Wearable Light Logger for the Treatment of Mood Disorders

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Problem Statement

- Currently there are no tools which measure light intensity reaching the retina in a research setting.
- Patient response studies to Bright Light Therapy (BLT) are scarce, and more research is needed to develop effective treatment.
- Determining the levels of illuminance that result in the most remission of symptoms of Seasonal Affective Disorder (SAD) and similar mood disorders is important for effective treatment.

Motivation

- Research indicates that approximately 21.4% of adults will experience a mood disorder at some point during their lifetime [1].
- SAD impacts up to 16% of the population worldwide [2].
- The effectiveness of first-line antidepressants is questionable, with a response rate of just 50-60% in adults, while only 35-40% experience remission symptoms [2].
- Research is needed to study the exact conditions of light therapy needed to best treat disorders like SAD.

Background

- Approximately 5% of the U.S. population is affected by SAD annually, with symptoms occurring for nearly 40% of the year [3].
- SAD is mainly due to circadian rhythm disruptions caused by shorter daylight hours in the winter months.
- Light passes through the cornea, pupil, and lens. When light hits the retina, photoreceptors transcribe electrical signals which travel through the optic nerve to the brain [4]. Serotonin, a neurotransmitter that can improve mood, energy, and focus, is then produced [5].
- Significant reductions in depression symptom severity is associated with BLT and dawn simulation in SAD and other mood disorders [3].
- BLT functions by correcting the circadian rhythm phase delay and increasing synaptic serotonin [5].
- The ClouClip is an existing design used in nonclinical settings for monitoring myopia, but does measure light intensity [6].

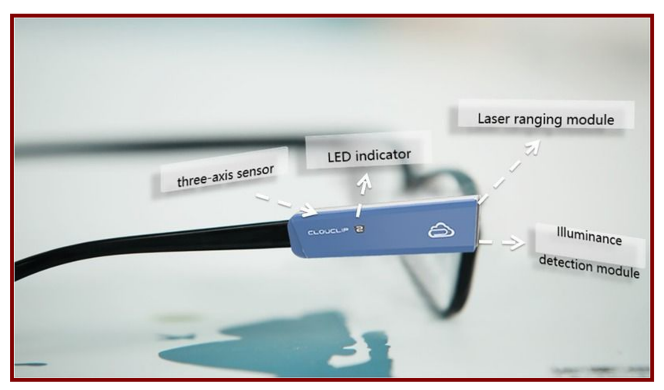


Figure 1: The Clouclip [6].

Design Criteria

- One prototype which measures light intensity (lux) near the retina from a light therapy source
- Outputs correct illuminance within a 5% range
- Weighs 300 g or less
- Used for 2 hour intervals
- Comfortable, inclusive, and safe for the patient
- Easy to use in research settings
- Costs less than $500

Final Design

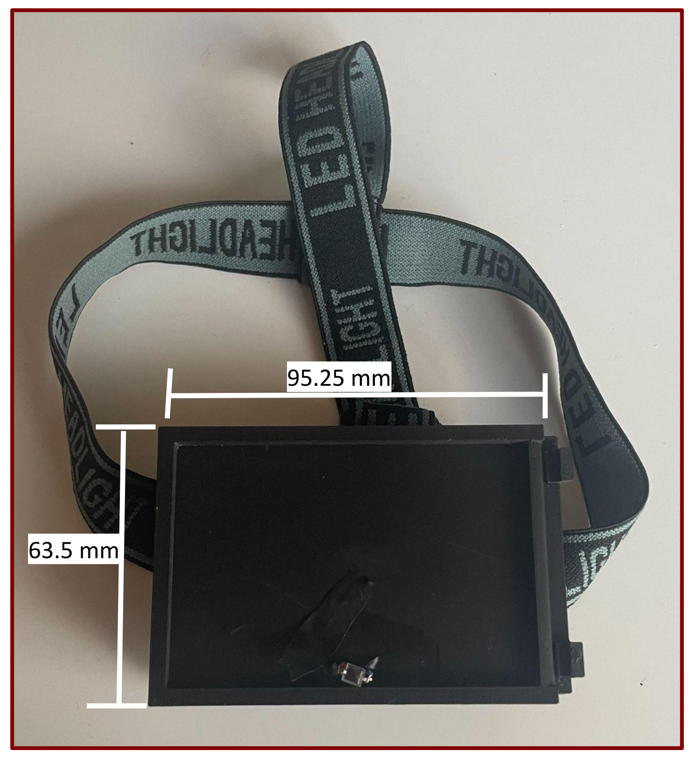


Figure 2: Final cohesive design

Wearable Device

- Elastic straps for inclusive and comfortable wear
- Hook-and-loop connection to box containing electronic components
- 3D printed circuit box slides open and the lid contains a hole for the sensor to protrude from

