Measuring the Swimming Reaction Time for Analysis

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Knowing an athlete's reaction time on the start is most crucial, as it can mark if there has been a false start. Over the past few years, technology has developed various starting systems that can track this type of data and provide a secondary check for officials/referees. In swimming, these devices are typically seen at higher meet competitions and are rarely accessible for practice means. This work hopes to provide an accessible way for both athletes and coaches to work on the swimmers' starts through tracking their data in a dashboard and device during their practices. For our early prototype, we used Arduino Uno and React charts for the dashboard that will be presented to the swimmer and coach upon usage. Upon analyzing other works, we attempt to answer the following research question - How can an early prototype measure and analyze a swimmer's reaction time and time off the blocks?

Additional Key Words and Phrases: athlete, data tracking, reaction time, Arduino, dashboards, swimming, false start

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1 INTRODUCTION

Over the past few years, there has been many technology devices that have developed in order to track an athlete's reaction time on their starts. These devices can help to flag and be used as a secondary check to see if the athlete has false started. In swimming, these starting devices are usually only seen at higher meet competition and most teams do not have access to them when at practice. There is also no known application that tracks the swimmers' reaction time to be able to analyze for a swimmer and coach in order to enhance the athlete's start work.

This research will aim to create a working early prototype to test a swimmer's reaction time, and to provide a mechanism to flag a false start. We use Arduino Uno boards and various sensors to provide an early prototype that athletes can test and give feedback for future devices. This data compiles into a dashboard for athletes and coaches to analyze to better their performance in practice and at competitions. The system will also keep track of false starts and average reaction time. It will flag the lane and set off an alarm. This device will be beneficial to both practice and competition. In order to make the device accessible, there will be a buzzer as well as LED lights for the start signal. This device will pave the way for future research and more advanced prototypes. Our research hopes to answer - **How can an early prototype measure and analyze a swimmer's reaction time and time off the blocks?**

The following sections describe related work, building and testing the prototype, study design, and possible future work.

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2 RELATED WORK

In this section we present prior work about the Science of Reaction Times, Existing Reaction Timing Systems, Dashboards for Data Tracking, and Waterproof Systems.

2.1 Science of Reaction Time

Milloz defines reaction time as the measurement of how long it takes the individual to perceive, process and initiate movement in response to a stimulus [Milloz 2020]. Start information systems (SIS) use different technologies to measure reaction time. The time it takes from the signal to the onset of muscular activation is called the pre-motor time. This process is estimated to take 55 - 119 ms. Next is motor time, which is the time it takes for the onset of external force production to begin, which is about 2 - 39 ms. Following this, there is the potential delay from SIS systems, which is an unknown value. All together, these stages make up the reaction time value outputted by an SIS system, ranging from about 122 - 259 ms.

Reaction time can vary depending on the type of stimulus the athlete receives. Simple auditory stimuli, which is typically used in athletics, produces the quickest response. Shelton compared auditory and visual simple reaction times, and found that auditory reaction time was faster [Shelton and Kumar 2010]. This study was completed in a lab, not in athletics, but previous research has also shown that auditory stimuli takes about 8-10 ms to reach the brain, whereas visual stimuli takes 20-40ms. This implies that the faster the stimuli reaches the motor cortex, the faster the response will be.

Reaction time below 100ms is considered a false start, because it is assumed the athlete anticipated the start. However, Milloz argues that this benchmark is not valid [Milloz 2020]. While there is a neuro physical limitation to perception and processing of the start signal, the 100ms mark was only determined by a study on male Finnish national level sprinters. It is argued that this would not apply to all performance levels or types of sensors, and it should be more widely tested. Overall, the study of reaction time is complex, as it is hard to determine the exact moment that an athlete's brain processes the signal. There are still many shortcomings in the technology.

2.2 Reaction Timing Systems

Milloz believes the goal of SIS systems is to keep races fair by limiting anticipation, so reaction time must be measured in uniform conditions. When a real gun was used in track races, every 3.5 meters an athlete is from the gun added .01 to their time, due to the speed of sound. Therefore, there must be a starting signal at each block. It has also been shown that the louder a signal is, the faster the reaction time is.

Currently, Milloz states that sensors on blocks are used to convert leg movement into a signal that determines reaction time. Force transducers, accelerometers and force dependent closure switches are all used. However, simple force threshold systems increase reaction time by 26ms on average when compared to more sophisticated systems. Visual detection is currently more accurate than automated detection, but it is not compatible with real time requirements in competition. Additionally, all existing tech measures leg movements, but the sprint start is a full body movement. Some research has suggested that the arms respond faster than the legs. There was an example trial where the reaction time in the arms was 61ms, but full body was greater than 100ms.

