REFLX: Reaction Enhancement in Fitness using Light-based Exercises for UPV Athletes

A Special Problem
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Abstract

From 150 to 200 words of short, direct and complete sentences, the abstract should be informative enough to serve as a substitute for reading the entire SP document itself. It states the rationale and the objectives of the research. In the final Special Problem document (i.e., the document you'll submit for your final defense), the abstract should also contain a description of your research results, findings, and contribution(s).

Suggested keywords based on ACM Computing Classification system can be found at `https://dl.acm.org/ccs/ccs_flat.cfm`

Keywords: Keyword 1, keyword 2, keyword 3, keyword 4, etc.

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Chapter 1

Introduction

1.1 Overview of the Current State of Technology

In the realm of sports science, the enhancement of athletes' response time and agility remains a critical focus, as these attributes directly influence performance in dynamic, unpredictable environments such as team sports and combat disciplines (Hassan et al., 2023). Traditional training methods, including cone drills and ladder exercises, have long been employed to improve these skills, yet they often fall short in replicating the rapid, stimulus-driven demands of real-game scenarios. Over the past decade, light-based reaction training systems—devices utilizing visual stimuli like LED lights to prompt immediate motor responses—have emerged as innovative tools to bridge this gap. Systems such as FITLIGHT, BlazePod, and XLiGHT have been critically analyzed for their design features, including sensor connectivity, battery life, and operational reliability, revealing strengths in portability and customization but limitations in diagnostic precision and validity (Ezhov et al., 2021).

Empirical studies have demonstrated that these systems can significantly enhance visual-motor coordination, reaction speed, and cognitive functions. For instance, interventions using FITLIGHT in small-sided games have led to marked improvements in harmonic abilities (e.g., rhythmization and responsiveness) and basic skills like dribbling among young basketball players (Hassan et al., 2023). Similarly, a 10-week FITLIGHT program improved reaction times and dribbling speeds in female basketball athletes, with effect sizes indicating substantial neural adaptations (Hassan, 2025). In motorsport contexts, light-based reactive agility training has boosted selective attention, cognitive flexibility, and cardiorespiratory capacity in car racing drivers (Horváth et al., 2022). A systematic review of visual training interventions, including light board and stroboscopic methods, further corroborates these benefits, reporting 5-27% reductions in reaction time across various sports, with greater efficacy in elite and younger athletes (Jothi et al., 2025). Reliability assessments of systems like BlazePod have also affirmed their validity for measuring simple and complex reactions in mixed martial arts (MMA) athletes, with high intraclass correlations supporting their use in training protocols (Polechoński et al., 2024).

Despite these advancements, significant gaps persist in the literature. While light-based systems show promise in controlled settings, their predictive value for field-based reactive agility remains limited, as evidenced by weak correlations between laboratory reaction speeds and on-field performance in soccer players (Broodryk et al., 2025). This suggests a disconnect between isolated visual stimuli and the multifaceted perceptual-cognitive demands of sports, highlighting the need for more integrated, sport-specific designs. Moreover, comparative analyses underscore inconsistencies in system performance, such as variable Bluetooth stability and sensor delays, which could undermine training reproducibility (Ezhov et al., 2021). Long-term efficacy studies are scarce, and few investigations explore the interdisciplinary integrations between sports science and engineering to optimize these technologies.

1.2 Problem Statement

While traditional methods such as cone and ladder drills have been widely used to enhance reaction time and agility, they often fail to simulate the complex, stimulus-driven conditions of real-game scenarios (Hassan et al., 2023). Recent light-based reaction training systems have shown potential in improving visual-motor coordination and cognitive response (Horváth et al., 2022; Jothi et al., 2025). However, these systems remain limited by high costs, connectivity issues, and questionable transferability of laboratory-based improvements to on-field performance (Broodryk et al., 2025; Ezhov et al., 2021).

If these limitations persist, athletes may continue to rely on training tools that inadequately reflect actual gameplay conditions, hindering optimal skill development and competitive performance. Addressing these gaps necessitates the development of a customizable, low-cost, and scientifically validated light-based reaction training system that bridges engineering innovation and applied sports performance research, which our study aims to do as well as evaluate the effectiveness of said system.

1.3 Research Objectives

1.3.1 General Objective

The goal of this study is to develop and evaluate a light-based reaction training system that enhances the response time and agility of athletes, specifically in racket sports such as badminton, tennis, and table tennis.

1.3.2 Specific Objectives

1. To design and construct a device equipped with infrared sensors, RGB lights, and speakers for accurate motion detection and response measurement, as well as a better user experience.
2. To develop a software application that manages the device operations, records performance data, and functions both online and offline.
3. To calibrate and test the system to ensure precision, responsiveness, and synchronization between hardware and software components.
4. To conduct experimental trials assessing the system's effectiveness in improving athletes' response time and agility compared to traditional training methods.
5. To evaluate the system's usability, functionality, and overall user satisfaction based on feedback from athletes and coaches.

