in the water, and when this did not provide the accuracy that was desired the team obtained a remote controlled facsimile of the device the team are attempting to create. Our final stage of testing consisted of testing with the existing protocol with this facsimile device. The script and exact protocol settled upon is 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 considered and notes from past semesters were thoroughly checked. It was in the technology team that the need to move towards recreational applications was discovered and in the vein

various electromagnetic solutions were the idea that the team chose to pursue. Research cannot be left out from the progress of the technology team. The team spent time researching the different approaches to constructing a circuit that would run via; EMF, magnetic field, and the eventually selected RF technology. Research was also necessary later on in the process to procure the necessary components for the technology prototype such as resistors, capacitors, and other components. After designs were created from this research calculations were executed to ensure that the final circuit would run on a reasonable amount of energy and within the desired range. A magnetic design was also researched and considered but was found to be impractical as it would require an amount of current surpassing that of a bolt of lightning. At this point a radio frequency transmitter was designed, and tested in simulation. Appearing sound, this design was built with available supplies, but did not fulfill the team's purposes. It was subsequently redesigned along with a corresponding receiver. Parts for these had to be obtained from various sources, before the prototype device could finally be built.

4. Analysis and Findings

After the Communication team ran a total of seven tests with six subjects, the following findings were reached. The major goal of training swimmers to create a strong mental map of the pool was not achieved in every test; however the sub-goal of allowing the swimmer to be comfortable through the employ of the device (both the passive and active stand-in devices) was achieved universally. This led the team to conclude that a sense of safety did not indicate the presence of a strong mental map. Also, the fact that some swimmers could create a strong mental map after only having the pool described to them for two laps around the perimeter, whereas others had a weaker mental map even after nine laps indicates the need for a large quantity of

further testing to determine the full range of outcomes possible and where the areas of high concentration are located. It was also concluded that further measurement needed to be applied to the strength of the final mental map achieved, which is discussed further in the recommendations section. The resources exploited by the communication team were the passive device, and later a remote control tactile feedback device, as well as the IIT community who provided test subjects, and lifeguards for the pool testing.

After the technology team designed the new transmitter and receiver, the team ran simulations on PSPICE software. This simulation was a bit problematic in that it did not have the exact parts we were planning on using. We accounted for this, and the results of the simulations showed a working transmitter. The receiver also was functional in the simulation. After ordering the parts, we began construction on the circuits. Initial testing on the devices showed that the operation amplifiers (constituent parts of the design schematic) were not processing input signals fast enough. This means that a higher slew rate is required. The oscilloscope we had access to also was problematic. Its maximum frequency was below the frequency used in the device.

5. Conclusions and Recommendations

The conclusions for the Communication team is that creating comfort for the subject has been achieved but more testing is needed to determine the average number of laps required for a BVI individual to develop a strong mental map as well as the permanence of that map. The recommendation of the Communication team is therefore that a great number of subjects need to be tested using the protocol outlined in appendix 2 so that a statistically significant amount of data can be gathered on the average amount of laps it takes a BVI individual to complete the listed tasks. In addition a study of a more longitudinal nature needs to be conducted to determine

the permanence of the mental map created and what steps need to be taken at each individual time of swimming after the initial training to maintain the strength of the mental map, and the safety of the swimmer.

The conclusions for the Technology team include: the simulations show that the circuits work, and that the circuit needs to be reconstructed with new operational amplifiers with higher slew rates, these rates should be on the order of 1700-2000 microseconds. For recommendations and next steps, we need to recruit EE's for the construction and design phase. Also, we need to talk to the EE department to see if we can get access to a higher quality oscilloscope.

6. Appendices

APPENDIX 1

Category	Requested	Approved	Explanation	Status
Supplies	$100 2/6/09	Awaiting	Wires, building materials, solder, and other miscellaneous items for modifying equipment	Pending
Equipment	$375 2/6/09	Awaiting	$10 x 10 Vibration Motors $15 x 5 Water resistant wristbands $20 x 5 Batteries (for motors) $100 x1 R.F. Transmitter and receiver	Pending
Services	$25 2/6/09	Awaiting	Printing etc.	Pending
Travel	$75 2/6/09	Awaiting	Trips to stores for equipment and facilities to administer surveys, interviews and product testing	Pending

Participant Support	$100 2/6/09	Awaiting	Used for experiment/trial participants if needed	Pending
TOTAL	**$675.00**	**$0**		

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APPENDIX 2

Communication Team Protocol and Script

Modified Experiment

1. Place tape/tappers at 6 locations (indicate midpoints also) to indicate positions at which to vibrate the egg.
    a. "You will have a device on your wrist which will vibrate when you are within 3 feet of any wall within the pool. (put the device on their wrist) 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 black-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, and I will describe the path" (stairs, obstacles, etc)
3. Describe vibration. (within 3 ft range)
    a. "When you get within 3 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 when to turn.
    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 3 ft range
    a. "We will now proceed to go around 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 comfort level
        i. "Do you feel comfortable enough to do a few tests regarding positioning in the pool?"
    b. If not comfortable
            1. "Since you did not pass, we will walk around again, this time combining the midpoint and quadrant information into one round." 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 "If comfortable" portion
    c. If comfortable
            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. "You now have 5 minutes to swim freely. Please make sure to swim and not walk. Any questions?...You have 5 minutes starting now"
vii. Have the subject move to a random adjacent quadrant from the one they are in (any Quadrant besides Quadrant I)
    1. "Please stop. Can you tell us which quadrant you think you are in? That is correct. Now, can you move to quadrant X from your current location, and let me know when you think you are there?"
viii. 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."

