UNIVERSITY OF WISCONSIN-MADISON
DEPARTMENT OF BIOMEDICAL ENGINEERING
BME 200/300 DESIGN

Reaction Time Measurement Device

Mid-Semester Report

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Abstract

In the case of simple reaction times, auditory stimuli yield faster reaction times than visual stimuli. A device is desired which can demonstrate this phenomenon in a classroom setting for school children in grades 1-8. Currently, no such device exists on the market. Based upon a set of guidelines and requirements compiled for the device with Dr. Tom Yin of the UW-Dept. of Physiology, four specific, well-developed design alternatives were created by the design team. The designs were evaluated in a design matrix to decide upon the Rube Goldberg design as the final design. Future work involves additional design of device components and eventually human subject testing for functionality of the device.

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Problem Statement

A device is desired that will measure and compare simple visual and auditory reaction times in order to demonstrate the difference between audio and visual processing times. The final device will be used primarily in educational classroom settings for children grades 1-8 as a means to generate excitement about physics and science. The device must be intriguing and intuitive for its target audience. There is also the potential to incorporate other sensory reaction times into the device.

Background and Motivation

Reaction time measurement is a fairly self-explanatory study: that of measuring the time it takes for a subject to react to some sort of stimulus. Whether a sports athlete is trying to boost performance times or someone is commuting to work, reacting to stimuli is a part of daily life. There are four types of reaction times commonly studied. *Simple* reaction time is a response time for a test subject to respond to the presence of a stimulus such as a light or sound. *Go/No-Go* reaction time refers to the required time for a subject to respond to one stimulus or withhold from responding to a different stimulus type (i.e. it involves a decision of hitting a button for one stimulus while not hitting it for another stimulus). *Choice* reaction time measures how long it takes for a subject to generate a distinct response for a distinct stimulus (example: push button 1 when one stimulus appears but push button 2 if the other stimulus appears). *Discrimination* reaction time measures response time for comparing pairs of simultaneous stimuli and distinguishing a certain difference (example: hitting button one or two based upon which stimulus was brighter/louder). A high degree of variability can be found within given trials for an individual due to their level of mental focus. Reaction time also varies from person to person due to genetic and environmental factors [1].

Simple reaction time has been studied extensively for quite some time. It has been shown that reaction times to visual stimuli are slower than reactions to auditory stimuli [2]. Many studies have confirmed this phenomenon over time. The reason for the faster auditory reaction time has also been studied. It takes 8-10 milliseconds for an auditory stimulus signal to reach the brain [3] whereas a visual stimulus signal takes 20-40 milliseconds [4]. In a study of healthy college aged individuals, an auditory stimulus generated an average reaction time of 160 milliseconds whereas the visual stimulus yielded an average reaction time of 190 milliseconds [5]. These are the reaction time values that have been widely accepted throughout the science community. However, modern online reaction time tests often yield slower results in part due to a delay in electrical programming of the software [6]. This difference has also been shown in research by Eckner, et al studying NCAA football players who averaged a 203 millisecond reaction time to a falling meter stick but 268 milliseconds for a visual stimulus computer test [7].

The research of Dr. Tom Yin-the client for this project-has yielded additional reasoning to the stimuli dependent reaction time phenomena. Yin has explained to the team that visual stimuli require signal amplification as well as a chemically gated cascade in order for processing to occur. Conversely, the auditory stimuli propagate quickly via hair cells basked in fluid and open mechanically gated ion channels which allow shorter duration to send the signal. Ultimately, he explains that a tradeoff exists between the sensitivity and signaling speed of the auditory and visual systems of the human [8]. The more sensitive visual system requires slower processing speeds than the less sensitive auditory system. Dr. Yin has expressed an interest in demonstrating this reaction time data research in classroom settings as an initiative to get children interested in physics and science.

Currently there isn't a manufactured device to demonstrate the variation in reaction times for auditory and visual stimuli. The client's desire to create such a device arose from a visit to the Chicago

Museum of Science and Industry where a simple reaction time test is performed for visual or auditory stimuli via a falling ruler held by an electromagnet. The desired device would be used heavily in outreach applications for students in grades 1-8 (ages 6-14) in local area schools as a demonstrative tool. The Madison Area School Boards have added, as part of the middle school curriculum, a requirement for hands-on scientific experiences involving the human body. Dr. Yin has seen this requirement as a prime opportunity to utilize such a device which would demonstrate a cognitive phenomenon and get students thinking about science.

