ARTICLE
Three Colossal Neurons: A New Approach to an Old Classroom Demonstration

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Research suggests that the key to optimal student learning, regardless of class size, is engaging students in active learning. It is my contention that to truly understand neural processing, one must not only understand the activities of the neuron as a living cell, but also how that cell works within the context of a neural network. The demonstration exercise described herein combines techniques expressed in three previously published articles, with certain modifications, allowing as few as 15 and as many as about 200 students to actively participate in the endeavor. Moreover, test scores from 158 students were examined, showing that students who participated in the demonstration performed significantly better on exam questions than students who did not take part.

Key words: Teaching Neuroscience; Classroom Neuron Demonstration; Teaching Neural Anatomy and Function

Increasingly, instructors espouse that regardless of experience, teaching neuroscience concepts is very demanding and difficult to do well, especially when trying to teach a large survey class. Moreover, the large-class experience is typically the least preferred class by most students and is often more difficult when advanced material is taught . Combine these factors with the reality that most large classes are survey courses (e.g., Introductory Psychology), where each chapter covers general material that represents coursework normally studied in detail in a full-semester upper division class.

Additionally, most survey classes are intended for first and second-year students whose academic careers are just beginning; and thus, the students are receiving much less individual attention than they were accustomed to in high school. The sad fact is that some students feel quite anonymous in a large lecture hall, and this anonymity may make it harder for them to be motivated and to keep up. That being said, the quality of the classroom experience is not always directly related to class size. Research suggests that the key to optimal student learning, regardless of class size, is engaging students in active learning (Mulryan-Kyne, 2010).

In 1985, Hamilton and Knox provided instructions on how to demonstrate neural anatomy and function by turning student volunteers into internal elements of a giant neuron and having them act out the function of the cell. While brilliant in its design, the Colossal Neuron demonstration is fairly complicated and is difficult for most students to grasp. Moreover, as a classroom activity, it only allows a few students to participate, while the rest of the class merely observes. Lastly, this exercise provides such a volume of information about the inner working of the cell, it overlooks the process and general nature of neural communication.

Accordingly, almost ten years later, Reardon, Durso, and Wilson (1994) described an activity that helped students understand synaptic transmission. Although the demonstration depicts concepts of neural transmission admirably, the context of the activity is so nuanced and abstract, it is difficult for all but the most advanced students to understand how it relates to actual brain cell function. Additionally, this demonstration focuses primarily on synaptic communication and not on the inner workings of each cell, making it difficult to appreciate the complex manner in which both systems interact and making it almost impossible to truly understand neural processing.

In order to address this problem, Gary Felsten (1998) proposed an exercise that could be used in conjunction with the aforementioned 1994 task to demonstrate how the action potential propagates across myelinated and non-myelinated axons. In this exercise, students act out the propagation of the action potential across the axon by raising their arms and tapping the next student in line. This is a very effective way to demonstrate the electro-chemical reaction in the interior of the axon, but the students are subjected only to those activities that occur within the neuron and not to the means by which neurons communicate with each other. As a result, even when combined with Reardon, Durso, and Wilson's exhibition, these demonstrations fail to give students an overall understanding of neural function. Indeed, all three exercises described above are limited in scope and are designed for use in smaller, more advanced classes; thus, they have limited value in today's typical introductory class that often ranges from 60 to 250 students. Recently, other demonstrations have been proposed exploring the computational (May, 2010) or cross-modal (Wolfe, 2010) aspects of neural communication. Although well-designed, interesting, and engaging, these demonstrations tend to be extremely intricate and cognitive in nature, and fairly removed from the basic view of brain cell function that needs to be conveyed in introductory courses.

It is my contention that to truly understand neural processing, one must understand not only the activities of the neuron as a living cell, but one must also understand how that cell works within the context of a neural network. The demonstration described herein combines techniques expressed in the aforementioned articles, with certain modifications, allowing as few as 15 and as many as 200 students to be active participates. Moreover, test scores from 158 students were examined, comparing students whose class participated in the demonstration with students whose class did not take part.

