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Meeting Your Potential

Abstract

We developed an instructional model to explain a concept of neuroscience that was both educational and entertaining for fifth graders. Our model demonstrated the basic properties of an action potential. We also covered the negative effects of drugs on action potential propagation. An interactive game with the children was used to convey our message and the children were rewarded with candy. Our model tied for third place out of four groups (average score= 4.6725). We were successful in the categories of “Friendly” (2nd place) and “Understand” (2nd place), but the main flaw seemed to be that the topic was not intriguing enough to children in fifth grade. Therefore, it seemed that the topics that educated about the functional ability of the brain were more effective.

Introduction

The conversion of stimulus into electrical and chemical responses is the most essential function of the central nervous system. At the very root of sending electrical signals is a phenomenon known as the action potential. By this method, we can react to and learn about our environment. In fact, researchers have described the action potential as the basic property of neurons, by which information is encoded in number and frequency (White, et al., 1989). Therefore, an understanding of this fundamental property can enhance our understanding of the way we perceive and interact in the world.

Hodgkin and Huxley (1952) first characterized the electrophysiological background for the action potential in the middle of the twentieth century. They found that the membrane of neuron was at a resting state when no ionic current was present, except for a slight leakage current through the channels. Then, upon the imposition of some stimulus an influx of positive current into the cell caused a depolarization. The positive ions responsible for the depolarization were found to be sodium and potassium. Once the cell was depolarized to a certain threshold, an all-or-nothing action potential was initiated in the squid giant axon. Hodgkin and Huxley (1952) further determined that at the height of the action potential spike, potassium would leak out to reestablish the resting membrane potential. The potassium current determines the relative refractory period. Toward the very end of this falling phase, a point called the absolute refractory period, the sodium channels will completely inactivate and no further action potentials can result for a certain amount of time.

Later research revealed that calcium influx after depolarization could induce burst firing, where the membrane could remain depolarized longer, therefore, allowing a cell to produce multiple action potentials (White, et al., 1989). It was discovered that this occurred because the relative refractory period was prolonged when calcium flowed into a cell, thus the capacitance required to induce further action potentials was decreased. Also, further research found that drugs and toxins could alter the properties of the action

potential. For example, TTX was a toxin that could block sodium channels and allowed no excitation to occur. Likewise, toxins like TEA decreased the conductance of potassium, which led to prolonged sodium influx, thus changing the falling phase characteristic (Ramon and Moore, 1979). However, the effects of drugs are secondary for this project, so the properties of the action potential will be the main emphasis.

The first action potential is generated at the hillock, or anywhere else that sodium channels open. From here there are several other factors that affect propagation down the axon. For example, the size of the axon has a great effect. Larger axons have a greater rate of conduction, so they it is easier to produce action potentials. Also, larger axons have a lower resistance, which allows the charge to spread more rapidly. This is based on a formula called the time constant, which is equal to the product of membrane resistance and membrane capacitance. The time constant determines how long it takes for an action potential to be generated at a specific part of the membrane. It is also equivalent to 63% of the threshold.

To enhance propagation velocity and efficiency, there are areas in many vertebrate axons that are coated with many layers of fat called myelin. It decreases capacitance and, according to the time constant, decreases the amount of time for subsequent action potentials to be generated. The rate of propagation is also improved by myelination through saltatory conduction. In saltatory conduction there is propagation at the nodes of Ranvier (the spaces in between myelin along the axon), where there are a greater number of sodium channels than in the internodal spaces, thus permitting a higher rate of conductance (Waxman, et al., 1989). When an action potential successfully propagates, it is passed on to another neuron or many other neurons by provoking neurotransmitter release from the axon terminal to the synaptic cleft. Depending on the neural connectivity, the effect can be inhibitory or excitatory for the next neuron in sequence.

We conveyed the concept of the action potential to the children at the Kids Judge! science fair. My partner and I decided a relay game, similar to the wave made popular at sporting events, would be the most effective way to model the action potential. With candy as an incentive, they will be encouraged to perform the task in the shortest time possible. We will explain to them that the nervous system can propagate at up to hundreds of miles per hour. Then, as a side note, we will briefly explain the negative effects of drugs (binding, reuptake blocking, NT release, etc.) on the generation and proliferation of action potentials. In the interactive game, the addition of the drug variable will eliminate the possibility of completing the task. As a result, no candy will be awarded. Finally, they will be allowed to repeat the assignment in the absence of the drug to, again, be awarded with candy.

Materials and Methods

Our model was very simple to set up. First, at least six children were needed. We also required about ten square feet of floor space. To demonstrate our concepts, we displayed a three-division poster board with drawings of the brain and spinal cord, the general shape of an action potential, a neuron, and synapses onto a muscle and a brain. A

shoebox, labeled "Response," was placed on the table and was filled with approximately 200 assorted chocolate candies. The last item necessary was a regular-sized foursquare ball with "NT" written on it with a felt-tipped pen. The ball represented a neurotransmitter and the box represented a successful neurotransmitter exchange at the synapse, which caused further neural activity.

We briefly overviewed the general properties of an action potential and neurotransmitter release/binding. We explained the necessity of salts in a regular diet that were important to create a membrane depolarization leading to an action potential, such as potassium, calcium, and sodium. As a wrap up for our overview, my partner and I mentioned that illegal drugs, alcohol, and nicotine all are responsible for various modes of disrupting proper neuronal functioning.

Two groups with equal quantities of children were aligned and spaced approximately five feet apart, one group named "Pre-Synapse," and the other called "Post-Synapse." Next, a single child centered in the space between the two groups acted as the post-synaptic receptor. These children all faced the same direction. Another child stood about six to eight feet directly across from the child whom was in the middle of the two groups and faced him or her. This child started by holding the ball labeled "NT" and acted as the neurotransmitter releasing point for the pre-synaptic cell.