Research has shown that for mathematical and science education, students in grades 2-8 learn best when given the opportunity for “interactive, hands-on, play-based” learning as is evident by the vastly growing number of children’s museums nationwide [9]. Therefore, as a critical aspect of a functional reaction time measurement device, an entirely “hands-on” learning approach will need to be considered.

Design Constraints

Due to the nature of the project as a demonstrative tool in an educational environment, the design is accommodating in a lot of aspects. However, the team must still adhere to some preset guidelines. The budget for the device is $200 which includes all materials, fabrication, testing, ect. Additionally, the final device must be easily transportable in the back hatch of a standard minivan. An overall mass of 20 kg should not be exceeded. The setup/teardown of the demonstration should not exceed 10 minutes. The device must incorporate a test of simple reaction times to audio vs. visual stimuli, although additional senses can be incorporated. Further opportunity exists in the potential to incorporate variations in the intensity level of the stimuli. The final device must accurately measure the auditory and visual simple reaction times, and thereby demonstrate faster auditory reaction times as per the literature. It’s also critical that the final design is visually appealing so as to draw attention of children and add to the hands-on learning experience. Safety is a concern of the design which must be anticipated so as to avoid any potential issues with electrical and mechanical components.

Design Alternatives

Laser Design

The Laser reaction time design would be set up as a game geared towards children ages 8-14. The device would be approximately 2 feet by 2 feet and would include a green laser, mirrors, an infrared sensor, a toy diamond, a hand placement cutout that looks like a security system hand scanner, very thin posts about 6 inches tall, a switchboard and a display timer as shown in Figure 1. The toy jewel would be placed in the middle of the setup while the laser beams, created by one green laser and 5 adjustable mirrors on posts, would surround it, as if it were an expensive artifact at a museum. The hand placement cutout would be placed where the subject positions his or her hand at the start of the trial. The object of the trial would be for the subject to react as quickly as possible to either the laser security system turning off, or to the indicated stimulating beeping noise, and to reach for the jewel at that time. The infrared sensor would be located parallel to, and very close to, the laser beam closest to the hand placement cutout and would span the plane that a hand could move through when reaching for the jewel. The security system laser turning off is the visual stimulus and a beeping noise is the auditory stimulus. The stimulus would start the timer and the hand breaking the infrared sensor beam would stop the timer. The reaction time would then be displayed on the LED display timer. It would be explained to the subject that if he or she reacts quickly enough, he or she could obtain the jewel without the security system coming back on. This would motivate the subject to react as quickly possible. The adult administering the trial would have control over whether the stimulus would be an auditory stimulus (beeping sound), a visual stimulus (the security system lasers turning off) or both, by using the switch.

