

Meeting Your Potential

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Abstract

For the Kid's Judge Neuroscience Fair, my partner Patrick Hines and I did a demonstration of an action potential in pre/post-synaptic cells before, during, and after neurotransmission using a foursquare ball and a throwing/catching game. Subsequently, catching the ball and preventing the game from being played correctly will explain the antagonistic effects of drugs on neurotransmission, in relation to the generation of action potentials. If the kids played the game correctly and passed the action potential from one neuron to the next we reinforced them by opening a box and letting them have one piece of candy. The game of neurotransmission and action potentiation was used as a model for the process involved at a neuromuscular junction in my arm to open the box of candy. In order to explain these complicated neuroscience topics; we had to concede some facts for the sake of understanding.

Introduction

Action potentials are the basic electrical property of neurons and information is encoded by neurons as the number or frequency of action potentials (1). Action potentials are propagated down the neuron axon and are created by a depolarization of the neuronal membrane. The stimulus can come from a synaptic connection with another neuron, at which the pre-synaptic neuron stimulates the post-synaptic neuron (an excitatory post-synaptic potential, or EPSP). Enough depolarization leads to the violation of the threshold potential, which activates sodium ion (Na^+) influx at the axon hillock and creates an action potential (2). Tetrodotoxin (TTX) has been used to block the sodium channel, resulting in no flow of sodium ions and no depolarization of the membrane. Because each EPSP causes a small depolarization, summation is necessary to create a sufficient depolarization to reach threshold. Summation occurs spatially or temporally. Spatially being the summation of several different stimuli across a certain space, and temporally being the summation of stimuli from one specific site.

Chemical synapses are represented by two neurons and separated by a synaptic cleft. Neurotransmitters communicate between the two, which modify the amplitude and frequency of action potentials and subsequent neurotransmitter release. At the peak of the action potential the sodium channels become inactivated, therefore sodium is no longer allowed to flow into the cell causing the depolarization. When the membrane is depolarized the potassium channels open to cause the hyperpolarization and return to the resting potential, however the channels open much slower, so the effect is not seen concurrently with the sodium depolarization. This has been shown experimentally through tests conducted using tetraethylammonium (TEA) in which the TEA blocked the potassium channel and consequently prevented the membrane potential from returning to its resting state (3). This also increases the length of the action potential and a decreased frequency of action potentials because the sodium channels were still in the inactivated state.

In myelinated axons, the action potential is propagated through saltatory conduction. The unmyelinated regions between the myelin sheaths are known as Nodes of Ranvier, where there is a greater concentration of sodium channels than in the internodal regions, resulting in a higher rate of transmission (1). Therefore, the action potential is propagated down the axon faster because the capacitance is decreased. Depending on the neural connectivity and the synaptic channels being activated, action potentials can cause inhibition or excitation. Drugs can alter action potential firing by changing the process of neurotransmission in the following ways: release, binding to receptors, enzymatic degradation, or reuptake. In each manner, the process can either be enhanced or inhibited, depending on the pharmacological action of the drug. Specifically for binding, an agonist refers to a drug that mimics or enhances the effect of a neurotransmitter, and an antagonist refers to a drug that block the effect of a neurotransmitter.

The concepts we wanted to explain to the kids with our model are the basics of action potential conduction. Including how ion flux changes the membrane potential that in turn affects the membrane potential of subsequent sections of the neuron. Also we wanted to convey how drugs alter and prevent neurotransmission and the basic effects of drugs on the body.

Methods

The purpose of our model was to demonstrate the way an action potential arises in a post-synaptic cell after a depolarized pre-synaptic cell releases a neurotransmitter. For this demonstration, we used a regular-sized foursquare ball with “NT” written on it, between six and ten grade school participants, and a box of any kind with assorted candies in it. To explain the model, we introduced a brief overview of the general properties of an action potential and neurotransmitter release and binding. For the activity, two groups of children were spaced apart with one group being the “Pre-Synaptic Neuron” and the other the “Post-Synaptic Neuron.” When we say, “begin,” the group representing the pre-synapse will begin to do the wave (the wave made popular at sporting events). When the wave approached the end of the pre-synaptic neuron, either my partner or myself passed the ball to the child at the beginning of the post-synaptic neuron, thus modeling the effect of neurotransmitter exchange. Then, the group acting as the post-synapse did the wave until the last child raised his or her hands. At this point, we will open a box if the action potential progressed correctly, which simulates the movement of muscles by neurotransmission.

