DYNAMIC BALANCE DEVICE

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Problem Definition

Motivation:
- Therapists require professional, engaging devices in order to maximize static and dynamic balance improvement among stroke neglect patients.
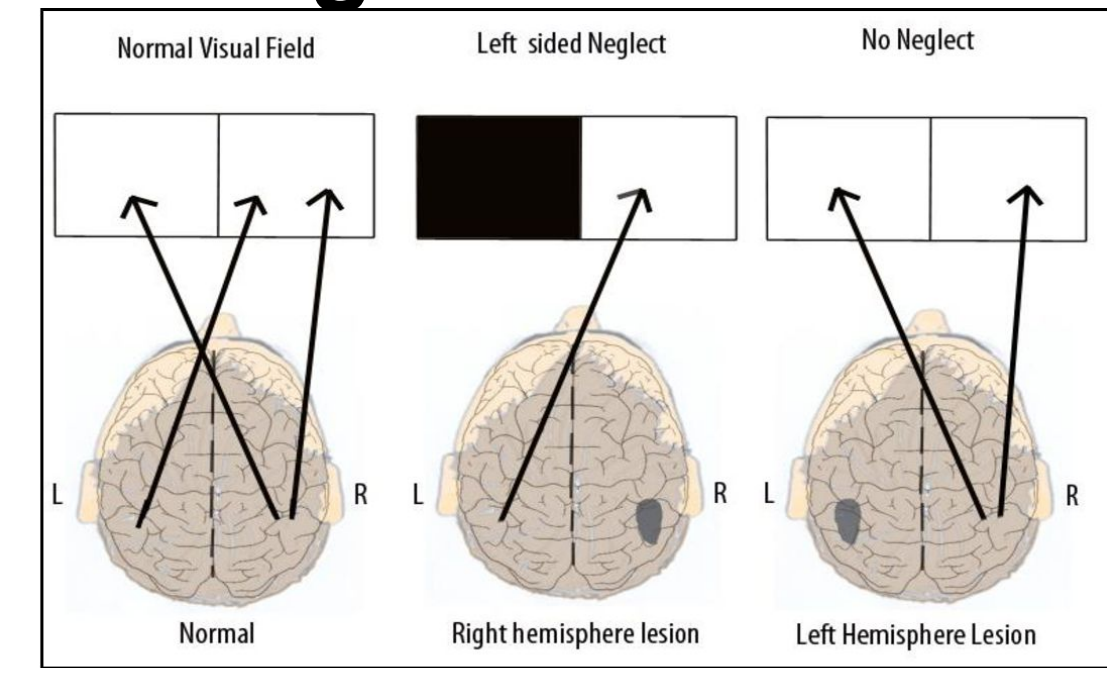
Background:

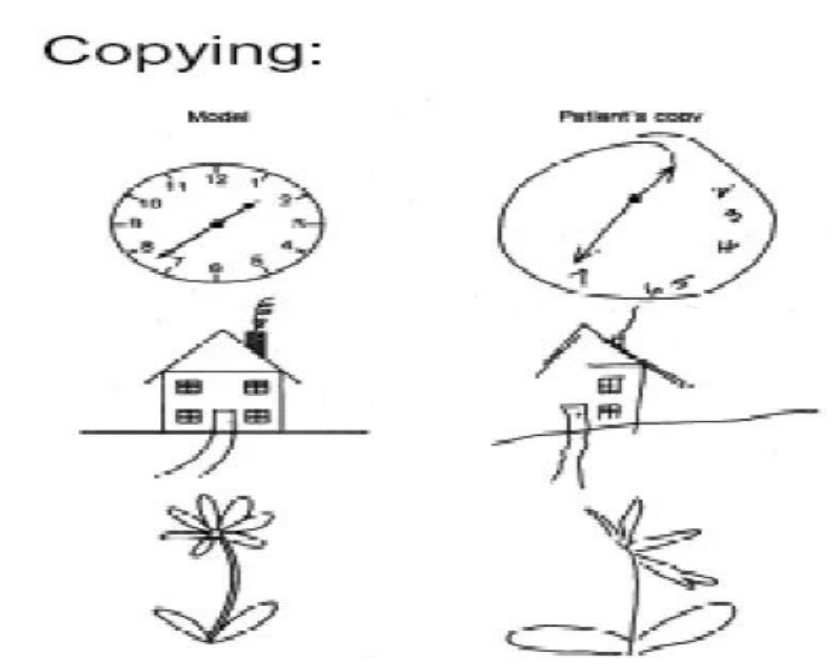**Figure 1.** Effects of brain damage from stroke on brain activity by hemisphere [1]