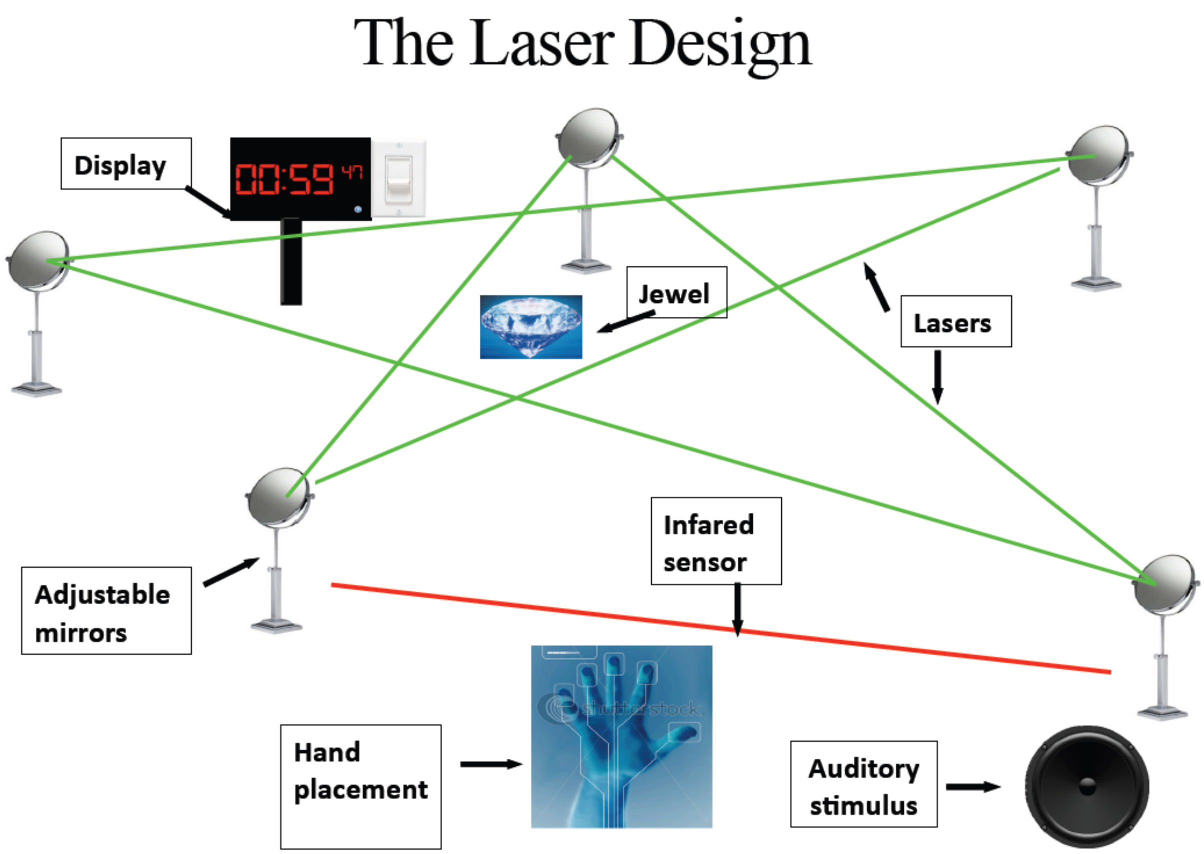


Figure 1: Diagram of the Laser Design Alternative

The advantages of the laser design include that lasers are visually appealing and fun for kids of all ages. The design would be straightforward and simple and the subject would have strong motivation to react quickly. The visual feedback for this design would be quite satisfying as the design relates to a real-life security system. Cost would be a slight advantage, since the laser design would be cheaper than 2 other designs. Also, since the laser design would be game board sized, the device would be easy to transport, store and set up. The device would depend on batteries and another power source, which are relatively reliable. Also, the device would be easy to manufacture.

Disadvantages of the design include that even with a green laser, the laser beams may be hard to see in a well-lit classroom. Also, there is a safety factor with the lasers that hasn't been well evaluated and therefore, the design could be potentially harmful. Small children may not understand the security system game without an adult carefully explaining it to them. They also might not be able to relate the game to anything that they are familiar with. Another major disadvantage of the laser system is the fact that there would be no direct physics correlation of distance as it relates to reaction time, which is one of the main qualities of a successful design. A final disadvantage is that the device would indirectly promote stealing. Therefore, stealing a jewel, or beating a security system would be a bad theme for the target audience.

Ruler Design

The ruler design alternative would include a wooden frame for the system (made out of 2x4 lumber), a circuit board, which would include a battery and a switch, a special glove with metal tips, an LED display, a meter stick, an electromagnet with a hook that would hold up the meter stick, a speaker that would provide the auditory stimulus and a light bulb that would provide the visual stimulus as seen in Figure 2. The ruler would drop as the stimulus occurred and the user would attempt to catch the ruler as quickly as possible to measure reaction time. The battery would supply power for the light bulb, the speaker, and the electromagnet. The glove with metal tips that would be wired to the circuit board, would be worn by the user so that at the instant the user catches the conductive meter stick, a circuit would be completed and the timer, which would be started as the stimulus occurred, would stop. The reaction time would then be displayed on the LED timer. The adult proctoring the use of the device would decide which type of stimulus to use by using the switch.

