The Axonal Highway
A model of intracellular transport

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Abstract

Our experiment was intended to model axonal transport within a neuron by relating the information to The Axonal Highway. Our objectives were to convey a fundamental knowledge of axonal transport to children and to learn to communicate complex scientific concepts to subjects at a fifth grade comprehension level. We utilized a display board for a lecture section and a relay race set up for a game that reinforced the concepts. We found that children apply themselves with incentives such as candy and games. We also found that an excess of new vocabulary can be difficult for children to learn. Improvement may result by cutting back on the number of new words introduced and by interacting with the children again. We conclude that the children were able to gain a basic understanding of the mechanism; though it is likely the vocabulary was lost soon after the model.

Introduction

The axonal highway is the means by which synaptic vesicles, mitochondria, and other neural machinery are transported from one end of the neuron to the other. Within a neuron, microtubules run down the axon. These microtubules form the road of the axonal highway. The mode of transportation for the vesicles are proteins: kinesin and dynein. Kinesin carries molecules away from the body, or soma, toward the synaptic cleft. This is anterograde transport. Dynein is responsible for the opposite direction called retrograde transport. When vesicles reach either the synaptic cleft or the soma, they release the neurotransmitters they are carrying. Once released, the neurotransmitters can perform specific functions.

Much is already known about anterograde and retrograde axonal transport. In 2004, Conley and others used the giant squid axon as a tool to study the mechanisms of axonal transport. They used the giant axon to determine the relationship of the vesicles to the transport proteins. They found that particles demonstrating anterograde movement recruit a protein as a molecular mechanism. This interaction of the cargo particle and the motor protein allows for a greater transport speed than that of particles not encapsulated by proteins. Additional investigations in this area may uncover the specific mechanism that allows for increased transport rate. Further research has shown that molecules such as mitochondria are transported bi-directionally having both anterograde and retrograde movement (Vanden Berghe, 2003). In another study, they found that the loss of mitochondrial function might affect axonal transport and cause axonal degeneration (Vanden Berghe, 2004). Axonal transport would be seriously compromised without mitochondria. Mitochondria supply most of the energy needed to perform transport. Vanden Berghe also determined that mitochondria are implicated in the calcium buffering which determines membrane excitability. This process is not possible in the distal regions of the axons without the transport of mitochondria. By understanding the consequences of axonal degradation we can better understand the purpose of axonal transport.

We modeled axonal transport within a neuron. The neuron—including a soma and an axon with a presynaptic terminal—was outlined on the floor utilizing masking tape. Within the neuron there were two parallel cords running the length of the "axon" to symbolize the microtubules. Buckets simulating mitochondria were placed in both the soma and the terminal. The mitochondria contained candies that represented the energy molecule adenosine triphosphate. There were also small, round plastic containers present in the soma and terminal to simulate vesicles. These containers held candies that represented neurotransmitters. The kids symbolized kinesin or dynein.

It was our intent that the children, who participated in our model, gained a basic understanding of intracellular transportation using microtubules, mitochondria, protein transporters, and vesicles. Specifically, the kids were to consider anterograde and retrograde transport: axonal transport from a neuronal soma to a terminal and from the terminal back to the soma.

Materials and Methods

The experimental setup for The Axonal Highway required a large open area. We began by outlining a neuron on the floor with masking tape, approximately twenty feet long and the axon of which was approximately five feet wide. The neuron included a soma and a synaptic terminal with dendrites. At each end of the axon (within the soma and the synaptic terminal) we placed a green bucket, which represented the mitochondria. Within the mitochondria, we placed chocolate candies, which were the energy molecules of ATP. Also located in the soma and the terminal were small, round plastic containers filled with hard candies. These were the vesicles containing neurotransmitters. We, as experimenters, stood at each end of the axon holding a yellow rope in each hand such that the ropes ran the length of the axon and were parallel to each other. The ropes simulated the microtubules. Refer to Figure 1. The children represented kinesin and dynein and were given brightly colored stickers to signify which protein they were. We also had a table for the children to write upon and a poster board to illustrate the process of The Axonal Highway.

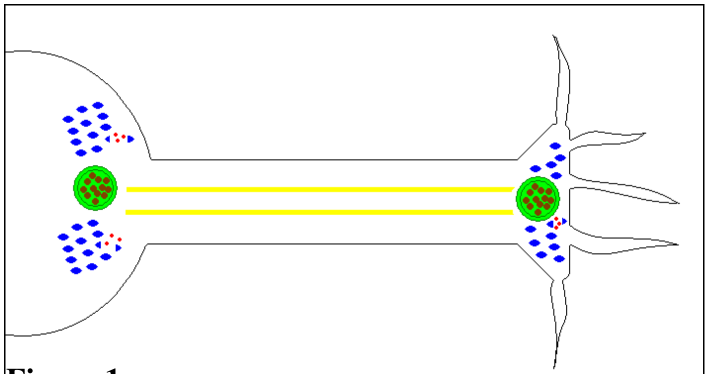

Figure 1

The children approached our table in groups of five to ten, accompanied by at least one adult group leader. We introduced our topic and ourselves and proceeded to explain the principles of axonal transport while utilizing the poster board for visual reinforcement. We encouraged the children to repeat new vocabulary words, including “microtubule,” “kinesin,” “dynein,” “mitochondria,” “vesicle,” and “neurotransmitter.” As we explained axonal transport, we likened each component to a highway scenario. We included the children in the discussion by allowing them to guess what the components were. The microtubules became the road of the highway. Kinesin and dynein were trucks. Mitochondria were the gas station where trucks could fuel with ATP. Vesicles became packages and neurotransmitters the message within the package. We explained the importance of being able to send a message from the head to the toe through The Axonal Highway.