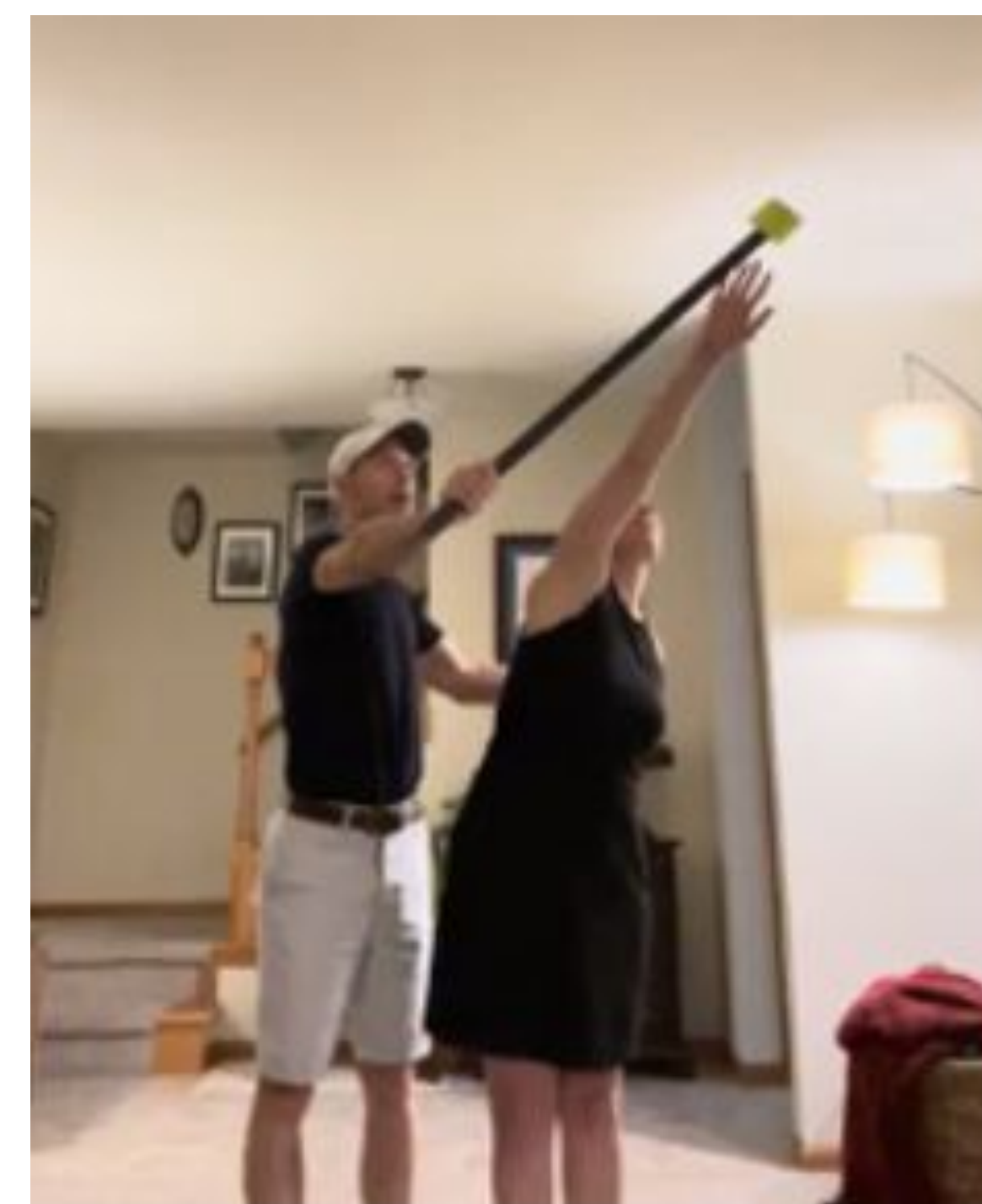**Figure 2.** A person with left neglect copying a drawing of left side. [2]

Competing Designs:

Figure 3 (left). Mr. Kutschera's current device of a meter stick with a colored dot on the end $5

Figure 4 (right). The "Selfie Stick" $20-$40 [4]

Figure 5. Bioness Integrated Therapy System $10,000+ [5]

Design Criteria

Therapist Usability: Appropriate weight for therapist to operate daily.
Patient Compatibility: Display contents are visible to patients from a 3 ft distance at various angles.
Durability: Functional for up to 1 year with minimum degradation; Not requiring maintenance after 2600 total minutes/week.
Ease of Use: Intuitive for a physical therapist to use.