How many learning trials are necessary for them to go around independently?
"The purpose of this experiment was to see if you could create a mental map of the pool and able to maneuver around and feel safe enough to swim recreationally. Did you feel safe? Do you have any other comments or suggestions? Thank you very much for your time."

Wet Pool Testing

Location: Keating Pool (shallow end)
Subjects 1 and 2: Tappers Subject 3: Vibrating Egg Device

Total Laps: 5
Total Time: 53 minutes
Comments: Unable to concentrate on position in the pool, did not fully understand purpose of test

Subject	Comfortable?	Laps until comfortable	Midpoints/Center	Walk/Swim	Adjacent/Quadrant 1 – Exit	
2	Y	2	F			
	Y	1	F			
	Y	1	P/F			
	Y	1	P/F			
	Y	1	P/P	F		
	Y	1	P/P	P/P	F	
	Y	1		P	P	

Total Laps: 7
Total Time: 45 minutes

Comments: After walking, had a minimal idea of map of pool. Said unless he had swam to different corners during the free swim, he would not really know where he was.

Subject	Comfortable?	Laps until comfortable	Midpoints/Center	Walk/Swim	Adjacent/Quadrant 1 – Exit	
3	Y	2	P/P	P/P	P/P	

Total Laps: 2
Total Time: 23 minutes
Comments: Felt like he had a good idea of where he was in the pool once he figured out his technique of knowing if he was near a wall or a corner.

Dry Test Results

Location: Basement of the HUB

Subject	Comfortable?	Laps until comfortable	Midpoints/Center	Free Walk	Adjacent/Quadrant 1 – Exit	
1	Y	2	P/F			
	Y	1	P/F			
	Y	1	P/F			
	Y	1	P/F			
	Y	1	F			
	Y	1	P/P	P	P/F	
	Y	1		P	P/F	
	Y	1		P	P/P	

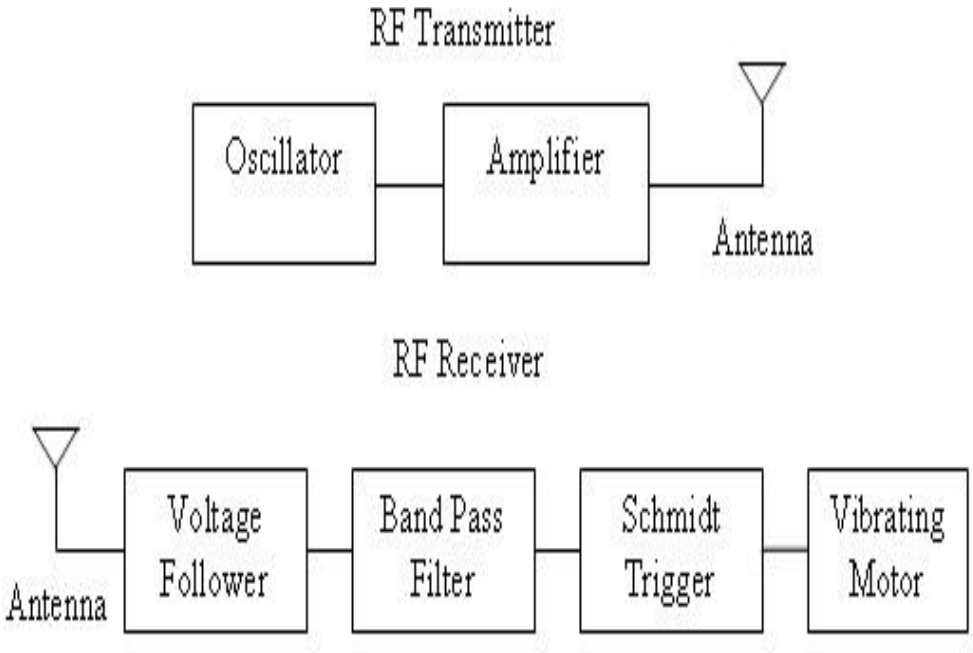
Total Time: 33 minutes
Total Laps: 9
Comments: After he actually used the egg to help him, he felt he had a good spatial map of the area towards the end.

Subject	Comfortable?	Laps until comfortable	Midpoints/Center	Free Walk	Adjacent/Quadrant 1 – Exit	
2	Y	2	P/P	P/P	P/P	

Total Time: 14 minutes
Total Laps: 2
Comments: Liked that guide was not telling him anything even if he asked. Thought corners were marked well. Actually thought about where the walls would be and gained a good understanding of where he was.

APPENDIX 3

Technology team transmitter and receiver block diagrams.



PSPICE display showing a need for higher slew-rate operation amplifiers