METHODS

Over two years one hundred sixty-eight freshmen from Arizona State University enrolled in one of four Introduction to Psychology classes that were taught by the same instructor (this author), using the same curriculum, textbook, and lectures. The overall grade distributions for all classes were equivalent. Students were divided by class as to whether they were given the opportunity to participate in the demonstration. Eighty-eight students were enrolled in classes in the first two semesters, and they did not have the opportunity to participate in the Three Colossal Neurons demonstration. Test scores from these classes were combined. The following year, the demonstration was offered, and of the eighty students enrolled in the two classes, seventy participated. Test scores were excluded from the ten pupils who were absent when the demonstration was given. The last class to participate was held as part of a five-week summer program. However, the test scores from that class were not significantly different from the previous 16-week class, so these sets of scores were combined in the same fashion as the no-demonstration classes. Ten exam questions were administered as a subset of questions nested in two tests that were a requirement of the course: Five questions tested knowledge of neuro-anatomy, and five tested knowledge of neuro-function; six of the questions were on the mid-term exam, and four were on the final.

MATERIALS

- A very large space
- Masking tape (or painter's tape if using a tile floor)
- Styrofoam chips
- Three to twelve lunch-size paper bags
- Several large plastic cups
- Sodium/potassium placards
- Paper identification signs

Student assignments (students per neuron):

- Sense Organ (1)
- Receiving Dendrite (who holds a cup in his or her hands denoting the receptor sites) (1 - inter and motor neurons only)
- Sodium (who carries placards and stands outside the neuron) (1 or more)
- Potassium (who carries placards and stands inside the neuron) (1 or more)
- (Optional) Sodium/Potassium Pump (who taps the sodium and potassium ions to make them return) (1)
- Action Potential (who runs down the axon and taps the terminal button) (1) OR
- Action Potential (who stands with others and lifts arms) (3 or more)
- Terminal Button (who holds a bag of Styrofoam chips and throws the Styrofoam chips at the receiving dendrite) (1)
- (Optional) Re-uptake Ducts (who picks up chips from the floor and fills a new bag/vesicle) (1)
- Crier (1 - motor neuron only)

PROCEDURE

On the floor, outline the shape of three neurons (sensory, inter, and motor) using the masking tape. Adjust the size and length of each neuron according to the number of students who will be participating. Make sure that the synaptic clefts are far enough apart to challenge the students throwing the chips (eight to ten feet). Freshmen can get very competitive and will sometimes try to lean over or even step out of the neuron into the synaptic cleft. When roles have been assigned and students are in place, the "annoying little brother" played by the instructor, teaching assistant, or helper touches the sense organ (a bruise) who begins the neural transmission by turning to face the inside of the neuron. This unlocks the ion channels, allowing potassium to begin flowing out of the neuron, and sodium to begin flowing into the neuron (1:1 ratio). The sodium/potassium pump, who is straddling the edge of the neuron, then starts tapping the ions (one of each kind, in succession), so that they quickly return to their original positions in order to be ready for another signal from the sense organ.

Meanwhile, as soon as the sodium and potassium students trade places and the all-or-nothing threshold (as determined by the instructor) is reached, the action potential students will begin to raise their hands in succession, as if performing a "wave" similar to those seen in sports arenas, simulating the depolarization racing down the axon. The last action potential person taps the terminal button, who is holding a vesicle (paper bag) filled with neurotransmitters (Styrofoam chips); the vesicle opens, and the terminal button "releases" (throws) the neurotransmitters into the synaptic cleft. Alternatively, if there is only one student available for the role of action potential, that student should simply run down the axon and tap the terminal button. When a chip lands in the "receptor site" (cup) on the receiving dendrite of the next neuron (the inter-neuron), the receiving dendrite turns around, unlocking the gates, and the process repeats with the inter-neuron, ultimately causing the motor neuron to fire. If the synaptic cleft has been laid out with enough distance between the terminal button and the receiving dendrite, it can take several bags of chips to have one actually land in a receiving cup. When the last neuron's terminal button (motor neuron) is tapped by the action potential, the terminal button taps the crier, who shouts "Ouch," inspiring the "annoying little brother" to touch the bruise again.