Final Design

4" ⌀ 3D-printed PLA Electronics Case
2" thickness
36" Extend-A-Reach Aluminum Telescoping Rod
1.28" ⌀ Waveshare LCD Touchscreen
Etched Measurements (in)
0.236"x 0.236" Tactile Clicker Button
1.18" ⌀i 1.58" ⌀o Foam Tubing
Arduino Uno Microcontroller

Figure 6. Final Prototype: Display Case, Telescoping Rod, Foam Handle, and Electronics

4 AAA 6V battery pack
on/off switch
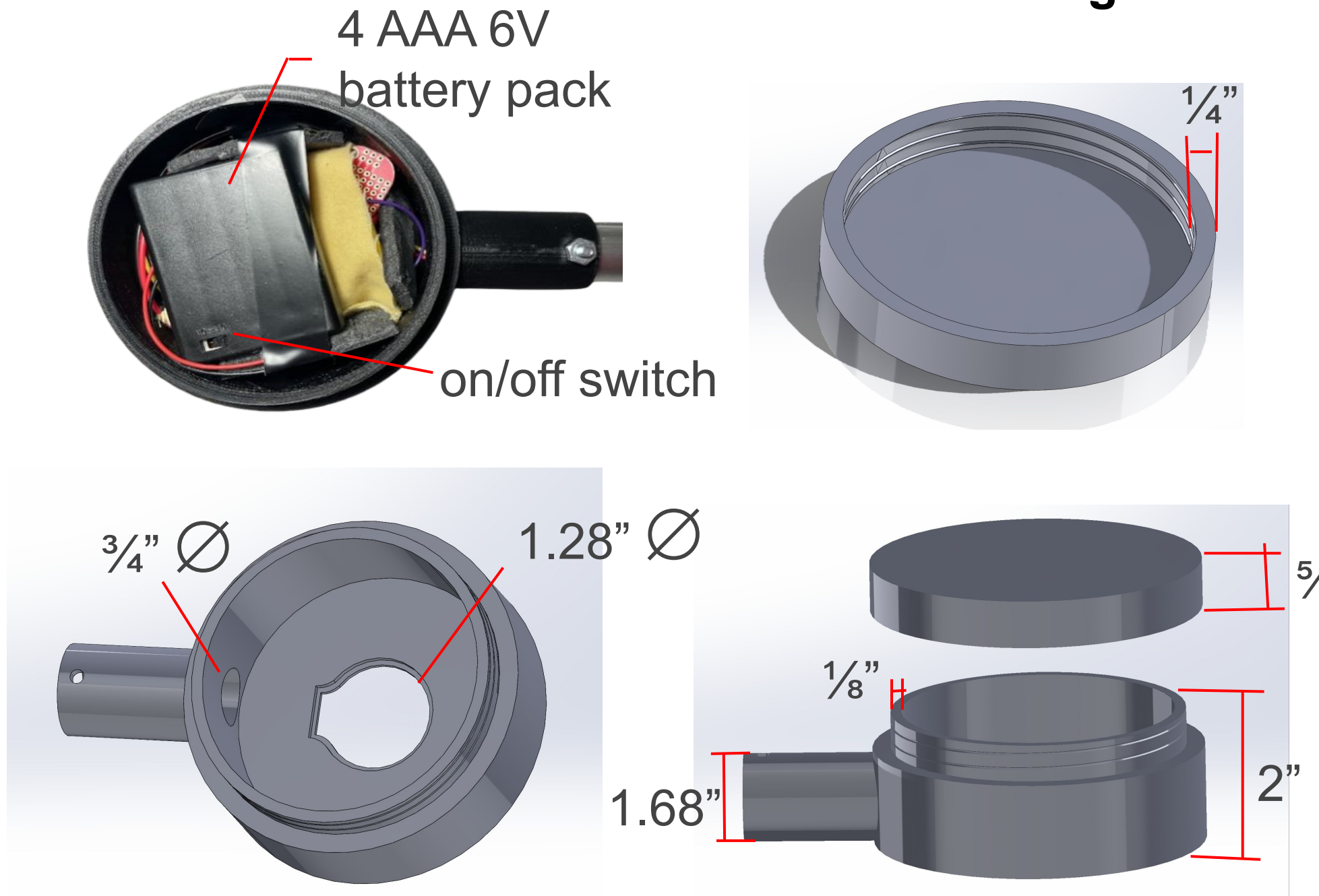¾" ⌀   1.28" ⌀
1.68"   ⅛"   ⅝"   2"

Figure 7. Electronics Case Design - 3D printed in PLA on Ultimaker

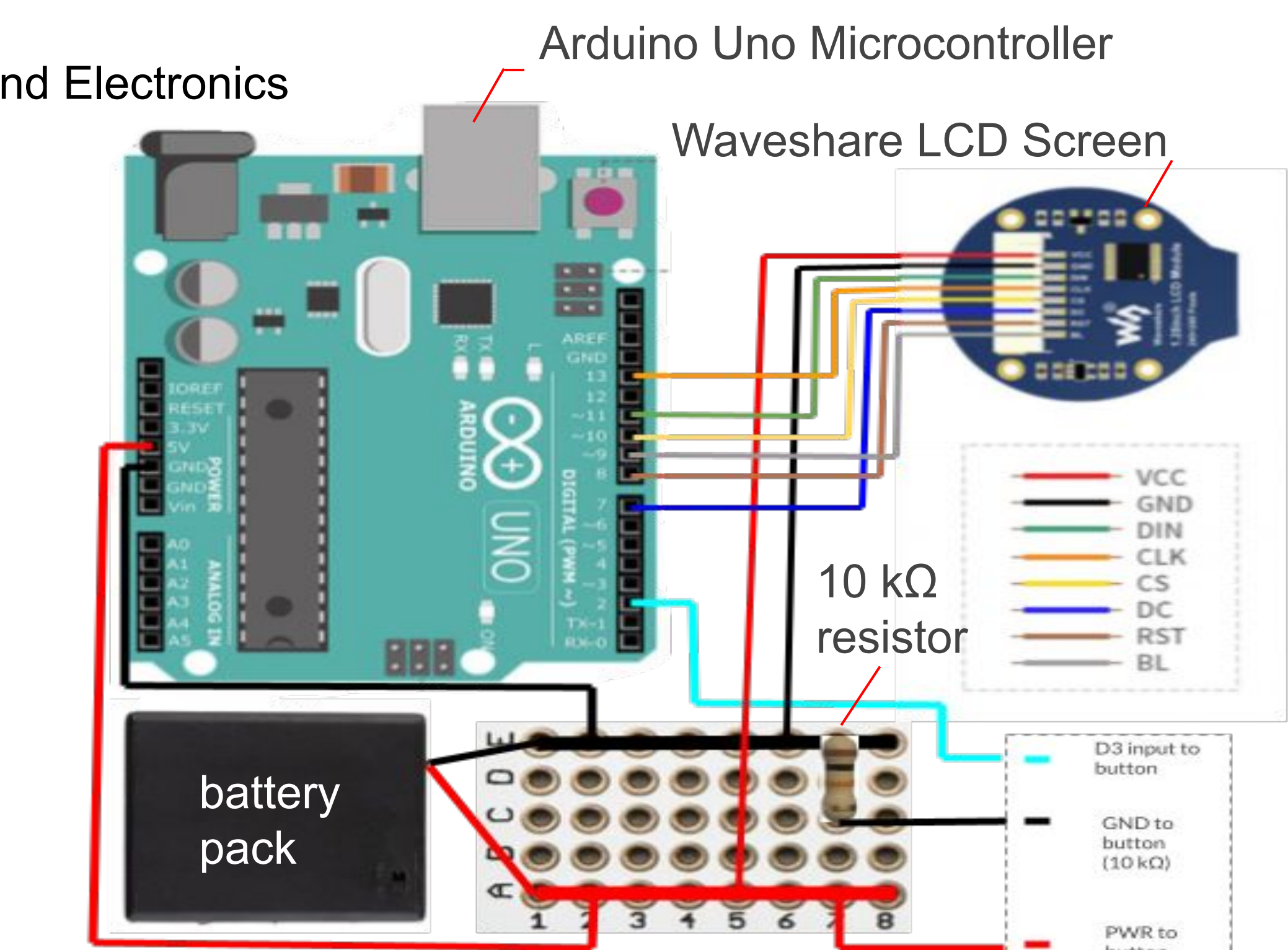**Figure 8.** Rod Engraving with Laser Cutter and Eastwood Aluma Aerosol Blast Paint