There are a few different existing reaction time starting systems developed for track. The Swiss Timing false start detection system ASC3 (Automated Start Control), prints reaction time ranging from 300 ms before the signal and up to 700 ms after the signal. The force curve is displayed on screen, with the sharp increase in force being the indication for reaction time. If an athlete false starts, a signal is transmitted to the central station that sets off the block loudspeakers. This product is sold as sets of 6, 8 or 10 blocks. Another technology is the Lynx ReactTime False Start Detection System, which uses sensor units that are sold separately from blocks. They analyze reaction time up to 1/1000th of a second, and it syncs with ReactTime championship software that views, analyzes, and graphs the force data.

2.3 Dashboards for Data Tracking

Studies have also looked into the usage of dashboard to track data. One study looked into using three sensors that connect to an Arduino micro-controller, that would then send data to a dashboard using Firebase, which could be analyzed by the athlete, coaches, and nutritionist [Islam et al. 2022]. Through this dashboard they were able to assess an athlete's workout and if their nutrition was in check. Overall, the study found to ensure for better athlete performance, for monitoring and managing. Another study also looked into designing dashboards for visual display in measurement and performance [Maheshwari and Janssen 2014]. If dashboards are simplified and allow for customization, users will find it to be effective and use it for their everyday use. Overcomplicated data or poor visualization can lead to misuse and confusion. The overall usage of dashboards are to create organized collected data that helps to visualize to a user and manage for own usage.

In sum, there is lots of data that looks into the science of reaction time and the marks of what is considered a false start. Additionally, there are lots of existing reaction timing systems that look at leg movement with different sensors to track the reaction. Dashboards have also been used to be able to communicate information between users that can help to create better performance and easy accessibility. Further studies are to look into mobile applications that can combine reaction time and dashboards that can help with athletic training purposes for later competition.

2.4 Waterproof Systems and Material

In order to use build waterproof, we think to use similar material to current swimming touch-pads. These are used within the water to capture when a swimmer touches to flipturn or finish a race. This consists of a non-skid surface to prevent slipping, internally sealed switches to capture touch, and all plastic construction making it durable. Ideally we would use this material or similar with similar sensors to capture the swimmer's reaction time.

There are waterproof sensors such as: Arduino waterproof temperature sensors and waterproof ultrasonic sensor. Using waterproof connectors with used along with potting compound to help make the device waterproof, but needs to be very cautious in setting it up. Unfortunately, these are not sensors that we would use for our project. In our early prototype, we did not test in the water, since our device and sensors are not waterproof.

3 BUILDING THE PROTOTYPE

In this section, we will talk about the device and sensors used to build the prototype. Additionally, the coding and charts built to be presented to the athlete and coach.

3.1 About the Device

The prototype utilizes two Arduino Uno boards. One board acts as the starting system which communicates with the Python code, while the other is the timing system that uses interrupt code to gather reaction time avoiding as much latency as possible. Sensors used for the starting system were: LED light, button, and buzzer. The button initiates the start signal, which sets off the LED light and buzzer and begins the timer. Meanwhile, the timing system used: LED light, touch, and buzzer. The timer stops when the athlete releases the touch sensor. This system will simulate the athlete jumping off the block. We also added the buzzer to sound off if the reaction time is under 100ms. The time is recorded and entered into a database, along with the athletes name. The data displays in a dashboard for analysis by the athletes and coaches.

3.2 Coding and User Charts

There are two Arduino sketches, one for the starting system board and another for the timing system board. The Python code acts as the controller, and it connects the two Arduino Uno's together and manages the data. The starting system sketch sends a command to the Python code, sets off the buzzer, and flashes the light when the start button is pressed. The Python code listens for this ’START’ command, and when it receives it, Python sends a command to the timing system Arduino. When this command reaches the timing Arduino, the time is recorded in milliseconds (ms), and an interrupt is attached to the touch sensor. When the interrupt is triggered, the end time is recorded. The reaction time is the difference between the start and end time. The time is sent back to the Python code.

Once the Python program receives the reaction time, it connects to a Firebase Realtime Database. The name of the user is inputted into the Python terminal. A child node is created using the user’s name, and it contains children for reaction time values, number of false starts, and average reaction time. There is also a child for the ’selected person’, which is reset to the user. We then created a simple React app that pulls the data from Firebase, and creates a chart using ChartJS of the selected user’s reaction times.