RESULTS

An omnibus single factor analysis of variance was conducted showing that students who participated in the neuron demonstration performed significantly better overall on all test questions pertaining to neural knowledge than students who did not experience the demonstration,

$F(1, 156) = 85.49$, $p < .001$ (see Figure 1). Moreover, a single factor t-test confirmed that students who were involved in the demonstration scored significantly better on the subset of questions pertaining to neuro-anatomy, $t(156) = -6.19$, $p < .001$, and neuro-function, $t(156) = 6.63$ $p < .001$, when compared to students who were not involved in the project.

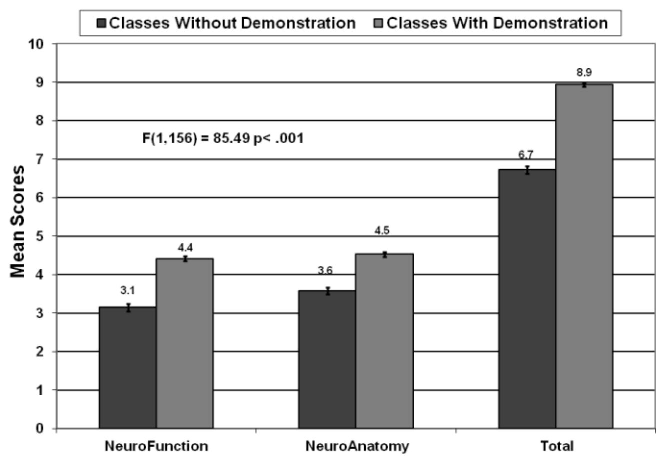

Figure 1. Mean scores for participants who did not experience the neuron demonstration as compared to those who did take part in the demonstration.

DISCUSSION

It is no surprise that quality demonstrations enhance and deepen a student's understanding of lecture materials and discussions. In fact, such activities are imperative in today's large and complex classroom environments. In large part, this was the initial motivation for developing the demonstration discussed in this paper. Anecdotally, most students who participated in the demonstration reported that they understood neural function and anatomy better after participating in the activity. Yet, here we show that students not only felt they understood the material better, but they actually performed better on their exams. The study presented here is a quantitative example of how a somewhat rudimentary and lively demonstration can engage and augment a student's educational experience and can actually help the student when it comes time to take an exam.

Moreover, the structure of this demonstration is such that it easily facilitates greater flexibility in explaining different neural functions. For example, I have used this activity to successfully demonstrate: How excitatory and inhibitory sites on a receiving dendrite affect neural firing; how selective serotonin re-uptake inhibitors affect synaptic communication; how myelin sheaths speed the propagation of the action potential; and how certain drugs mimic neurotransmitters - all within the time span of a normal class period.

Limitations of this study include the fact that a sample of convenience was used. Consequently, despite great pains taken to present the material equally in all classes, we can not discount the potential of an outside factor influencing these results. Additionally, the fact that the measures for this study were a subset of questions nested in a couple of existing exams means they were less controlled than I prefer and leaves room for criticism. However, considering that overall student performance was equivalent in all the classes, the data show a very clear effect, and I believe these results speak to the true consequence that a quality classroom demonstration can have on learning.

A testament to the flexibility of this demonstration occurred in March of 2010, at the Arizona State University Brain Fair, when we hosted hundreds of underprivileged first through fifth graders and exposed them to many aspects of neural function and anatomy. At the event, we used a simplified version of the Three Colossal Neurons demonstration that was suitable for the ages of our guests. All of the students were engaged in the activity, and we had great success in teaching neural function to even the youngest participants. In many ways, the details of the task that we used with the first graders were quite different from the demonstration that we used with undergraduates. However, the basic structure of the activity remained the same, demonstrating that it is a useful, flexible, and invaluable tool for teaching neural activity within the context of a neural network. Afterwards, it was quite satisfying to hear a couple of seven year-old girls arguing over whether a sensory neuron could be located in the brain.

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