Foam tubing
½" ⌀
15 g ½" steel counterweights

Figure 9. Rod counterweight and handle design

Waveshare LCD Screen
10 kΩ resistor
battery pack
VCC / GND / DIN / CLK / CS / DC / RST / BL
D3 input to button
GND to button (10 kΩ)
PWR to button

Figure 10. Electronics Schematic

Testing

a. Survey Feedback by Client

Therapist Usability (Weight)	43%
Patient Compatibility	50%
Durability	100%
Ease of Use	64%

- ~5x a day, 10 min per patient
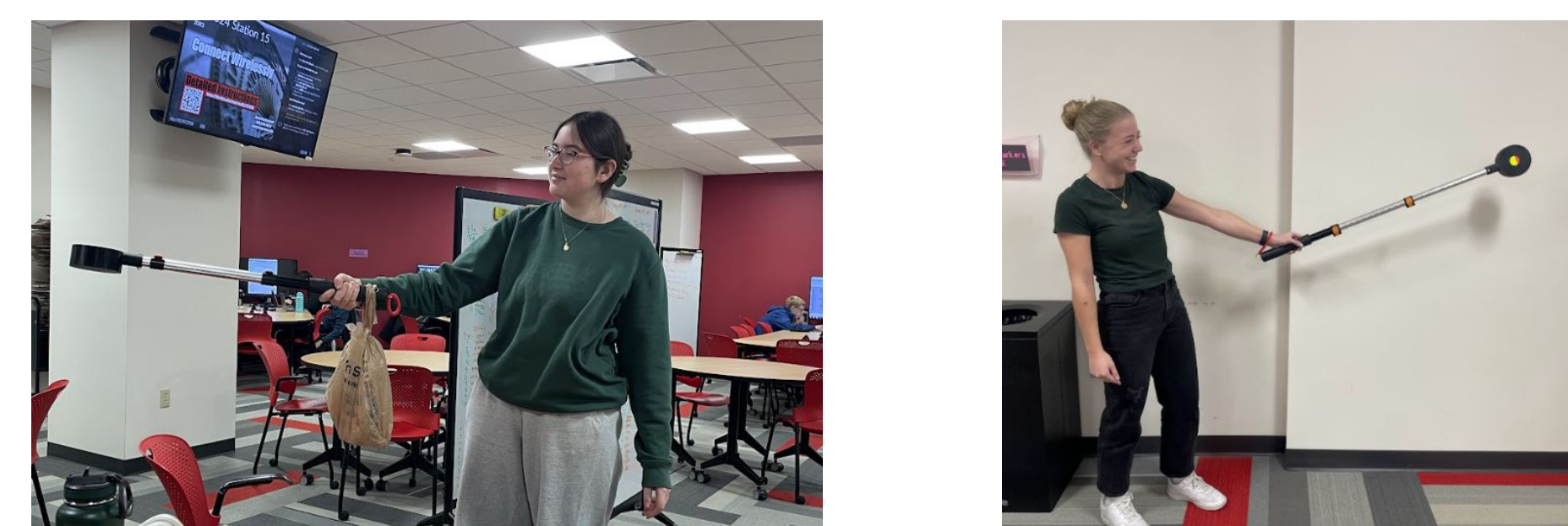- Larger display, shorter rod
- Colors need adjustment