1.4 Scope and Limitations of the Research

This study focuses on the design, development, and short-term evaluation of a programmable light-based reaction training system specifically tailored for racket sports, including badminton, tennis, and table tennis. These sports were selected because they demand rapid visual processing, anticipatory decision-making, and fine motor control—abilities strongly linked to reaction time and agility.

Experimental trials will be conducted in controlled indoor training environments, using drills that simulate racket-sport scenarios such as serve returns, directional changes, and split-step reactions. The prototype system will incorporate

LED visual cues and integrated speakers to deliver multimodal stimuli, allowing assessment of both single and dual sensory response conditions.

The evaluation will be limited to short-term performance outcomes, measuring pre-post changes in reaction and movement response metrics following exposure to the prototype system. Long-term effects, such as learning retention, in-game transfer, or perceptual-cognitive adaptations, are beyond the scope of this research.

1.5 Significance of the Research

This research integrates engineering, computer science, and sports science by developing a light- and sound-based reaction training system that enhances athletes' response time and agility through multimodal stimuli and data-driven feedback. Through a technical lens, the study contributes to the computer science community by implementing real-time sensor processing, audio-visual cue synchronization, and a user-centered software design. The inclusion of both infrared sensors and speakers allows for dynamic and varied training scenarios that engage multiple sensory pathways, thereby improving cognitive-motor coordination. Compared to existing systems that rely solely on visual cues or require expensive proprietary hardware, this design offers a more versatile, customizable, and cost-efficient solution.

From a societal perspective, the system democratizes access to advanced reaction training technologies by providing an affordable and portable tool suitable for athletes, coaches, and educational institutions. It can also serve as a supplementary device for rehabilitation programs that aim to improve motor control and sensory processing. By combining technical innovation with accessibility, this research promotes evidence-based athletic development and supports the broader integration of smart, adaptive technologies in sports and human performance training.

Chapter 2

Review of Related Literature

2.1 Physiological Basis of Reaction and Agility

Reaction time and agility in athletes are influenced by a complex interplay of neurophysiological factors, including perceptual-cognitive processing, neural pathways, and motor control. Reaction time encompasses the interval from stimulus detection to response initiation, modulated by sensory input (primarily visual), central nervous system processing, and efferent motor commands. Agility, defined as the ability to change direction rapidly while maintaining balance and speed, integrates these with biomechanical elements like strength and coordination (Pojskic et al., 2019). Neurophysiological mechanisms involve the visual cortex for stimulus detection, the prefrontal cortex for decision-making, and the basal ganglia for motor planning, with reaction accuracy linked to efficient attentional orienting and split attention across multiple stimuli (Chow et al., 2022). The prefrontal studies highlight that perceptual factors, such as anticipation and visual search efficiency, contribute significantly, alongside physical attributes like explosive strength and elastic strength (Yıldız et al., 2020). For instance, factor analyses reveal independent components: explosive strength for acceleration, elastic strength for rebound, change-of-direction speed (CODS), and maximal strength. Correlations show that faster reaction times predict superior agility test performances, such as in the Illinois Agility Test or 20-m shuttle sprint, emphasizing the role of neural efficiency (Wang et al., 2024).

Methodologies in these studies often employ systematic reviews and correlational analyses, drawing from diverse athletic populations (e.g., team sports like soccer) (Turna, 2020). Limitations include reliance on lab-based tests that may not fully replicate field conditions, potentially underestimating contextual factors like fatigue or cognitive load (Pojskic et al., 2019). Implications suggest that training targeting neuroplasticity—through repeated stimuli—can enhance synaptic efficiency, reducing reaction latencies and improving agility in sports requiring rapid responses, such as basketball or racing (Chow et al., 2022). Patterns indicate stronger associations in high-level athletes, where cognitive fatigue and sleep quality positively correlate with prolonged reaction times, highlighting the need for holistic training approaches (Yıldız et al., 2020).

2.2 Existing Reaction Training Technologies

Commercial systems like FITLIGHT Trainer and BlazePod represent established light-based technologies for reaction training, with evidence supporting their effectiveness in enhancing athletic performance. FITLIGHT, a wireless LED sensor system, simulates game-like conditions to improve reaction time, reflexes, and cognitive functions (Hassan, 2025). Studies demonstrate its reliability, with test-retest intraclass correlation coefficients (ICC) ranging from 0.81-0.90 and minimal detectable changes in reaction metrics (Steff et al., 2024). In young basketball players, a 10-week FITLIGHT intervention improved executive functions (e.g., inhibition, working memory) and fitness, though gains were comparable to traditional training, suggesting added cognitive demand without superior outcomes (Hassan, 2025). Another trial integrated FITLIGHT into small-sided games for 18 weeks, yielding significant enhancements in coordinative abilities and basic skills, outperforming controls with large effect sizes (Steff et al., 2024).