4 TESTING THE PROTOTYPE

In this section, we talk about how we conducted using our prototype with participants. This is only a pilot run of the prototype. In the Methods section, we explain how we would conduct this study in the future work.

4.1 Participants

We brought it to the RIT pool to briefly test with members of the RIT Swim Team and the head coach. In total there were 3 participants whom which we tested with.

4.2 Testing the Device

We did a quick demo of our prototype and explained what each of the Arduinos do. We then set up two laptops: one with the code, both Arduinos, and console output, while the other with the Firebase Database and React Chart. We wanted the users to be able to see everything working in real time, specifically with the graph changing in response to the inputted reaction time.

4.3 Analysis

Data analysis can be done using our React app, which contains a chart of the current user’s reaction times. It provides a good visual presentation of trends, and it is easy to quickly get an idea of the user’s status and improvement. It also shows the average and the number of false starts. The members of the RIT Swim Team, as well as the head coach, thought that charts and graphs were a helpful way to organize information, since it is scannable and easy to interpret.

5 METHODS

The main goal of this study is to understand the reaction time of athletes, specifically swimmers. Also to inform both the athlete and coach for training purposes through a dashboard.

5.1 Participants

For this study, we would recruit participants that are current collegiate swimming athletes and coaches. A total of 5 or more athlete participants are to be recruited to allow for various data points. Also, at least one coach to view in their perspective.

5.2 Structure of Study

This study will be broken into 3 parts: a semi-structured interview, testing the device and dashboard, and a follow-up questionnaire. The interview will provide useful feedback from the athletes and coaches on their initial thoughts about utilizing reaction time data in training, as well as how they would like the information to be presented. The device will be tested to ensure that is it working according to plan, and the follow-up questionnaire will provide additional feedback on the successes and shortcomings of the device.

5.2.1 Semi-structured Interview. Upon meeting participants, we will conduct a semi-structured interview to inform about our device and dashboard. Initial thoughts about using reaction time metrics for training will be collected from the participants. Participants will also be asked about how they would like the data to be presented and what customization should be used, if applicable.

5.2.2 Testing the Device and Dashboard. Each of the athlete participant is to test with the device five times by diving into the pool. Each trail will be recorded in order to see helpful data points for their training. After completing the five trials, they will be shown their data on the dashboard.

5.2.3 Follow-up Questionnaire. Afterwards, participants will be presented with a questionnaire, that will consist of short answers, 5-point Likert scale, and multiple choice questions. The questionnaire is to reflect on the participants final thoughts: reaction to the device and dashboard and any other final thoughts.

5.3 Data Analysis

After all data is collected, the participants’ responses will be analyzed to find common themes. The interview responses will be generate a codebook, along with assigned codes or themes to each response. Upon completion of the codebook, Cohen’s Kappa coefficient will be used. The analysis will be done by both researchers, to ensure reliability. All collected data would be kept anonymous and confidential.

6 RESULTS FROM PROTOTYPE

From our pilot test run with the prototype, there were significant data, results, and comments made from our participants. In our charts displayed to the coach or swimmer, they are able to see how many trials have been recorded, average time, and number of false starts. In our code we do have the old average as well, to which we would add. The graph is a good visual that allows the swimmer see the trends, rather than just looking at numbers. Results of this study will help to leverage a swimmer's reaction time in practice in hopes to build a fast time off the block during meets. Overall, the participants were curious of how the device was built and would like to see it in it's final version to help them in practice.

7 DISCUSSION

During our pilot test, we were able to learn how we would set up our application and further our study for future use. There were lots of trial and errors trying to think of what might be useful for the swimmer and coach. Some things we had to figure out was how to set up both Arduinos to communicate with each other and be read into Firebase. For the IDE, we used the fastest speed of 115200. Also, to avoid latency, we used interrupt which would respond quickly and is used for timing purposes. We wanted to provide an indicator that would notify the swimmer if the reaction time was 100ms. To do this, we ended up using the buzzer sensor to sound similar to the actual starting system for a false start. Meanwhile, one error we currently have is that sometimes the reaction time is over the anticipated/actual reaction time. For example, if it should be 300ms, the output is actually 7000ms. Currently, we are unsure if this is a code or device error. A way to solve this problem would be to make the range within 1000ms or 1500ms. If outside the range, we would not add it to the trials. Currently if a data is recorded with a high reaction time, the average time is not accurate. Another way to solve this problem would be manually deleting the data-point within the database or deleting from the application.