b. Moment Calculations

0.546 m
0.152 m
0.178 m
Md = 200g   Mr = 300g   Ma   Cw

$F = mg$ $mass\ rod = 300g$ $mass\ disk = 200g$ $F_{rod} = (0.300\ kg)(9.81\ m/s^2)$ $F_{disk} = (0.200\ kg)(9.81\ m/s^2)$
$\Sigma Ma = 0 = F_{red}(0.178\ m) + F_{disk}(0.546\ m) - Cw(9.81\ m/s^2)(0.152\ m) - Ma$ $Ma = 1.595 - 1.49Cw$

Figure 11. Half extended reaction moment (Ma) and counterweight (Cw) calculation

c. Usability Weight Testing

Figure 12. Weight usability ½ extended with Cw (left) and fully extended without Cw (right)

Applied Counterweight (kg) vs User Comfort (Pain Scale)
- $4.59 - 6.74x + 4.88x^2$ $R^2 = 0.961$
Polynomial Type Fit Curve
min pain: (0.69 kg, 2.26)
SE = ± 0.478
PAIN ASSESSMENT TOOL

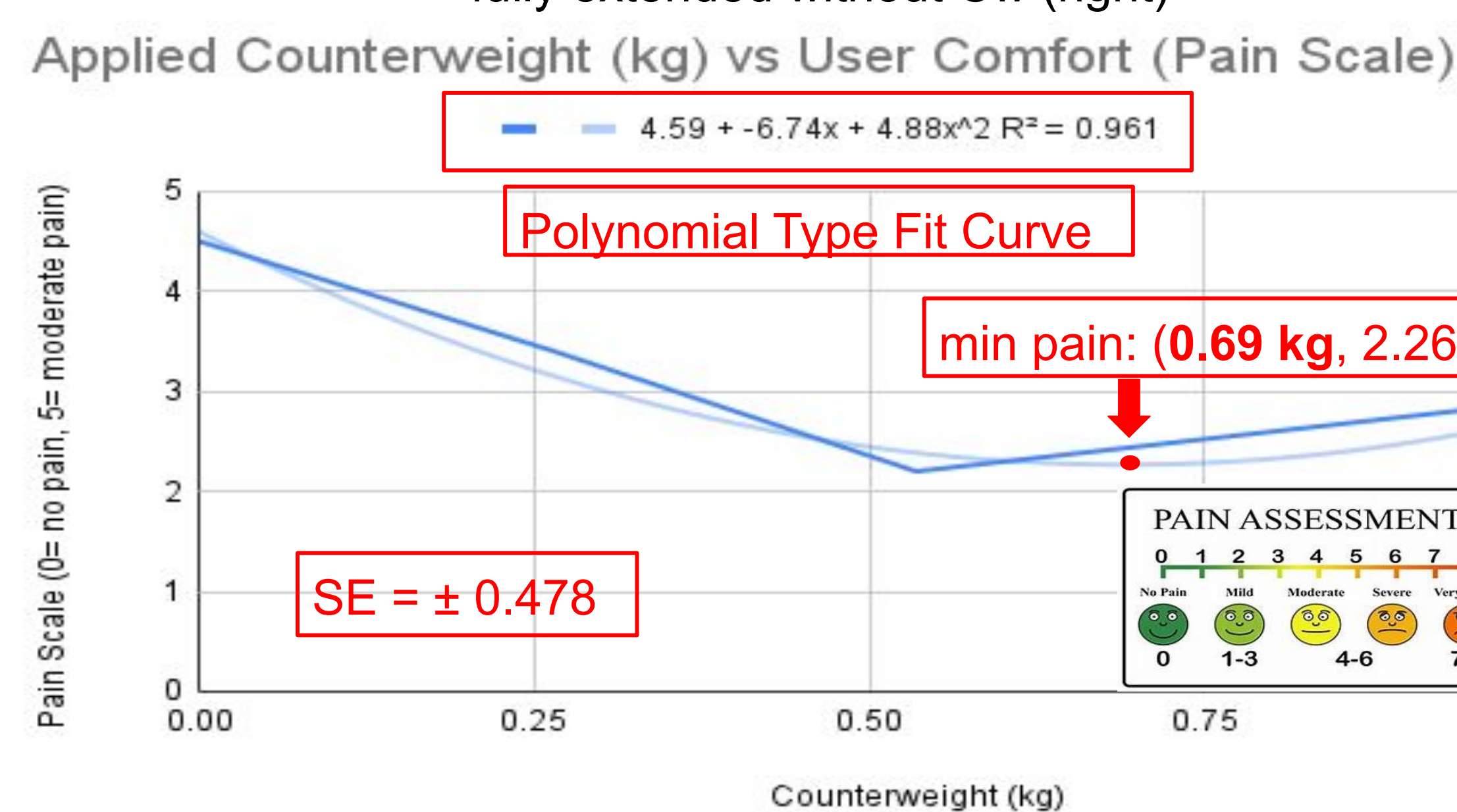**Figure 15.** Half extended rod with Cw added to end versus the comfort of the user by pain scale - 6 trials at 4 different Cw's [6]
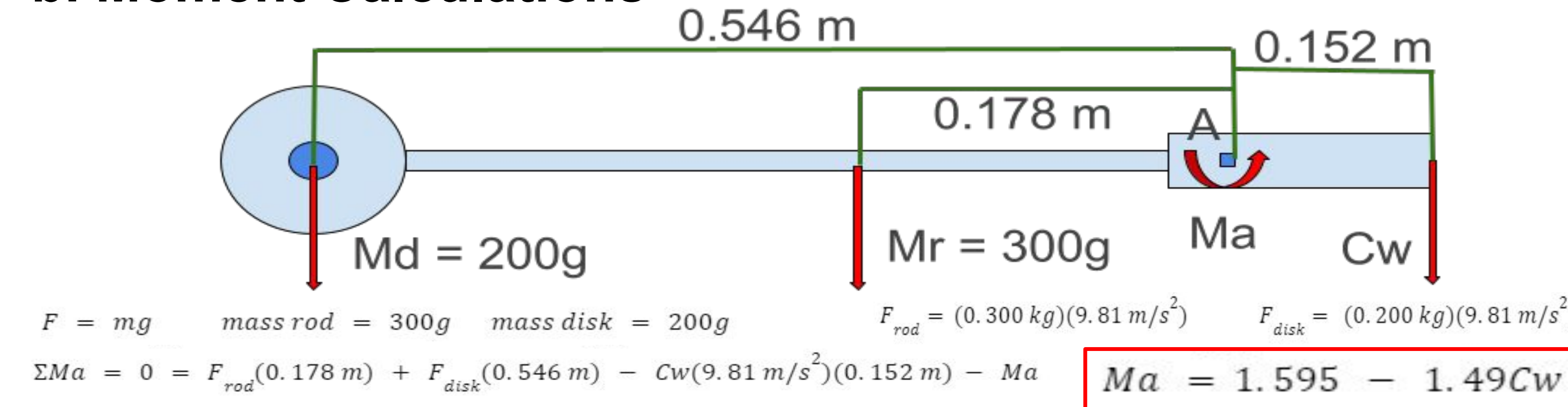
Fully Extended Rod Moment (Nm) vs Counterweight (kg)
- Battery in disk   -1.49x + 2.54 R² = 1   Battery at handle   -1.49x + 1.66 R² = 1
1.70 kg
1.11 kg

Figure 13. Calculated function between reaction moment and Cw in fully extended rod

Half Extended Rod Moment (Nm) vs Counterweight (kg)
- Battery in disk   -1.49x + 1.6 R² = 1   Battery at Handle   -1.49x + 0.973 R² = 1
1.07 kg
0.65 kg