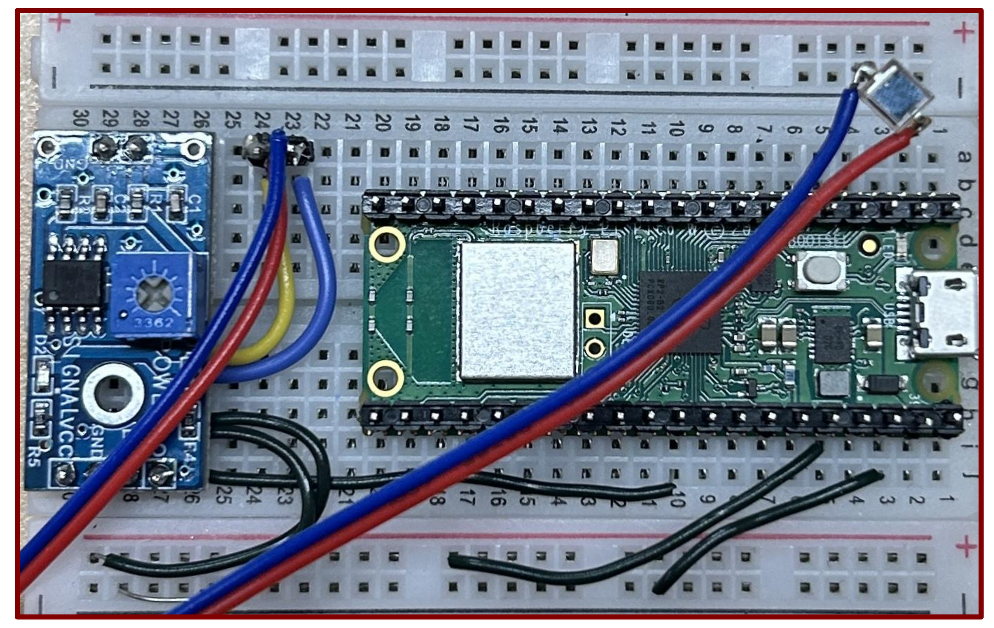


Figure 3: The finished circuit

Circuitry

- Operational Amplifier
- Potentiometer
- Raspberry Pi Pico W
- Photodiode Sensor 900 nm

```python
from machine import ADC, Pin
import time
import math

adc = ADC(Pin(26))

def read_voltage_u16():
    adc_value = adc.read_u16()
    adc_real = 65535 - adc_value
    voltage = (adc_real / 65535) * 3.3
    return voltage

def calculate_lux(voltage):
    if voltage <= 0:
        raise ValueError("0 lux")

    lux = (math.log(voltage / 0.0702)) / 0.000162
    return lux

while True:
    voltage = read_voltage_u16()
    try:
        lux = calculate_lux(voltage)
        print("Illuminance: {:.2f} lux".format(lux))
    except ValueError as e:
        print("Error computing lux:", e)
    time.sleep(0.5)
```

Figure 4: The final code

Code

- Reads input voltage
- Converts voltage to lux using the calibration curve
  - y = 0.0702e^1.62E-04x
  - y is voltage, x is light intensity (lux)
- Displays lux values on serial monitor

Testing

Sensor Calibration

- Sensor sits 30.5 cm from HappyLight
- Three settings of HappyLight's light intensity is tested with sensor
  - 5000, 7500, and 10000 lux
- Values from sensor are recorded from code and converted to lux

Figure 5: The HappyLight [7]