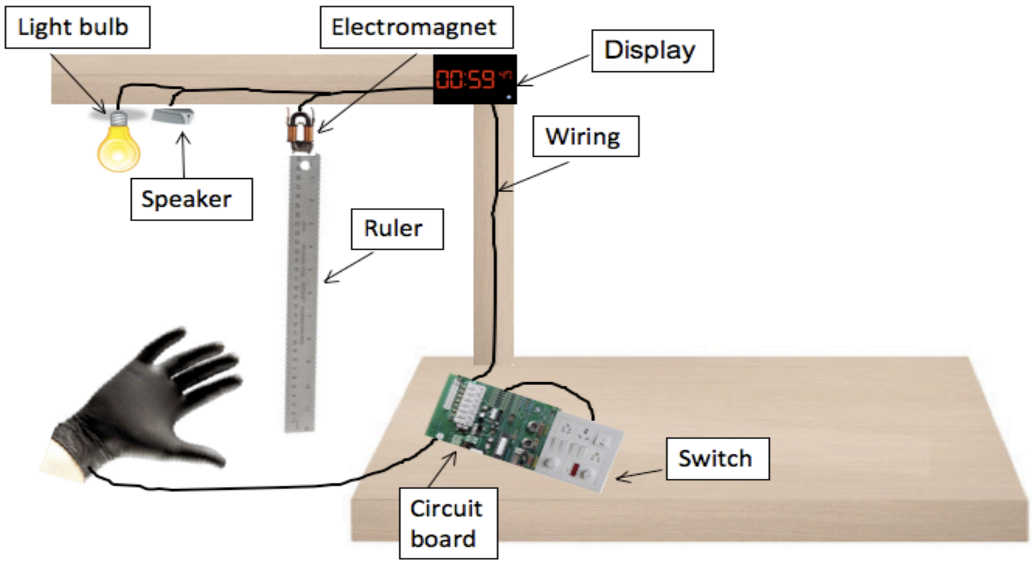


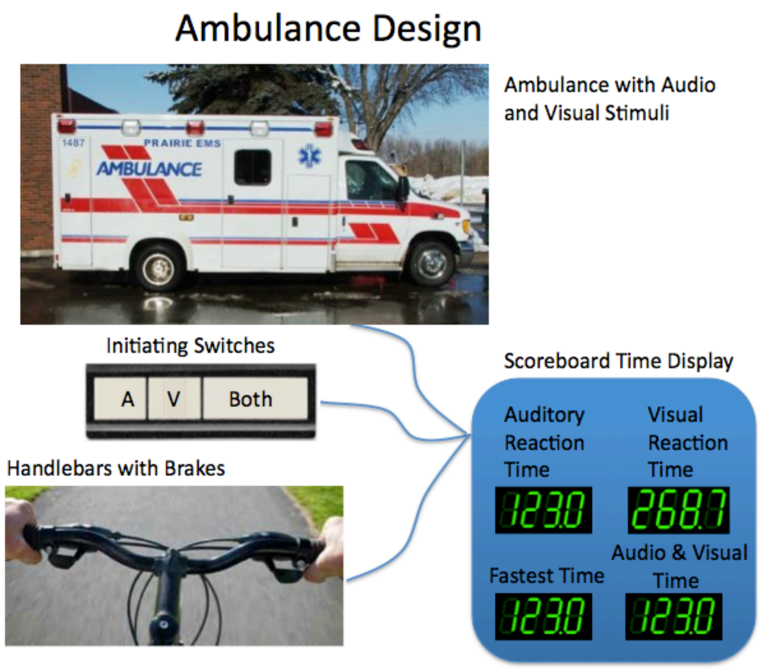
Figure 2: The ruler design alternative including a table it would be set on.

Advantages of the ruler design include the direct physics correlation. Reaction time could be directly measured based on the distance the ruler fell using constant acceleration due to gravity. Also, the ruler design would be quite reliable.

Disadvantages include the lack of appeal of the ruler design. When compared to the other design alternatives, the ruler design would be the least amusing. Also, ease of transport and cost are weak points of the ruler design alternative.

