Class Discussion Questions and Answers

Instructions: Lead a class discussion with the following questions:

- 1. What were some limitations of the experimental design?
 - Here are some potential limitations of the experimental design:
 - Slight changes in electrode placement can significantly affect EMG signal strength and clarity. Also, surface electrodes only detect superficial muscle fibers, not deeper muscles.
 - Two-minute recordings might not capture the full dynamics of muscle fatigue or longterm signal changes. Muscle fatigue over the two-minute trials can cause variability in signal amplitude.
 - Background electrical noise (e.g., 60 Hz power-line interference) can distort EMG signals.
 - With fewer trials or limited participants, individual differences could significantly influence results.
 - Human errors in performing rhythmic gestures precisely at metronome beats may introduce inconsistencies.
 - Sensitivity limitations of the Muscle SpikerBox may affect detection of very low amplitude signals.
 - Variations in skin preparation, hydration, electrode gel usage, or skin properties can affect electrode conductivity.
- 2. What causes the spikes that you saw? Where did it originate? What do we know about the neuromuscular junction?

The spikes observed were caused by the muscles themselves responding to nerve signals. Neurobiologists have demonstrated that, when the brain decides to move, it sends an electrical signal down nerve cells, releasing chemicals at the neuromuscular junction, causing muscle fibers to activate electrically. The spikes we see on the EMG show this electrical activation, letting us observe how our muscles and nerves work together.

3. What is occurring when the spike is positive? What is occurring when the spike is negative? EMG is recording all activity as it is detected by surface electrodes, and propagation of muscle and nerve impulses such that it involves both depolarization and repolarization phenomena. The EMG signal consists of a series of spikes, which are the electrical signals generated by the firing of motor units. Each spike in an EMG signal typically has both positive and negative components. The "spikes" amplitudes, therefore, will be influenced by the location of the recording electrodes with respect to the number of active underlying skeletal muscle and motor nerve fibers.

A positive spike in the EMG recording occurs when the muscle fibers underneath the electrodes become electrically active (depolarize), a key event in muscle contraction. The negative spike represents the main repolarization of the muscle fiber, muscle relaxation.

The amplitude and frequency of the EMG spikes can provide information about the level of muscle activity, the recruitment of motor units, and the presence of any abnormal electrical activity.





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- 4. If we were to redo the experiment, would you change the placement of electrodes? Where would be the best place to record from? Why? Yes, changing electrode placement might improve the quality of our EMG signals. Optimal placement would help reduce noise, improve signal strength, and provide clearer data for analysis.
 - a. For wrist muscles, electrodes are placed centrally on the flexor/extensor surfaces rather than near tendons or bones. Electrodes are placed parallel to the muscle fiber direction on forearm muscles (wrist flexors/extensors).
 - b. For finger muscles, small spacing (around 1-2 inches) between electrodes on small muscle groups could capture clearer, more precise signals.
 - c. Placing the reference electrode on a neutral, non-active site (such as the elbow or upper arm) rather than the hand, to reduce interference.
- 5. Identify the ways in which the experiment could be improved so that the results are consistently reliable, repeatable, and reproducible.
 - a. Students can utilize diagrams or anatomical landmarks—that is, follow a clearly marked anatomical guideline for placing electrodes to consistently position them precisely every time. Consistently clean skin surfaces with alcohol pads, use electrode gel, and confirm proper electrode adhesion each trial. Replace electrodes regularly and verify electrode condition before each recording.
 - b. Check cable connections and hardware functionality regularly before starting data collection.
 - c. Have practice sessions to accurately perform rhythmic movements synchronized precisely with the metronome. Clearly define and practice the exact movements (roll, pitch, yaw) to reduce human variability.
 - d. Include more participants to account for variability among individuals. Conduct multiple trials per participant at each BPM to obtain more consistent and statistically robust data.
 - e. Standardize the duration of rest between trials to minimize the effects of muscle fatigue. Include explicit warm-up and cool-down protocols to maintain consistent physiological conditions.
 - f. Confirm and double-check settings (bandpass filter 70–2500 Hz, 60 Hz notch filter) before every recording. Record in environments with reduced electrical interference (away from outlets, chargers, or electronics).
 - g. Integrate quantitative analysis (amplitude measurements, spike counts, frequency analysis, Fourier transforms). Calculate statistical values (means, standard deviations, and variability measures) to objectively assess reproducibility.
 - h. Clearly label and organize data files (gesture type, BPM, participant initials, trial number). Maintain detailed experimental notes and document exact steps, conditions, and procedures in every trial to facilitate repeatability.





- 6. How would the recordings differ if you were recording right inside the cell? What would be different about such an experimental set-up? Would you see the same number and type of spikes? How would the amplitude change? If we recorded EMG signals directly inside a muscle cell instead of on the skin, we would see much clearer, bigger, and distinct spikes from just one muscle fiber, rather than a combination of many. This approach, while more precise, is invasive and technically challenging. The spikes inside the cell would have higher amplitudes, clearer phases, and provide detailed insights into exactly how each muscle fiber fires.
- 7. What does muscle fatigue look like, how could you measure it, and what is causing this? Muscle fatigue on EMG looks like weaker spikes and fewer spikes happening over time. You can measure fatigue by seeing how the spikes become smaller or slower as muscles tire, or by timing how long it takes until spikes significantly weaken. Fatigue occurs because muscles use up their energy, accumulate waste products, and nerves become less effective at signaling the muscles to contract over sustained periods.
- Do different people have different rates of fatigue? Different muscles? Yes, different people fatigue at different rates because everyone has unique fitness levels, muscle fiber types, age, health, and nutrition. Some examples of this include:
 - a. Athletes or physically active individuals typically experience slower muscle fatigue because their muscles are better trained, more efficient at energy usage, and have improved blood flow.
 - b. Older individuals or people with health issues (e.g., neuromuscular disorders, metabolic conditions) may fatigue faster due to decreased muscle strength, energy efficiency, or nerve function.
 - c. Individuals who are poorly nourished or dehydrated fatigue more quickly because their muscles cannot efficiently sustain energy production and waste removal.
- 9. Students qualitatively compare the spike signals from the wrist vs. finger movements. Actions students follow for both wrist and finger movement and the output they shall record to compare are as follows:

Step	Example Action	Example Output
1	Clearly record initial hypothesis	Written clearly on worksheet
2	Collect/organize EMG data systematically	Organized data folders and files
3	Visually analyze and compare signals	Note spike amplitude/frequency differences
4	Summarize qualitative observations	Written descriptive summary
5	Connect observations back to hypothesis clearly	Clearly stated conclusion



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