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Kids Judge Neuroscience Fair 2007 Exhibit
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Too Tired to Move

Abstract

The purpose of the Kids Judge Neuroscience Fair is to take a complex neuroscience concept and simplify it such that fifth-grade evaluators can grasp and enjoy the concept. Our model addressed the concept of a muscle stretch, beginning with the action potential initiated by the brain and culminating in the stretch of a leg muscle. The students participated in the model by reenacting neurotransmitter binding in the neural junction just prior to the muscle. The concept was demonstrated by having the students carry rubber balls from one end of the “synapse” to the other, after which a student would stretch a representative muscle connected by a bungee cord. Our expectation for the model was to add other action roles in order to teach the students how nutrients and an adequate supply of neurotransmitters are necessary to keep muscles contracting normally under exercise conditions.

Intro

In order to study the mechanism by which muscles become tired after prolonged use, we explored the large role of nutritional intake; specifically, we researched how the ingestion of particular nutrients such as carbohydrates and branched-chain amino acids could potentially prolong the onset of fatigue symptoms (Coyle et al., 1983; Davis, Alderson, & Welsh, 2000). In the research by Coyle et al., experienced cyclists were given either a carbohydrate supplement or a placebo before undergoing strenuous exercise conditions. When a prolonging of fatigue symptoms occurred in participants in the treatment condition, the researchers proposed that the improvement in performance was due to the carbohydrate supplement increasing glucose uptake, resulting in glycogen sparing. The decreased depletion of muscle glycogen, the primary storage form of glucose in the body, resulted in the observed delay in fatigue symptoms in participants who took carbohydrates. Due to an abundance of studies such as these, it has become apparent that nutritional supplements such as carbohydrates have a significant role in delaying muscle fatigue under exercise conditions.

We also investigated the central fatigue theory, which suggests that the presence of serotonin in the brain speeds the onset of muscle fatigue. This research led to the natural consequence of developing ways to reduce 5-HT in the brain. Such studies hypothesized that branched-chain amino acid (BCAA) feedings may cease increases in 5-HT and therefore improve performance (Davis, Alderson, & Welsh, 2000). The authors of this study utilized the mechanism of reducing 5-HT in which lowering the ratio of free tryptophan (fTRP) plasma to BCAA concentration in the brain decreases 5-HT synthesis. Because BCAAs are taken up from blood and oxidized for energy during muscle contraction, Davis et al. conducted an experiment involving BCAA feedings to change the concentration of BCAA and therefore the concentration of 5-HT in the brain. The branched-chain amino acids being studied are still a theoretical solution for delaying the onset of muscle fatigue under exercise conditions due to inconclusive results, though they have been proven to decrease the amount of 5-HT buildup in the brain; further research into the central fatigue theory may aid in putting BCAAs into practical application. In addition to replenishing the glucose supply used to keep the muscles functioning in the peripheral system, it is possible that nutritional supplements such as branched-chain amino acids and carbohydrates in the correct doses (Coyle et al., 1983; Davis, Alderson, & Welsh, 2000) will prevent fatigue via the central nervous system.

Stevens and Tsujimoto (1994) describe the release rate of vesicles available for neurotransmitter release at the presynaptic junction (20 quanta per sec per synapse), as well as how long it takes for the terminal bouton to replenish its vesicles once the neurotransmitters have been released (a time constant of 10 sec). Thus, another of the primary factors in muscle fatigue is the limited supply of vesicles at the neuronal level (which can be depleted during strenuous exercise) as well as the overarching problem of excess serotonin in the brain, a dilemma which can be solved by proper nutrient ingestion.

To demonstrate the occurrence of muscle fatigue, our model demonstrated how a muscle stretch occurs, incorporating the presynaptic action potential, neurotransmitter release, postsynaptic receptor binding, and eventual muscle stretch. The chief goal of the experiment portion of the model was to teach how muscles can get tired from overuse by means of lack of neurotransmitter and lack of proper nutrients.

While the model taught students about the role of neurotransmitter binding, it also demonstrated the necessity of metabolites to continue muscle function. The primary experiment with which to test the knowledge of students involved getting them to repeat a basic muscle stretch with the additional physiological limitation of neurotransmitter supply. Children were asked before the final run to guess what makes them tired when they exercise, and they were asked what might go wrong in this muscle stretch scenario. The final run, which incorporated limited neurotransmitter reuptake, enforced their understanding that while neurotransmitters help muscle function continue, the repeated

use of the muscle drains the supply of neurotransmitters until the muscle cannot work properly.