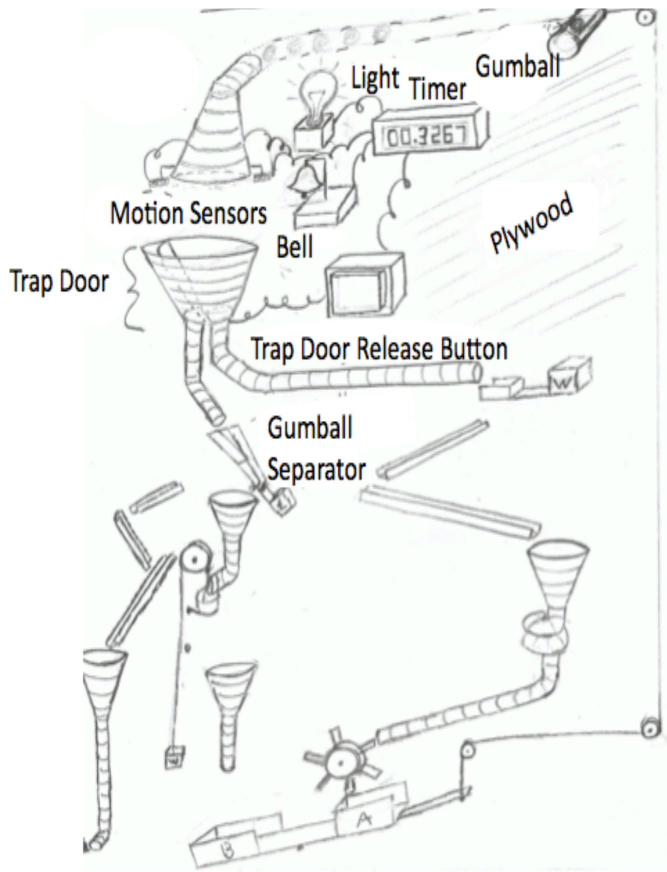
Ambulance Design

Another design would model a real-life intersection that an individual on a bike might encounter. The design would be built around a toy ambulance outfitted with a siren and flashing lights. This ambulance would be placed in a mock intersection in front of the participant. In front of the participant there would also be a set of bicycle handlebars outfitted with handbrakes. The handbrakes would be hardwired to stop a timer upon depression of the brake. The person controlling the demonstration would have three potential buttons to press: one to sound the siren, one to activate the lights, and one to activate both stimuli. All of the buttons simultaneously would start the respective timer on the scoreboard time display. The participant would squeeze the handbrakes as soon as they hear the siren or see the flashing lights, which would stop the timer. Once stopped, the reaction times would be presented on the scoreboard so the user could compare their different reaction time scores and see which reaction method is fastest. This is shown in Figure 3. The life-like situation would help get participants involved with the test and would provide motivation.



Even though the subject may be motivated to perform well there would be no direct physics correlation with this design. Despite this, the ambulance would be the simplest, cheapest, and most durable alternative. The only components that would be repeatedly used (the button and the handbrakes) are both designed for repetitive use and are thus unlikely to break. Also the small compact design allows it to be easily transported without any risk of breaking.

Rube Goldberg Design



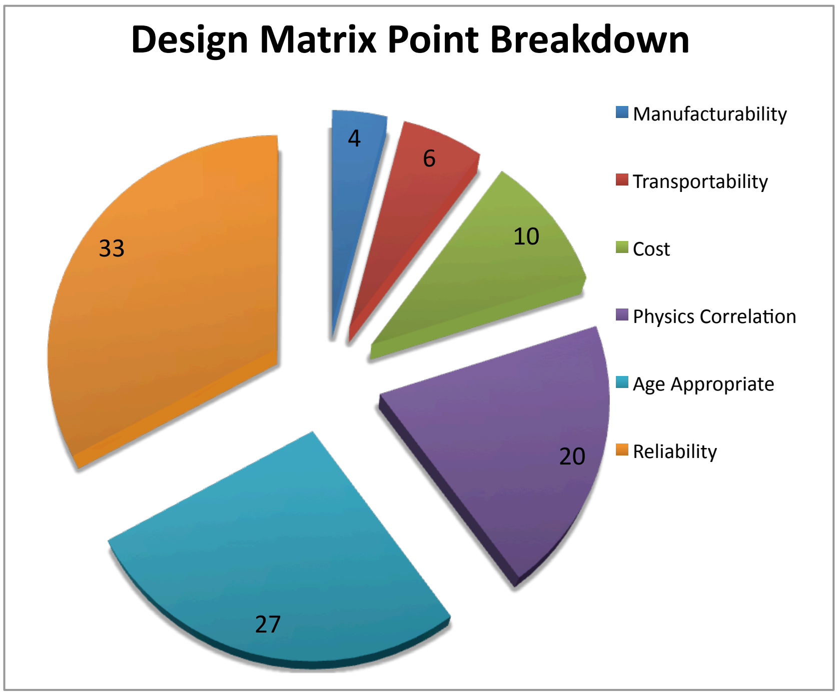
The final design alternative is a version of a Rube Goldberg machine. As the most creative and visually appealing design, this alternative would likely grab significant attention and interest. The machine can be best understood by grouping the components into two main parts: the reaction process and the user feedback.