To demonstrate that drugs alter the binding and release of neurotransmitters, we intercepted the ball while it is being thrown. Therefore the action potential was disrupted and no candy was received. At this point we emphasized the negative effects of drugs and encourage the children to perform the activity in the absence of drugs.

Results

The presentation portion of this project went better than I initially expected. The kids were attentive, for the most part, and seemed to enjoy playing the game. A few of the groups liked playing the game so much they asked to play it again after we presented the material and before they had to switch stations. The presentation for the first group

ran a little bit fast, and we had several minutes before passing time. We adapted by asking more questions of the kids, so that the kids weren't running around with more time between group presentations.

Patrick and I tied for third place in the "A" group. This surprised me because the reaction from the kids was so positive. They all really seemed to like our model, and I expected to place higher in the ranking. I attribute it to the fact that a certain other group used a live mouse to acquire more votes.

To explain the action of drugs in the nervous system, I intercepted the ball while it was being thrown, therefore the action potential couldn't continue down the line. We explained that drugs prevented your nerves from communicating correctly and changed the way your body functioned. Also, because I intercepted the ball, the "action potential" couldn't connect to my arm muscle and open the box of candy. We asked each group whether they would like to play with or without the drugs, and every time they responded, "Without the drugs." Except one time one of the boys wasn't paying attention and he said that he wanted to play with the drugs.

Using the foursquare ball as a neurotransmitter and the passing/catching game as a model of neurotransmission worked very well. The kids were interested and seemed to want to know more about this topic.

Discussion

Because of the complex nature of this topic, it was necessary to simplify the explanation and model so that the 5th graders would be able to understand the material easier. The concepts of axonal resistance and capacitance, as well as the complex manner in which ions travel across the membrane are far too complicated for elementary school students to understand. Therefore, we simplified it by saying that ions from foods, mainly salt, cause the action potential to travel down the axon. Doing this compromised the accuracy of the concept explained, but it was necessary to get the point across to the kids. Another problem was explaining what an action potential was. We explained it as an electrical impulse and gave an example of an electrocardiogram monitor with the waveform as the action potential.

We simplified the effect of drugs on neurotransmission by simply taking the ball away. This is analogous to the receptor antagonistic effect of drugs. However drugs affect synapses in several ways: blocking reuptake of neurotransmitter into the pre-synaptic neuron, increasing release of neurotransmitter from the pre-synaptic neuron, mimicking a neurotransmitter or altering binding to create an agonistic effect, blocking a neurotransmitter or altering binding to create an antagonistic effect, and preventing the enzymatic breakdown of neurotransmitters.

Upon analyzing the evaluations and the voting, I see there is an inconsistency between the two. We were tied for third in the "A" group with group A2, but looking at the evaluation scores, Patrick and I scored higher on every category. This could be because neither of our presentations made a great impression on the kids, so during voting we got equal votes. But, if voting would have perfectly corresponded to the evaluations, A2 should have gotten fourth place, instead of sharing third with us. Also, Patrick and I scored higher on "Understanding" and "Friendliness" than group A4 who

received second place. We scored nearly equal on the ‘Fun’ factor and the average of the evaluation scores. However, they scored higher than us on the ‘Learn More’ category. This could be the contributing factor to our receiving third place. Also that model was more interactive with ping-pong balls and balloons, so the experience might have been fresher in the minds of the kids when they voted for their favorites. There is no incongruity between the first place score team A1 obtained and the evaluation results.

The most difficult aspect about this project was getting and maintaining the attention of the kids. For the most part, the girls seemed to pay more attention than the boys, some of whom appeared to have Attention Deficit Hyperactivity Disorder (ADHD). The key would be to make the model more entertaining and present the material in a way that relates to the kids better. If I were to do this project again, I’d put more pictures on the poster board and have more animated drawings of the neuron and nervous system. Overall, I think our project went very well and the model was fun and entertaining while being a good representation of action potential propagation.

References

- White, G., Lovinger, D. M., & Weight, F. F. (1989) *Proc. Natl. Acad. Sci. (USA)* **86**, 6802-6806.
- Hodgkin, A. L., & Huxley, A. F. (1952) *Jour. Of Phys.* **117**, 500-544.
- Ramon, F., & Moore, J. W. (1979) *Jour. Gen. Phys.* **73(5)**, 595-603.