With our current prototype, we plan on creating the current dashboard to be on an app, rather than displaying it on a computer screen website. The dashboard would allow you to select any swimmer in the database or add a new swimmer. Then once a dive is completed be able to see all the information: chart, reaction time, old reaction, new reaction, and number of false starts. Additionally, we also only initiate the code once, which is inconvenient. Ideally, we would run the code as many times as needed in a continuous loop. We hope to leverage from this to perform future trials and prototypes.

The results of this study will help us learn the recording of reaction time and use of dashboards for athlete and coaches' use for better performance. This will help to determine what can be initially created and what features can be implemented upon further research and access to better building materials. Also, to learn thoughts of athletes and coaches on what might be beneficial to their training towards their competition events. Other researchers may benefit from this by continuing to look at an athlete's reaction time, especially with the expansion of technology. In future studies, looking into what useful information and customization should be available in dashboards, specifically for athlete usage. Results can also look to what other technology and devices might be useful for athletic use.

8 LIMITATIONS

There are many limitations to our study and they are centered around the available technology. A false start is classified as any movement on the block, so a touch sensor would only be used for our prototype. In reality, we would need either a force sensor or an accelerometer to determine the initial movement on the block, not just when the athlete leaves the block. Unfortunately, we only have access to the touch sensor. In future trials, we would like to track initial movement, as well as, time off the blocks; however, in this study, our prototype will only measure time off the block. Additionally, we are using Arduino sensors, which are not fit for the actual pool environment. They are not waterproof and the sensors are too small. For future prototypes, we plan on having a prototype in each individual lane.

Upon building our prototype, there were limitations in not knowing the latency between the Arduino and system. We used the highest IDE of 115200 in the Arduino. There were also times when starting the system, the output of reaction time was higher than the actual. We are unsure if the problem relies within our code or system.

Lastly, we realized that Arduino systems can only do one thing at a time. To help this issue, we connected two different Arduino's together, but we still have some code that should be running simultaneously. For example, the starting button sends a command to Python, flashes the LED, and starts the buzzer. Theoretically, these should be occurring at the same time, but in reality, they are all occurring a few milliseconds apart. A real starting system would have to use a more advanced microcontroller that supports simultaneous commands.

9 CONCLUSION

In this study, we built an early prototype and dashboard that would be used for both swimmers and coaches to measure reaction time in practice sessions. While there have been studies done for reaction time, none focus on swimming and practice usage. Additionally, starting systems are typically used during meets and are not accessible to everyone. Our current prototype consists of two Arduinos, buzzer, LEDs, touch, and button sensor that reads into Firebase that outputs a graphs with all trails, average reaction time, and number of false starts.

From the pilot tests, we received positive feedback which will be used to help leverage in the next steps of our research. Before testing it with more participants there are a few changes that needed to be added, such as: creating it into an application, displaying the reaction time (not just in chart form data-point), and old average time. In later studies, we hope to use waterproof systems, to be able to test in the pool. Hopefully this study can help advance reaction time systems and be available to teams for practice usage to help improve an athlete's reaction for meets.

REFERENCES

Noor Nafiz Islam, Nafiz Imtiaz Khan, Md Abdur Razzak, and Muhammad Nazrul Islam. 2022. Design, Development, and Evaluation of a Physical Exercise Monitoring and Managing System for Athletes. In *The 23rd International Conference on Information Integration and Web Intelligence* (Linz, Austria) *(iiWAS2021)*. Association for Computing Machinery, New York, NY, USA, 443–451. https://doi.org/10.1145/3487664.3487725

Devender Maheshwari and Marijn Janssen. 2014. Dashboards for Supporting Organizational Development: Principles for the Design and Development of Public Sector Performance Dashboards. In *Proceedings of the 8th International Conference on Theory and Practice of Electronic Governance* (Guimaraes, Portugal) *(ICEGOV '14)*. Association for Computing Machinery, New York, NY, USA, 178–185. https://doi.org/10.1145/2691195.2691224

Hayes K. Harrison A.J. Milloz, M. 2020. Sprint Start Regulation in Athletics: A Critical Review. (2020), 21–31. https://doi.org/10.1007/s40279-020-01350-4

Jose Shelton and Gideon Praveen Kumar. 2010. Comparison between auditory and visual simple reaction times. *Neuroscience and Medicine* 01, 01 (2010), 30–32. https://doi.org/10.4236/nm.2010.11004