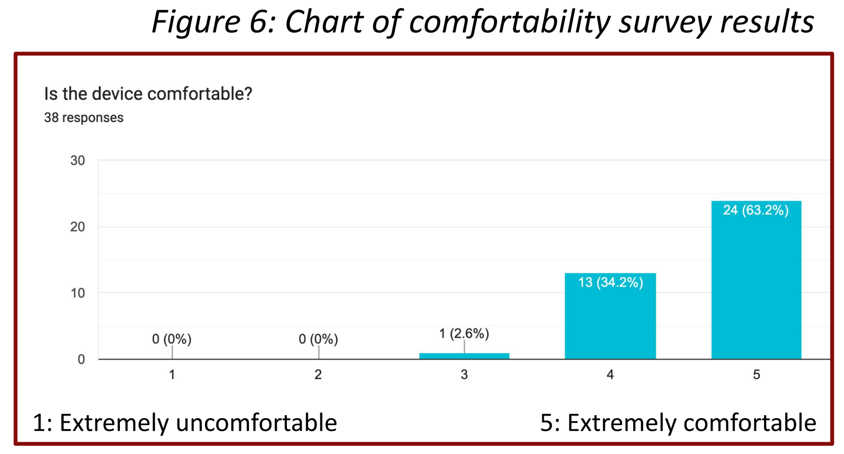
Accuracy of Wearable Device

- Light logger was worn on users head and positioned 30.5 cm from the HappyLight
- Three settings of HappyLight's light intensity were tested
- Device was tested in both dark and ambient light conditions
- Intensity values from light logger were recorded

Comfortability of Wearable Device

- Polled 38 students on comfort and other criteria
- Survey questions regarded:
  - Comfort level of design
  - Weight of the design
  - Inclusivity of the design

Figure 6: Chart of comfortability survey results



Results

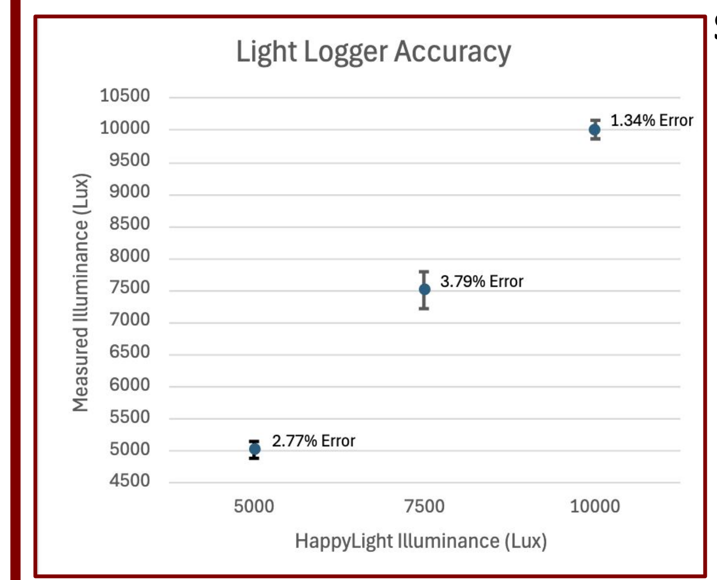


Figure 7: Accuracy graph in dark conditions

Sensor Testing

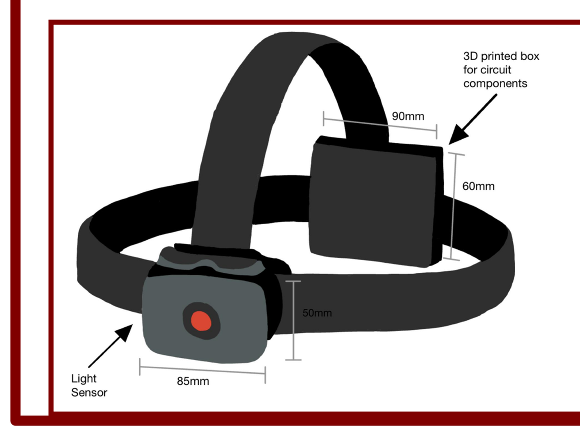
- Results within 5% of the actual lux values in dark and ambient light
  - 2.77% error at 5000 lux
  - 3.79% error at 7500 lux
  - 1.34% error at 10000 lux

Results from survey

- 63.2% ranked the design "extremely comfortable"
- 100% of responses state the design's weight was "extremely comfortable," and could be worn for two hours

Discussion

- The design met the client's criteria of:
  - Time of use, useability, comfortability, weight (138.07 g), and accuracy (within 5%)
- Design could be modified to be even more lightweight to increase comfort
- For the most accurate results:
  - The sensor should be used in a dark room compared to in a room with ambient light
  - Sensor should be 30.5 cm in front of HappyLight



- Original design in Figure 7
  - Featured two connected circuits and a wireless design
  - More complicated compared to final design

Figure 8: The initial design

Future Work

- Wireless design
  - Raspberry Pi Pico W connects to a website using WiFi
  - Allows the product to be used in a personal setting
- Lightweight design
  - Using a PCB board instead of a solderless breadboard
  - 3D print box with a smaller infill value

Acknowledgements

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