The purpose of our model was to demonstrate a simplified version of this information to a fifth grade audience. The primary points directed at the students were that muscles contract as a result of the brain's initiation, the ingestion of proper nutritional supplements is necessary for muscle usage, and the supply of neurotransmitters in repeatedly firing neurons can be depleted. We anticipated that the students would come away from the model with the understanding that the failure of any of these mechanisms would prevent the firing of the leg muscle demonstrated in the model. We accomplished these objectives by questioning students on their knowledge of how messages are sent from the brain to a leg muscle, providing any missing information about the brain's initiation, neuronal communication by means of action potentials, and how neurotransmitter binding takes place in order to propagate the action potentials from one cell to another. We then recruited students to fill the various roles necessary to demonstrate this process, including brain initiation, neurotransmitter binding, and muscle stretching. Later experimental runs included the roles of monitoring nutrition and neurotransmitter recycling. By this means, we were able to communicate to the students the extensive process required to keep a muscle firing under exercise conditions.

Methods:

Construction of the model entailed filling two one-gallon milk cartons half-full of water and connecting them with a bungee cord attached to their handles, displaying the stretching property of the muscle. Red tape was placed on the floor under the muscle to demonstrate the spindle shape of the muscle. A stuffed animal sitting on top of a box was placed next to the muscle, providing a target for the students to reach as they stretched the muscle. Neurotransmitter "binding sites," or up to two 18-count egg cartons, were placed at the end of the exhibit next to the muscle. A box containing approximately 60 "neurotransmitters," or bouncy balls, was placed at the other end of the exhibit. When we chose students for roles, we handed them the necessary materials; the "brain" received a buzzer to hit in order to begin the action potential, and another student received a small slotted piggy bank with 18 pennies in order to monitor how many "nutrients" the muscle had available for muscle contraction.

In order to begin the game, we yelled out a situation requiring action of some type, and the student assigned the role of the brain had to decide if this action would require the stretching of the leg muscle demonstrated at this synapse. (Examples are "smelling a flower" versus "kicking a soccer ball.") If the child decided that the leg muscle should be stretched for the scenario, he or she hit the buzzer, signifying the beginning of an action potential. The remaining children then ran from one side of the

station to the other, carrying one neurotransmitter apiece. They placed the balls in the egg cartons before returning for more. On the first run, children only had to fill the “receptor binding sites” with “neurotransmitters” before the muscle could stretch, which was signified when the student assigned the role of the muscle stretched the milk jugs apart and successfully knocked the stuffed animal to the floor. During the next run, one of the children had to count out 10 metabolites (nutrients) into the slotted bank before the stretch could occur. In order to challenge the students to apply their knowledge, they conducted a final run during which the muscle was activated repeatedly. One student was assigned the task of neurotransmitter reuptake; after the muscle stretched the first time (complete with receptor binding and nutrition counting), this child could run neurotransmitters back to the vesicle storage box at the other end one at a time, which contained only 25 balls for this portion of the experiment.

Results

While students were more interested in conducting the experiments at the exhibit than asking questions about it, they answered questions excitedly and competently. When we asked questions between the various runs of the experiment, answers showed that students seemed able to apply what they learned from each previous test. For instance, after we demonstrated the principles of nutrition use in the muscle and neurotransmitter release, we asked the students if they could predict possible reasons for muscle failure under exercise conditions; several students were able to conjecture that insufficient nutrition intake and limited supplies of neurotransmitters could both interfere with the firing of the muscle. Because the model received second place in a group of four exhibits, we surmised that it was received well by the students. Comments from the judging evaluation forms showed that students were most excited to be given the opportunity to run, though several came away with the insights we had attempted to teach about the necessity of nutrients and neurotransmitters for muscle stretch. Questioning the students after the model experiments led them to reveal that they understood the cellular mechanisms underlying the admonition to eat foods of proper nutritional value. Follow-up letters from the students reinforced the notion that they were predominantly happy to be able to run during the model. Multiple letters were written about the principles behind the exhibit, including one relatively insightful letter about the limited supply of neurotransmitters and how the delay in making more can cause muscle exhaustion.

The ratings accorded to the exhibit showed that, as might be expected from the fact that running was a highlight, our model was ranked as (tied for) the most fun exhibit in our group. While this could be seen as an unfortunate switch with the more important criteria of comprehension, which dropped in relation to the first-place model, our model did score the highest in the group in regards to a desire to learn more, another chief goal of Kids Judge Neuroscience Fair.

