Photoplethysmography of a finger

FizziQ activity · Middle and high school · 25 min

Scan to open in FizziQ

The phone camera and its LED become a photoplethysmography sensor: the FizziQ colorimeter records green light variations and yields heart rate, on smartphone.

Learning objectives

- Detect cardiac pulsations using the smartphone camera as a photoplethysmography sensor
- Measure the green light intensity fluctuations caused by blood volume changes in the fingertip
- Calculate heart rate from the period of the PPG signal
- Understand the optical principles behind pulse oximetry
- Compare the PPG-derived heart rate with manual pulse counting

Instruments and sensors

Colorimeter · Camera (light sensor) · LED flash (light source)

Materials

- Smartphone with FizziQ app and functional LED flash
- A quiet environment for measurement
- FizziQ experience notebook
- Note: the protocol remains adaptable to any comparable colorimetric or light-intensity measurement tool.

Protocol

1. Open FizziQ and select the Colorimeter tool or the green channel intensity from the camera sensor.
2. Turn on the smartphone's LED flash to provide a constant light source. (Some phones do this automatically in FizziQ.)
3. Place your index finger gently over both the camera lens and the LED flash, covering them completely but without pressing too hard.
4. Start recording. You should see a pulsating signal in the green channel intensity, fluctuating with each heartbeat.
5. If the signal is not visible, adjust your finger pressure: too hard blocks all light; too light lets ambient light in. Find the sweet spot where the green signal oscillates clearly.
6. Record for at least 30 seconds to capture 30-50 heartbeat cycles.
7. Stop recording and examine the graph. Count the number of peaks (one per heartbeat) over a 20-second interval.
8. Calculate your heart rate: HR (bpm) = (number of peaks / time interval in seconds) × 60.
9. Verify your result by counting your pulse manually at the wrist for 15 seconds and multiplying by 4.
10. Now perform 2 minutes of light exercise (jumping jacks or jogging in place), then immediately repeat the measurement.
11. Compare your resting and post-exercise heart rates. The post-exercise rate should be significantly higher.
12. Try to identify the dicrotic notch in the PPG waveform: a small secondary dip that corresponds to the aortic valve closing.

Expected results

The green channel intensity should show clear, regular oscillations with a period of 0.6-1.0 seconds (corresponding to heart rates of 60-100 bpm at rest). The amplitude of the oscillations is typically 1-5% of the mean green intensity. After exercise, the heart rate should increase by 30-80% (to 90-160 bpm), and the signal may also show larger amplitude pulsations. The PPG-derived heart rate should agree with manual pulse counting within ±2-3 bpm. The dicrotic notch may or may not be visible depending on the phone's camera quality and sampling rate. Some phones produce cleaner PPG signals than others due to differences in camera sensitivity and LED brightness.

Questions

- Why is the green light channel most sensitive to blood volume changes?
- How does a hospital pulse oximeter measure blood oxygen saturation in addition to heart rate?
- Why does the PPG signal decrease (more absorption) when the blood volume in the fingertip increases?
- What factors other than heart rate could affect the shape of the PPG waveform?
- How do smartwatches measure heart rate continuously using the same principle?
- Could you use this technique to detect irregular heart rhythms (arrhythmias)?

Going further

- Compare the PPG signal from different fingers and discuss whether the signal quality varies
- Investigate how caffeine consumption affects heart rate by measuring before and 30 minutes after coffee
- Record the PPG signal during slow deep breathing and observe how the signal amplitude modulates with respiration
- Compare the green, red, and blue channel signals to understand why green is most sensitive
- Use the PPG waveform to estimate pulse transit time by simultaneously recording from a finger and from the forehead