When my partner and I said the word "Go," the group representing the pre-synaptic axon terminal began to do the wave (the wave made popular at sporting events) starting from left to right. As the wave approached the center, the child initially holding the ball made a bounce-pass to the child in between the two groups, thus modeling the effect of neurotransmitter exchange. Then, the group acting as the post-synaptic cell did the wave, again starting from left to right, until the last child raised his or her hands. At this point, we opened a box labeled "Response," which was filled with assorted candies, when the action potential progressed appropriately. Next, to demonstrate that drugs hinder the binding and release of neurotransmitters, we intercepted the ball exchange. Therefore, the action potential was disrupted and no candy was received. We then reemphasized the negative effects of drugs briefly. Finally, the children were encouraged to perform the activity properly in the absence of drugs to receive candy again.

Results

In our group (the Blue group), we were awarded third place out of four groups in a tie with another team. The total number of first place votes from the children after the day was over determined the place that a team was awarded. The most first place votes was awarded first place, the team with the second most votes was awarded second place, and so on. Our individual ratings from the children in certain categories, on a scale of 1 to 5, for the demonstration showed our model to be more effective than our ranking.

In the category of "Understand," or how well the students understood our message, we received a 4.84. I assumed this would be the case because very little questions were asked about the action potential. For "Friendly" we attained an average score of 4.89. In

the category of ‘Fun’ we received a score of 4.69. All of the groups scored relatively high in this category, which is no surprise because all of the groups had interactive games. The children liked to bounce the ball and play the role of the drug, while intercepting the ball. Finally, under the heading of whether the children wanted to ‘Learn More,’ we had an accumulated score of 4.27. The children seemed bored by our overview and only made comments that repeated the information told to them at the beginning of the science fair by our professor. For example, a frequent question was, ‘Do more neurons grow when you read?’ Yet, when we asked the children to name drugs they were very quick to respond. Overall, our average score on a scale of 1 to 5 was 4.6725. An observing faculty member scored our model 9 out of a possible 10. Finally, out of the total number of student models, our average was fourth place. The figure and table for the previous data are represented below.

Figure 1

Table 1

Team Name	Group #	Understand	Friendly	Fun	Learn More	Average vote	Place
Palce Power	A1	4.81	4.95	4.84	4.5	4.7875	1
Ouch My brain	A4	4.8	4.8	4.7	4.4	4.675	2
Meeting your	A3	4.84	4.89	4.69	4.27	4.672	3
Seeing is	A2	4.56	4.76	4.56	4.13	4.5025	4

The data we received to produce the figure and table above were based on evaluation forms filled out by the fifth graders. There were also questions on the forms, which had an area for the children to relay what they remembered about our model and what they liked or disliked about it. Almost all of our evaluations stated that our model was ‘cool’ and that they thoroughly enjoyed playing the interactive game. Most of the children recalled the fact that the neurotransmitter was exchanged at the synapse and resulted in an action potential that could happen at an incredible rate. Based upon the reactions we got during our presentation, it appeared that the candy was the most intriguing part of the model. After lunch, the children were less enthusiastic about receiving candy for completing the task successfully and seemed less attentive.

Discussion

We developed a clever way to convey the properties of an action potential to

children, as was shown by a high ranking in the category of “Understand.” The fact that we timed the children at the task and explained how the electrochemical properties of the body allow action potentials to propagate at up to hundreds of miles per hour was effective. At this point in their academic career they were not aware that biological signaling could occur so rapidly. Candy, of course, was a good reward. Yet, our model oversimplified the exchange of neurotransmitters to a single molecule exchange. Also, the act of intercepting the ball to portray the negative effects of drugs only actually modeled the blocking effect of certain drugs. Our model could not display other aspects of drug interaction, like antagonism. Finally, our model would have been much more effective if we would have had a greater number of participants. We had originally intended on having no less than ten children, so the act of propagation could be understood more easily.

The data shows that if our average score from the evaluations were used, we would have attained a higher rank, since our average was not significantly less than the second place team. So, we could have been considered for a tie for second place in our group, based on that data alone. Furthermore, the data shows that we were friendlier than our third place rating showed and we were well understood by the children. This means our presentation style and dissemination of content was effective. As mentioned above, we attained an average score that was fourth overall out of the eight total college student groups, yet the other four groups not represented in the figure or table were judged by a separate group of children. Therefore, as a within-group design, the results could not be compared without acknowledging a major confound. When simply compared to our group (the “A” group), the major flaw seemed to be that our topic was just not interesting for fifth graders. This can be seen in the category “Learn More,” in which we received a third place rank.

However, there are many other factors that may have come into play. By chance alone, many children may have just marked arbitrary rankings. In fact, my partner and I observed that several children had ranked our model before we even began presenting. They were possibly more excited to be on a field trip than to be responsible for adequately grading a model design. Another flaw in our design may have been that our poster was not as decorative as the other groups. By enhancing our aesthetics, the interest of the children may have increased, since they seemed to focus more on the peripheral cues than the lecturing aspects of the presentation.

In total, the Kids Judge! Science fair was a success. We all presented many topics to fifth graders that they would not otherwise see until high school or college. Particularly, and not surprisingly based on the age of the children, a model derived from a topic on the functional properties of neuroscience and not the electrophysiological or cellular properties appears to be most effective. As they age and are introduced to more chemistry and biology, their opinions may change and the appreciation for the physiological properties may increase, too. I believe that several of the children were attentive and generally intrigued by neuroscience, which will hopefully lead to the recruitment of future scientists.

Works Cited

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