BlazePod, a pod-based visual-cognitive system, shows similar promise, with excellent reliability in balance activities (Çekok & Anaforoğlu, 2025). A 6-month program in adolescent soccer players improved simple reaction time and cognitive tasks, but between-group differences were non-significant compared to standard training, indicating contextual benefits rather than inherent superiority (Theofilou et al., 2022). Methodologies typically use randomized controlled trials (RCTs) with pre-post assessments, validated via tools like the Stroop Test for cognition and TUG for effort (Çekok & Anaforoğlu, 2025). Limitations include small samples (n = 20-50) and short durations (6-18 weeks), risking overestimation of effects due to novelty; discrepancies arise in massed vs. distributed scheduling, with longer protocols showing sustained gains (Steff et al., 2024b). Implications underscore these systems' role in individualized drills, boosting engagement through gamification, though high costs and proprietary designs limit accessibility for broader athletic populations (Hassan, 2025).

2.3 Light- and Sensor-Based Training Research

Research on light-based stimuli consistently shows enhancements in sports performance, particularly cognitive-motor integration and agility. A 6-week RCT using Witty SEM lights for car racing drivers improved cognitive abilities and cardiorespiratory fitness, with significant group-time interactions (Horváth et al., 2022). In basketball, light stimulation exercises enhanced attention focus (visual/auditory) and skilled hand speed, with pre-post improvements attributed to neuroplastic adaptations (Shimi et al., 2025). VR-adapted light tasks revealed attentional mechanisms, with orienting speed predicting performance, emphasizing split attention for larger stimuli arrays (Shimi et al., 2025). Soccer-specific lighting interventions (6 months) manipulated visual processing, reducing reaction times under varied conditions, though transfer to matches was inferred rather than directly measured (Theofilou et al., 2022).

Methodologies favor RCTs with tools like the Vienna Test System for cognition and breath-by-breath gas analysis for physiology, ensuring objective evidence (Horváth et al., 2022). Limitations encompass single-blinding, uncontrolled nutrition, and lab-based focus, potentially inflating effects; patterns show greater benefits in open-skill sports, with discrepancies in exercise vs. rest conditions (Zhao et al., 2024). Implications highlight light stimuli's potential for dual physical-cognitive gains, transferable to agility-dependent sports, but call for ecological validity in future studies (Shimi et al., 2025).

2.4 Identified Gaps in Literature

The literature reveals notable gaps, particularly the scarcity of open-source, customizable systems for individualized athlete training. While commercial tools like FITLIGHT dominate, they are proprietary and costly, limiting adaptation for diverse needs (Seçkin et al., 2023). Emerging technologies emphasize open-source platforms for tele-exercise, enabling collaborative customization via AI and IoT, yet only 9% of trials target healthy populations, with inadequate standardization of training parameters (Rebelo et al., 2023). Gaps include high dropout in asynchronous modes, data security concerns, and underexplored adherence factors (Rebelo et al., 2023). Methodologies in gap analyses rely on narrative reviews, highlighting sustainability challenges in open-source projects (Seçkin et al., 2023). This implicates the need for accessible systems to democratize training, addressing disparities in research on healthy athletes.

Chapter 3

Research Methodology

This chapter lists and discusses the specific steps and activities that will be performed to accomplish the project. The discussion covers the activities from preproposal to Final SP Writing.

3.1 Research Activities

Research activities include inquiry, survey, research, brainstorming, canvassing, consultation, review, interview, observe, experiment, design, test, document, etc. Be sure that for each method, process, or algorithm used, there is a justification why that method was chosen. The methodology also includes the following information:

- who is responsible for the task
- the resource person to be contacted
- what will be done
- when and how long will the activity be done
- where will it be done
- why should be activity be done

3.2 Calendar of Activities

A Gantt chart showing the schedule of the activities should be included as a table. For example:

Table 3.1 shows a Gantt chart of the activities. Each bullet represents approximately one week worth of activity.