The reaction process starts with a line of marbles waiting to be released down a chute. As each marble is released, they enter free fall past a motion sensor en route to a funnel ready to catch them. When the motion sensor detects the marbles dropping through its field of vision it either rings a bell, flashes a light, or both while simultaneously starting a digital timer. When the individual using the device detects the stimuli they are to press a stop button for the timer as fast as possible. When this button is pressed the timer stops and the time is displayed on the digital screen. This also opens a trap door in the funnel sending the marbles down a series of mechanisms before being deposited into a box on a fulcrum. When the participant gets enough marbles into the right side of the balance, it tips the seesaw and applies tension to a rope attached to its side. This rope ultimately releases a gumball into the system. The gumball then rolls to the marble release mechanism and drops through the chute and past the motion sensor.

When the participant sees the gumball dropping from the chute they would be expected to refrain from pressing the button. This would allow the gumball to follow a separate path down to the user. The gumball would act to motivate subjects to perform their best with the experiment. The downside of this project would be the cost and structural instability. Because the project would be unstable and would have gaps between its components, all components would need to be attached to plywood.

Design Matrix

The design matrix was split into 6 different categories: manufacturability, transportability, cost, physics correlation, age-appropriateness and reliability. The breakdown of the available points in each category is illustrated in Figure 5. The first three categories to be discussed only represent 20% of the total points. Manufacturability, the first and smallest category, is a measure of the ease of fabrication. This category was not given much weight due to the fact that the fabrication process for each design was not thought to be excessively difficult. The problem addressed by this design project is not very technical, and therefore any fabrication that will be needed should fall easily within the team’s capabilities.



Transportability was also given a small point value. Although the client stressed the need for the design to be transportable by one person, and fit easily in the back of a van, these minimum specifications were thought to be easily attainable. For this reason, any further advantages in terms of transportability, while practical, were not highly valued.

The last of the three smaller categories is cost. The team was given a maximum budget of $200 to work with. While spending less money may be preferable, the team should not sacrifice other important aspects of the project in order to stay well under the budget. As long as the design stays under $200, preference should be given to the categories that work to address the problem statement.

A table of the points awarded to each design in every category is shown in the design matrix below (Table 1). As illustrated, the ambulance design does very well in the first three categories. This is due to the fact that this design is relatively simple and has few parts. The Rube Goldberg design on the other hand struggles. It is the most complicated design, and with its vast amount of interacting parts, it would be by far the hardest to manufacture. Its size and number of parts make it costly and difficult to transport. The other two designs score moderately in these categories. They lose points for the same reason as the Rube Goldberg, though in smaller amounts.

Physics correlation is an evaluation of how intuitive each design is. Since the purpose of the project is outreach in a middle or elementary school setting, it is essential for students to have an understanding of what is going on. The design should encourage independent thought and introduce basic physics concepts. Both the Ruler and the Rube Goldberg do very well in this category due to their moving components. With both designs the students can be encouraged to draw the connection between the movement of the falling component and reaction time. The Laser and Ambulance lack any moving component and therefore do not score many points in this category.