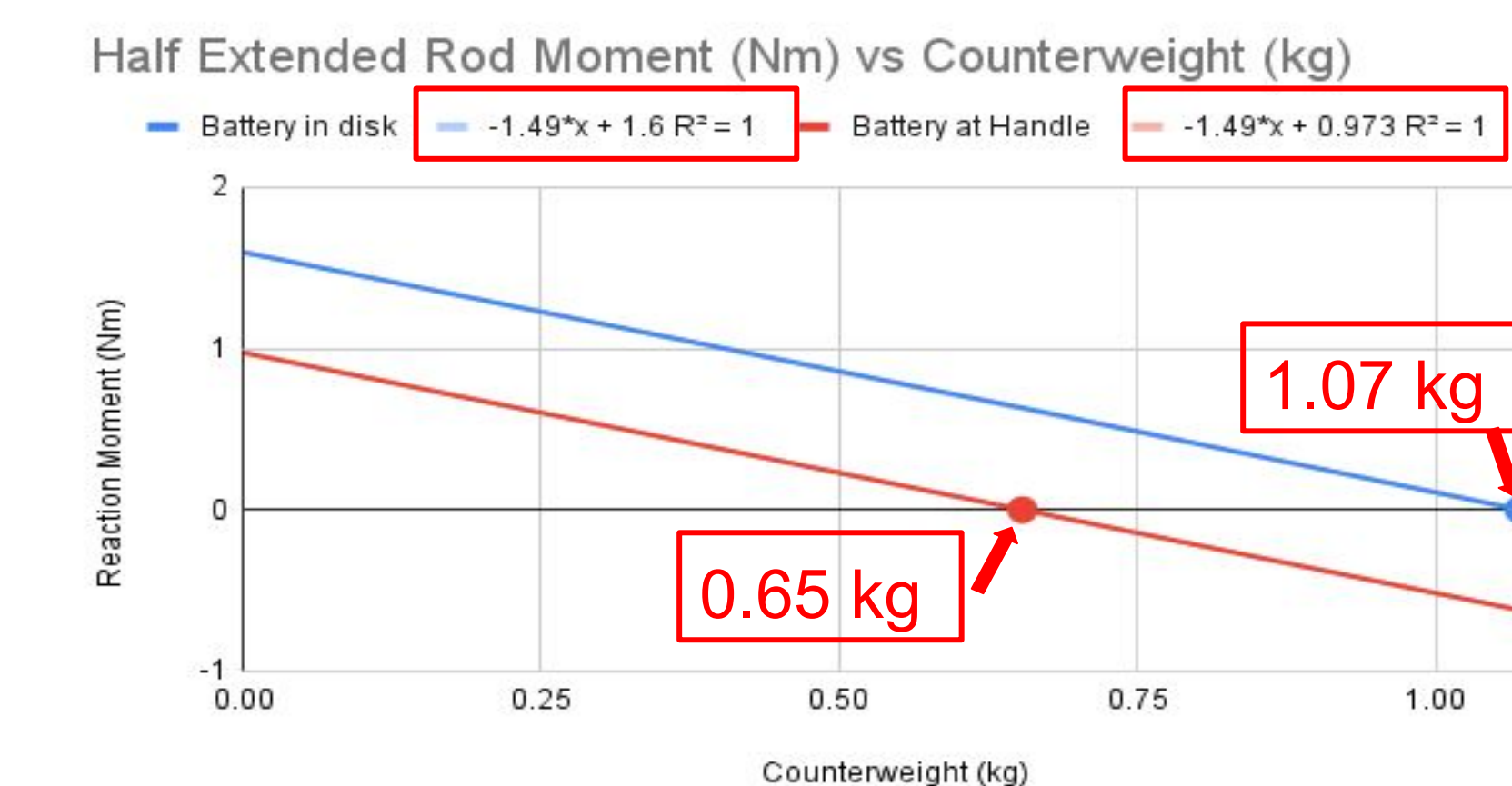**Figure 14.** Calculated function between reaction moment and Cw in half extended rod