Table 3.1: Timetable of Activities

Activities (2009)	Jan	Feb	Mar	Apr	May	Jun	Jul
Study on Prerequisite Knowledge			••	••••			
Review of Existing Racing Strategies	••	••••	••••	••••			
Identification of Best Features				••••	••		
Development of Racing Strategies				••	••••	••	
Simulation of Racing Strategies				••	••••	•••	
Analysis and Interpretation of the Results					••••	••••	•
Documentation	••	••••	••••	••••	••••	••••	••

Chapter 4

System Prototype

4.1 System Design and Architecture

This study will employ components to gather accurate measurements of reaction time. The device will be composed of one master controller and multiple stations. The study will use the ESP-NOW protocol to achieve wireless connection between the main controller and the stations. ESP-NOW is a wireless communication protocol defined by Espressif which enables multiple ESP based microcontrollers to communicate wirelessly. It is a quick and low-power way to handle connection that is based on the data link layer to achieve faster transmission. The main controller will be the master for the station controllers who will send commands and where data will be gathered and sent to a web-based player development tracker.

4.1.1 IOT Components

In the Figure 4.1 shows the schematic circuit diagram of the main or master controller. It will use a standard ESP32 controller who will handle the sending of commands to the smaller stations on what they will be performing as well as gathering the data from the stations and sending them to a web based player development tracker where the data will be displayed. A python app will be used to display the data sent by the main controller and will then be uploaded online in the firebase online database. Other components that the main controller has is the DF mini mp3 player module which will be responsible in playing audio sounds for trainings that need audio queue. The audio files will be stored in an SD card

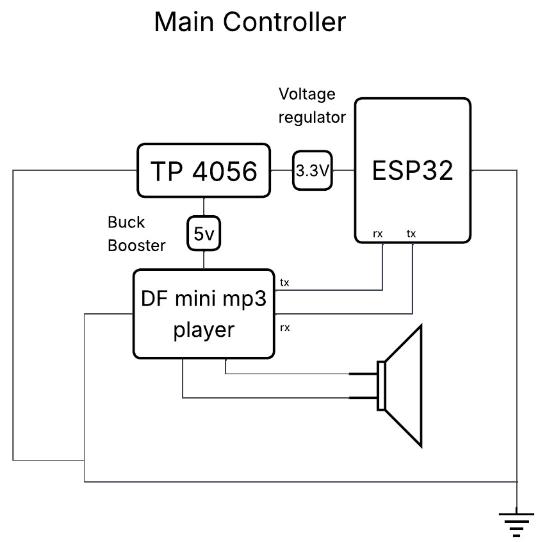

Figure 4.1: Schematic Circuit Diagram of the Master Controller

for the module to read. It is also connected to a 3W speaker to help amplify the sound it needs. All of these will be powered by an 3.7v 18650 battery. A TP 4056 module with protection will be used to safely charge the battery without overcharging it. A voltage regulator for 3.3v will be connected from it to stably supply the needed voltage of the ESP32. A buck booster will also be connected to the power source to power the DF mini mp3 module and the 3w speakers.

For the station nodes, the Figure 4.2 shows its circuit schematic diagram. An ESP32 super mini C3 is used. It is used as it has a smaller footprint and the sensors needed doesn't exceed the amount of its usable GPIO pins. It will receive commands from the main controller and will execute them. A programmable led strip is connected and will change depending on the command as well as will be turned off by the infrared sensor connected to the station controller. The station controller will then record the reaction time of the performer and will then send the data to the main controller. Similar to the main controller, the station controller will be powered by an 3.7v 18650 battery with a TP4056 module with protection for charging. Again, a voltage regulator for a steady supply of 3.3v will be used to power the station controller and a buck booster for 5v to power the led. The led however will be connected to a dual mosfet driver connected to the station controller to act as a switch for the 5v led strip.

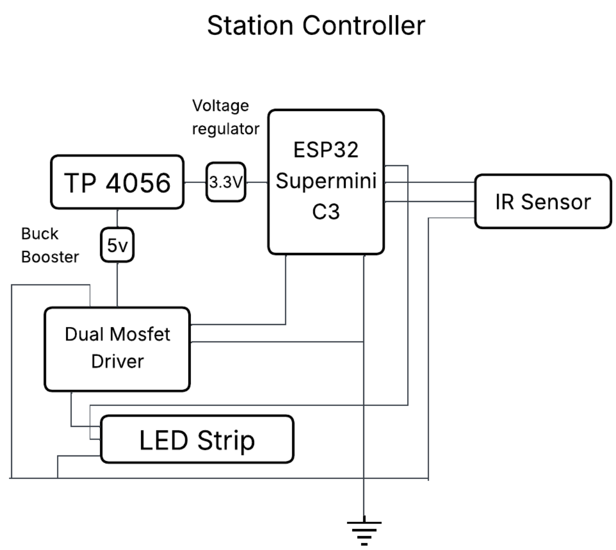

Figure 4.2: Schematic Circuit Diagram of the Station Controller

Appendix A

Appendix

Appendix B

Resource Persons

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References