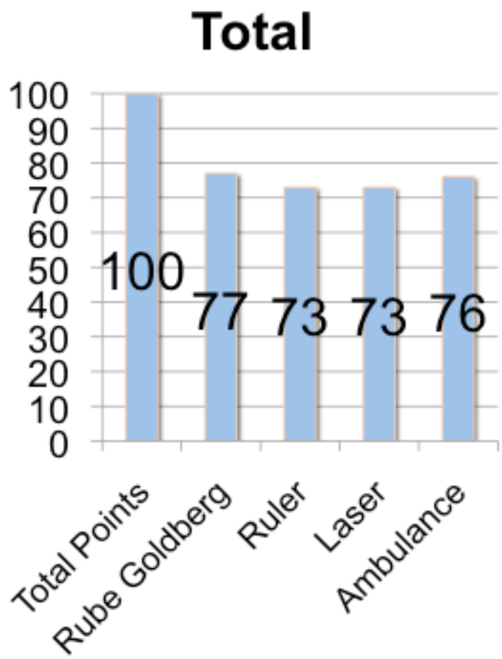
Category	Total Points	Rube Goldberg	Ruler	Laser	Ambulance
Manufacturability	4	2	3	3	4
Transportability	6	2	4	5	6
Cost	10	4	7	7	10
Physics Correlation	20	18	20	7	5
Age Appropriate	27	27	10	25	20
Reliability	33	24	29	26	31
Total	100	77	73	73	76

Table 1: Design matrix

Age appropriateness is an indication of how well each design captures and holds the attention of elementary and middle school students. Since the intent of this design is solely for outreach, it is essential that any proposed design have the quality of being fascinating for the target audience. Only if the device is intriguing will the client be able to teach his lesson before a receptive audience. For this reason, both the Laser and the Rube Goldberg dominate this category. Both would be highly interesting, challenging, and rewarding to children in the target age group. By offering strong positive feedback for quick times, both encourage students to focus on doing their best. The Ruler design suffers the most in this category. Although it may be appropriate for an older, more scientific audience, it would seem boring to children in the target age group.

Reliability is the largest category in the design matrix. This is a result of the client's emphasis for a design that could be taken anywhere, set up, and work properly. It is also essential that the design give consistent results showing that auditory reaction time is faster than visual. Due to the number of parts in the Rube Goldberg design, and the potential inconsistency in the way the reaction time will be measured, it loses reliability points. The ambulance, being a very simple design with an accurate way to calculate reaction times, scores very well in this category.

The final point breakdown is shown in Figure 6. Although the Rube Goldberg did score the most points, the difference between the highest and lowest score was only four. This illustrates the uniqueness of the project. Unlike most other design projects in the course, this project is not very technical. For this reason, a lot of emphasis was placed on the brainstorming process in order to come up with the best, most unique designs possible. This resulted in four thoroughly developed designs, each of which could have adequately addressed the problem statement. This is represented by the small difference in total points.



Although the design matrix does not provide compelling support for the Rube Goldberg design, the team does feel that it will be the best choice to move forward with. The Rube Goldberg has tremendous potential in terms of originality and innovation. The excitement that will be inherent with it will make every child want to test it out. Though other designs are viable options, compared to the Rube Goldberg, they lack the creativity and excitement that will make the Rube Goldberg design great.

Future Work

Due to the nature of the project, much time was spent brainstorming multiple ideas rather than finalizing the design on any specific one. For this reason, the current Rube Goldberg design has many areas that need in-depth design before any further steps toward fabrication can be made. One of these areas is the releasing mechanism.

The mechanism which releases the marble from a stationary position will need to be both silent and release at a random interval. It is essential that the release be silent since any auditory cue given to the test subject will allow them to anticipate when the marble will drop. A random release interval is also needed for this reason. Only by preventing the student from anticipating when the marble will drop can accurate results for reaction time be measured.

Another area of the design that will need more detail is the electronics aspect. In order to measure reaction time, an accurate and consistent mechanism is needed that will start and stop the timer while activating the stimulus. This part of the design is essential to the overall project since the goal is to consistently show, in an unbiased way, that auditory reaction times are faster than visual reaction times. For this reason, the auditory and visual stimuli must occur at exactly the same instant, and the time it takes the subject to react must be precisely measured. There is little room for error in these measurements since the difference between auditory and visual reaction times is in the range of tens of milliseconds.