Once we described how The Axonal Highway worked, we explained our relay race to the children. We split the children into two even groups. For uneven numbers of children, we encouraged the group leader to participate. We then gave the children in each group a colored sticker and told them that it signified that they were either dynein or kinesin. The dynein group was sent to the terminal and the kinesin group to the soma where the children formed a single file line beginning at the mitochondria bucket. The children were told that before they could travel along the microtubule, they must consume an energy molecule from the mitochondria. They were told that they had to swallow the chocolate candy before beginning transport and consuming the wrapper was strictly prohibited. Once the energy molecule was consumed, the children picked up a synaptic vesicle and ran backwards while sliding their left hand along the microtubule (which we held above the ground) until they reached the other end of the axon. Once at the opposite end, the children were asked a question that reviewed the material covered, such as, “Where did you get an energy molecule to perform this task?” The child would have to respond, “From the mitochondria.” After correctly responding, children released the neurotransmitters from their synaptic vesicle, signaling the next child on the team to begin the process. When each child from the team had completed the relay, the game was over. Children were encouraged to ask questions and were given time to fill out evaluations.

Results

In order to test whether or not the children understood, we incorporated review questions into the relay race. The children seemed to understand the mechanism, however they displayed limited trouble pronouncing and remembering words such as microtubule, kinesin, dynein, and others. As the children filled out the evaluations, they were given an opportunity and encouraged to ask questions relating to the exhibit. The children did not initiate many questions on their own after the presentation of our exhibit, though some did.

Our exhibit placed very well. The average of the number of marks for each scale number is presented in Table 1 below. The scale ranged from one to five, with five being better than one. Questions one and four tend to focus more on the conceptual components of the exhibit, which is where we scored fairly low compared to the other criteria on which we were evaluated. The children gave us quite high marks on questions two and three, which relate more to the enjoyment factor.

Evaluation questions:	**Average Score**
1. Could you understand what the presenters were trying to tell you?	4.38
2. Were the presenters friendly?	4.95
3. Was the exhibit fun?	4.90
4. Would you like to learn more about this topic?	4.15

Table 1

We received many comments on our evaluations. Most of the kids said their favorite part of the exhibit was the relay or the game. Almost all of the rest said the candy was their favorite part. A majority of the kids claimed they learned about one of the vocabulary words from our exhibit. Most children wrote a single term such as ‘microtubule’ or ‘axonal highway.’ Four children said they learned the function of kinesin and dynein. One child mentioned that he or she did not learn much and one said he or she learned that chocolate tastes good. Additional comments included a lot of excitement for the game, the candy, and the presenters. There were some “thank you’s” and one child stated, “This was a blast and I learned a lot!”

Discussion

The rationale for the development of this model was twofold. First, utilizing this model, children were given the opportunity to learn about a neurophysiological principle, namely axonal transport, while enjoying the learning experience. Second, development of the model should allow us, as experimenters, to learn to communicate scientific information to a general public with a reading/comprehension level of an average fifth grade student.

There were some issues with our model that resulted in an effort to simplify the concept for the children and for the relay. For example, our vesicles were pre-stocked with neurotransmitters rather than simulating uptake. In addition, we decided to make the game a race so that the competitive nature would encourage greater involvement from the kids. However, within a cell, the anterograde and retrograde motion are not in competition. Also, the processes of anterograde and retrograde transport were presented as the same in an effort to make the race fair between the two teams, though these processes are actually distinct. Furthermore, we had the children run backwards just to make the game more interesting. The backwards motion did not simulate a specific mechanism.

Another issue that our model presented was that, in the interest of not sacrificing accuracy completely, we introduced many large, unfamiliar words. We intended to help the children learn these words by having them written on the display board, by repeating them several times, by having the children verbalize them, and by incorporating them in the review questions. The quantity of new words may have been overwhelming to the children, especially considering the number of other exhibits in which the children participated.

In order to test whether or not the kids understood, we incorporated review questions into the relay race. We decided to make review part of the game, rather than asking questions after the game, to give the children more incentive to learn the concepts and to make the review more fun. Based upon our review questions, the children seemed to understand, though some displayed difficulty pronouncing and remembering new terms. Because not many children asked questions pertaining to our model, it is likely that they enjoyed the game more than the concepts.

Based upon the rating the children gave us on our model, it was well received. Our ratings were lowest concerning how well the children understood and whether they would like to learn more. This, coupled with additional comments centered on the game and candy, are evidence that the kids were more into the candy and competitiveness of the game than the actual neurophysiological principles. Because many of the kids just chose to write a word under the question, "What did you learn from this exhibit?" it is likely that many didn't actually take concepts away. Rather, they may have simply copied words from our display board.

Our model may be improved by reducing the number of new vocabulary words we expect the children to learn. Also, I believe it would be valuable to the learning experience if we could interact with them at a second, later date to review the concepts again. The integration of both candy and a chance for the children to participate in a competitive way seemed to be valuable in gaining their attention and encouraging them to apply themselves.

Conclusion

Children gained a basic understanding of intracellular transport through relating the mechanism to The Axonal Highway and a relay game. However, the use of a large number of new, complex words seemed to be overwhelming. To that end, our model was not as successful as we hoped. The use of candy and a game worked well in relating to the children.

Literature Cited

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