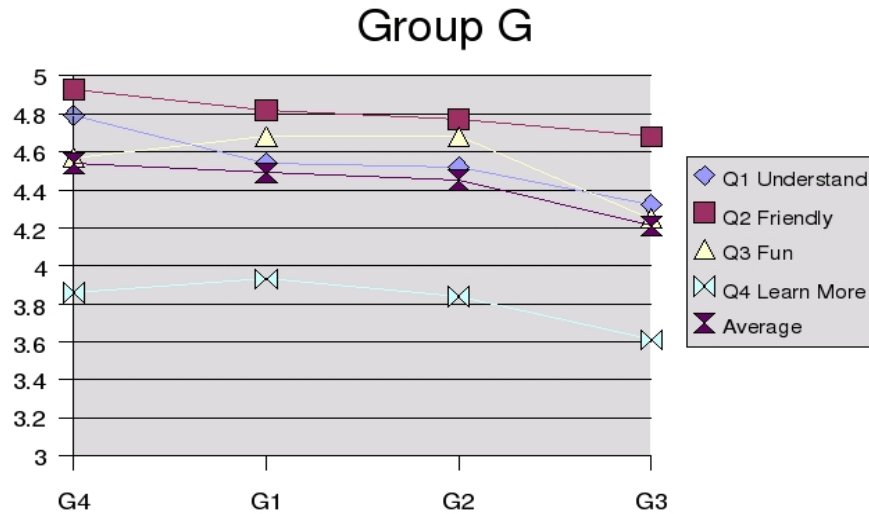


Figure 1: The graph shows average scores for all four teams in four categories. Scores for “Too Tired to Move” (G1) occupy the second column.

Discussion

As seen in the results, the rankings for “Too Tired to Move” demonstrate a moderate success rate in the most important criteria for Kids Judge Neuroscience Fair. While the exhibit underwent an unfortunate drop in comprehension from the first-place exhibit, the fact that the students seemed to want to learn more about our topic than those of the other groups could be construed as success at the primary goal of the entire event. Because the event is intended to get fifth-graders interested in neuroscience (usually achieved by a high fun rating, also the highest in the group) and encourage them to follow up on the material (seen in the first-ranked “learn more” criteria), our exhibit could actually be perceived as quite successful in the criteria most significant for the event. We could have viewed the model as even more successful if a higher comprehension rate had been achieved.

The issue that lay at the heart of the success of the model was the running utilized in the exhibit. While this was an approach specifically designed for fifth-graders, this could make the model less generalizable to older audiences. Additionally, some students were prone to interrupting the lesson in order to ask when they would get to run; this leads to the assumption that some students were far less interested in learning about the model than they were in running off excess energy. This seems to have been offset in the final results but was a problem seen in several individuals, particularly when these students interrupted their companions who were actually interested in answering questions and learning about the model.

Other improvements to the model could be brought about by making the model more self-sufficient; as seen in the free browsing time, the model requires the presence of attendants to explain the process at hand, meaning that the students could not participate

on their own as in other exhibits. Though our model was usually attended by entire groups, thus avoiding the dilemma, the model would not succeed in a science center scenario if seven children had to be present before a lesson and experiment could ensue.

A final improvement that could be made to the model would be making the role of all the students more interactive. While one of the students commented on the evaluation sheet that his favorite portion of the exhibit was “being the brain, because I didn’t have to do anything,” this was not the desired feedback. It could be viewed as advantageous to the model that students who did not like running had the ability to volunteer for a more sedentary role (such as the brain, muscle, or nutrient-counter); however, they should still have walked away from the model with the feeling that they contributed to the experiment in whatever role they fulfilled, regardless of how labor-intensive the role seemed to be.

Certain compromises in accuracy had to be made for the presentation of the model. While the concept being addressed spanned the route from the brain to a leg muscle, our model itself only showed the final synapse before a leg muscle. We attempted to offset this by reminding the students that this process occurs in every single neuron on the way from the brain to the leg muscle (which is also not completely true; chemical transmission is not always utilized between neurons). Also, the ratio of neurotransmitters being released to neurotransmitters being recycled was not completely accurate, as neurotransmitters are actually released in greater numbers by means of vesicles; this compromise was made to keep the students from getting tired as well as to fit the experiment into the given time frame. Additionally, neurotransmitter recycling was portrayed with no demonstration of neurotransmitter formation in the presynaptic soma (though this concept was explained verbally). Finally, the muscle stretch itself is a much more complex process than could be demonstrated by the model; the role of various muscle fibers, kinases, and second messengers had to be forsaken in order to keep the model simple. Though the model was limited by such problems as these, it still served its purpose of involving children from the community in an experience in such a way that they will hopefully look forward to learning about neuroscience in the future.

References

- Coyle, E.F., Hagberg, J.M., Hurley, B.F., Martin, W.H., Ehsani, A.A., & Holloszy, J.O. (1983). Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. *Journal of Applied Physiology*, 55(1), 230-235.
- Davis, J.M., Alderson, N.L., & Welsh, R.S. (2000). Serotonin and central nervous system fatigue: nutritional considerations. *American Journal of Clinical Nutrition*, 72(suppl), 573S-578S.
- Stevens, C.F., & Tsujimoto, T. (1995). Estimates for the pool size of releasable quanta at a single central synapse and for the time required to refill the pool. *Proceedings of the National Academy of Sciences of the United States of America*, 92(3), 846-849.