A third area needing further design is the trap door mechanism. This mechanism is used in the feedback aspect, designed to give positive feedback when the subject reacts fast enough (i.e. the ball goes into the correct hole), or negative feedback when the subject is too slow (when the ball goes down the wrong hole). The trap door mechanism will need to be extremely robust due to the high number of trials it will undergo.

After these complications in the current design are worked out, dimensions for all aspects of the design will be calculated. These dimensions are a critical part in the time, velocity and energy calculations needed in order to specify the locations for all mechanisms in the design. Materials will then be ordered, and fabrication of the design will commence. Any available time left in the semester will be used for testing and modification. Possible testing includes doing a trial run in an actual school setting to gauge the reception of the design from younger audiences. A method to calibrate the light and speaker so each activates at the exact same time is also needed. This will help ensure that neither sense is given an unfair advantage in the testing process.

Ethical Considerations

Throughout the design process, any potential ethical considerations of the design must be thought out. Currently, there are no demonstrative devices for reaction time measurement on the market, yet the team must be careful to avoid any sort of copyright infringement or patent copying. All ideas incorporated into the design should be entirely original. The altercations made to any materials and components purchased during the fabrication process shouldn't conflict with laws and guidelines placed upon those components. User safety is a fundamental concern in any project, especially when the user audience involves children. The team must design and fabricate all components to ensure user safety throughout the duration of the device's lifetime. Future ethical considerations will include truthful data during testing phases of the device. Generating false data to verify a device is entirely unethical and unacceptable.

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Appendix

Product Design Specifications

Problem Statement: A device is desired that will measure and compare simple visual and auditory reaction times in order to demonstrate the difference between audio and visual processing times in a classroom setting. The device must be intriguing and intuitive for its target audience. There is also the potential to incorporate other sensory reaction times into the device.

Client requirements

- Portable to allow for easy transportation and setup
- Simple and easily operable
- Low cost (a maximum of $200)
- Digital time display
- The device must be thought-provoking and appealing
- Must be accurate (down to the millisecond)

- Allow for bimodal testing
- Must clearly demonstrate that auditory reaction times are faster

Design requirements

1. Physical and Operational Characteristics

a. *Performance requirements*: This device must be able to operate on a continuous basis for short periods of time during demonstrations. It must be able to be disassembled and loaded into the back of a van for transportation. Performance must clearly demonstrate quicker reaction times for auditory vs. visual stimuli.

b. *Safety*: Must be child-safe. All electrical components must be secured in a safe manner. Moving components should not pose any harm for user. The device should always be operated by an adult and small children must be supervised while using the device. The components of the device must be easily sterilized.

c. *Accuracy and Reliability*: The time measurements must be accurate to the millisecond. Device must be designed for repeated assembly, disassembly and operation.

d. *Life in Service*: Must be designed for use at a maximum of 10 times a year for a duration of 4 hours at a time. Device should be designed to last indefinitely with minimal maintenance.

e. *Shelf Life*: Device should be designed to last indefinitely with minimal maintenance. Any batteries used should be easily replaceable.

f. *Operating Environment*: Operation will be in a classroom environment at room temperature. Device should be stored in standard indoor environment. The device must be protected against various weather conditions while in transit.

g. *Ergonomics*: The device should be operable with adult supervision for ages 6 and up.

h. *Size*: Must be able to be disassembled and transported in the back of a van.

i. *Weight:* Easily transportable by a single adult (<40 lbs)

j. *Materials*: All materials are allowed baring anything that poses a threat to user (i.e. common allergenic materials).

k. *Aesthetics*, *Appearance, and Finish*: Appearance should be the strong point of the device. It must be attractive to all audiences with an emphasis on middle school-aged children.

2. Production Characteristics

a. *Quantity*: One is desired

b*. Target Product Cost*: Minimal cost is preferable with a limit of $200.

3. Miscellaneous

a. *Patient-related concerns*: In order to limit the spread of common germs and illness the device must be easily disinfected.

b. *Competition*: The intention of building this device is strictly for educational purposes and therefore will not compete with current devices. It will not be used for marketing purposes.