d. LCD Screen Visibility Testing

Average Reaction Time (sec) per Color
SE = ±0.053
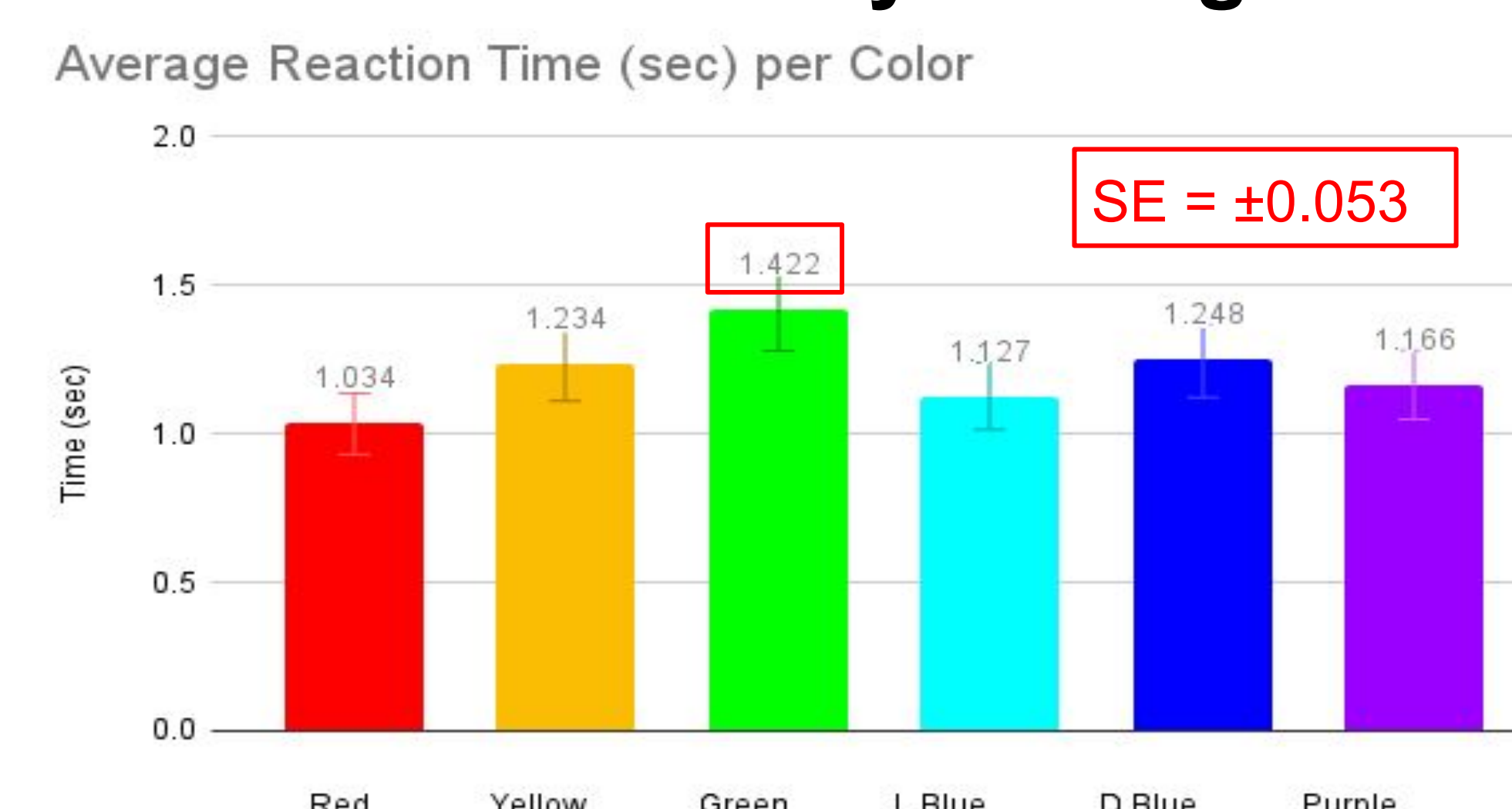Red 1.034 Yellow 1.234 Green 1.422 L Blue 1.127 D Blue 1.248 Purple 1.166

Figure 16. Average reaction time per color from a 20 ft distance - 10 trials for 6 healthy ~20 yo subjects

Figure 17. Color recognition accuracy tests performed at 5',10',15' and 20' for 10 trials on 6 healthy ~20 yo subjects

Results

a. Survey Feedback by Client:
- Intuitive, professional device
- Device is too heavy
- Shorter rod, larger display, more apparent colors

b. Moment Calculations:
- For ½ extended with battery in disk: Cw for Ma = 0 is **1.07kg**

c. Usability Weight Testing:
- ideal Cw = **0.69kg** for minimum pain

d. LCD Screen Visibility Testing:
- Green was hardest to identify correctly, with an average accuracy of **89.1%** (all other colors were **100%**)
- Green reaction time was the slowest at an average of **1.42 sec**

e. Total cost for materials & fabrication: **$152.87**

Future Work

- Reduce the weight of device
- Shorten carbon fiber rod
- Larger screen (3" diameter)
- Add shapes/symbols to display
- Accessible on/off battery switch
- Redesign disk backing
- Audible response to touchscreen

References

[1] Teasell, Robert et al. "Ebrsr [evidence-based Review of Stroke Rehabilitation] 13 Perceptual Disorders Key Points.", Semantic Scholar https://www.semanticscholar.org/paper/Ebrsr-[evidence-based-Review-of-Stroke-13-Disorders-Teasell-Salter/6939881363ac6c2e09794c55206ade7cbc66e53e (accessed Oct 10, 2023)
[2] M. Sutton, "Left Neglect After Stroke - Definition & Treatment Exercises," Tactus Therapy Solutions, Aug. 29, 2018. https://tactustherapy.com/what-is-left-neglect/ (accessed Oct 12, 2023)
[3] "Treat and recover from stroke," Centers for Disease Control and Prevention, https://www.cdc.gov/stroke/treatments.htm (accessed Oct. 4, 2023)
[4]"TelePodTM 325," Tripods for Phone, Camera & Tablet | JOBY, 2023. https://joby.com/us-en/telepod-325-jb01549-bww/ (accessed Dec. 06, 2023).
[5]"Bioness Integrated Therapy System (BITS)," Brooks Rehabilitation. https://brooksrehab.org/technology/bits/
[6]"Learning About the 0-to-10 Pain Scale | Kaiser Permanente," healthy.kaiserpermanente.org. https://healthy.kaiserpermanente.org/health-wellness/health-encyclopedia/he.learning-about-the-0-to-10-pain-scale.abs0043

Acknowledgements