

Melissa Wu
Neuro 430
Kids Judge Neuroscience Fair 2006 Exhibit
(with: Danielle Tulloss)
Writing in the Major Assignment
April 27, 2006

How Big is Your Leg in Your Brain?

Abstract

To engage children in one aspect of neuroscience we chose to model the process, perception and area of the brain devoted to touch. Mechanosensation requires deformation of receptor endings to open ion channels resulting in action potentials coding for intensity. This information travels into and up the spinal cord to the thalamus before being passed onto the somatosensory cortex. The somatosensory cortex is organized somatotopically and uses information from receptive fields to allow us to perceive touch. However, perception is not always accurate and we devote more of our brain to small but highly sensitive areas of our body. We used a two-point discrimination test, receptive field poster and homunculus as a model. Overall, we were not entirely successful in engaging the children's interest, but our failures serve to guide future projects.

Introduction

Like any of our senses, touch can be a very powerful influence. Somatosensation involves touch (mechanosensation), but also thermoreception, nociception and proprioception, which allow us to sense heat, pain, stretch and position. Instead of teaching the kids all of somatosensation we focused on mechanosensation. Touch receptors are encapsulated nerve endings such as Merkel disks, Meissner's corpuscles, Pacinian corpuscles and Ruffini endings. Deformation of the capsules results in a change in firing rate. Our perception of touch begins with the transduction of a mechanical stimulus into electrical impulses, which enter the spinal cord through the dorsal root ganglion neurons, travel up the spinal cord, through the thalamus and into the primary somatosensory cortex. The pathway is known as the dorsal column-medial lemniscal pathway (Kandel et. al., 2000). While the mechanisms and molecules behind transduction are still elusive, some studies have suggested the transient receptor potential (TRP) and degenerin/epithelial Na⁺ (Deg/ENa) channels may be transduction channels (Lumpkin and Bautista, 2005). The better-known characteristic of the somatosensory system is the somatotopic arrangement of the somatosensory cortex.

Past and present research supports the idea that the primary somatosensory cortex (SI) is somatotopically arranged (Hlustik et. al., 2001, Castillo and Papanicolaou, 2005). Penfield and Boldrey originally showed the somatotopy of SI by mapping the effects of electrocortical stimulation during brain surgery, leading to the first homunculus or representational drawing of the body surface. However, a homunculus can be deceiving showing that the somatotopy is very precise. Compared to the primary motor cortex, which also shows somatotopy, the primary somatosensory cortex organization is more discrete and segregated but some overlap does occur (Hlustik et. al., 2001). While Hlustik et. al. focused on proprioception during simple hand and finger movements, they state their results are similar to what has been previously shown in other studies using skin stimulation. Although most studies have looked at areas of high tactile resolution, Castillo and Papanicolaou obtained results supporting the somatotopic representation of the body by mapping dermatomes using tactile stimulation and MEG imaging. Overall, somatotopy has been shown using invasive and noninvasive imaging techniques during direct electrical stimulation and tactile stimulation (Hlustik et. al., 2001, Castillo and Papanicolaou, 2005).

However, the brain does not distribute the same amount of resources for touch around the body. Some areas have more receptors and more area in the brain devoted to sensing touch (Kandel et. al., 2000). Our fingers, lips and face are good example of where touch discrimination is very high, but our legs, arms and trunk do not require the same resolution (Castillo and Papanicolaou, 2003). Touch discrimination depends on the size of the receptive fields. Large receptive fields result in poor resolution while small receptive fields result in fine discrimination.

The purpose of our model is to show the fifth graders that the brain devotes more neurons and space to certain areas of the body, and to show them that smaller receptive fields result in greater touch discrimination. We also want to convey that a larger stimulus causes a larger increase in depolarization of the neuron, which increases the firing rate. This tells the brain that the touch receptor is “feeling” a lot. By having the students conduct their own two-point discrimination test, we hope the concepts will be readily apparent. Areas with high resolution will be able to detect two stimuli that are very close together, whereas, poor resolution areas will only be able to detect two points when they are far apart. Pictures of small versus large receptive fields will help demonstrate why more neurons and more space are devoted to areas of the brain that have a high touch resolution. Hopefully, the children will walk out of Kids Judge with a better understanding of how they perceive touch, and why their brain does not devote equal portions to all areas of the body.

Methods

Our model consisted of a two-point discrimination test, a receptive field poster, and a presentation on touch receptors, somatotopy and the relationship between stimulus intensity and firing rate. First the kids completed the two-point discrimination test hoping that they would not try to say that they could always feel two points. The judges were split into two groups. In each group, one participant would be blindfolded (the subject), one person would be the experimenter (be in charge of touching the subject with the two points) and one participant would record. The two-point discrimination test consisted of three paperclips of which the ends were positioned apart at 2cm, 1cm and 0.5cm (see Fig. 1). The paperclip ends were applied to the skin on the back of the hand, the cheek and the fingertip. The subject being touched with the paperclip then said whether they felt two points or one. The information was recorded in a table and questions followed. Next we explained receptive fields and why the subject could only feel one touch when two points were actually touching them.

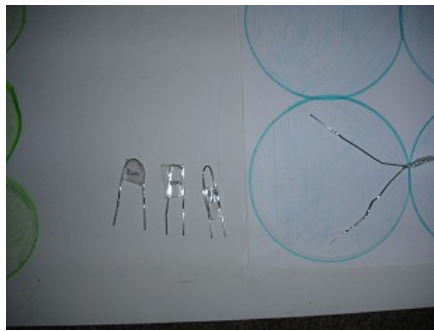


Figure 1. Different sizes of paperclips used for the two-point discrimination test. The “large paperclip” on the right is demonstrating why only one touch is perceived in a large receptive field.

The receptive field poster consisted of two equal size pieces of paper on which were drawn two different sizes of circles. The circles represented receptive fields of mechanoreceptors. The paper with small circles contained more “receptive fields” (12) than the one that contained large circles (6). Above the receptive field papers was a segmented arch (see Fig. 2) that represented the somatosensory cortex. Each section of the arch had a piece of Velcro where a “neuron” could be placed. The neurons were pieces of colored construction paper (the colors corresponded to the color of the receptive field) with Velcro on the back. A pair of participants was asked to place a neuron in the somatosensory cortex for each receptive field. Neurons were grouped by color so all the green neurons were on one side of the somatosensory cortex while all the blue neurons were on the other side. As a result, a small region of the somatosensory cortex corresponded to the large receptive fields and the small receptive fields were represented by a large region. We also showed them how the two ends of a large paperclip fit into one large receptive field, but the ends of the same paperclip touched two small receptive fields. We asked how big they thought the receptive fields were on their fingertips, hand

and cheek. Then we explained that areas like their fingertip where they could tell the two points apart even when they were close together had small receptive fields and were very sensitive to touch. Other areas like the back of their hand had larger receptive fields and were not as sensitive.

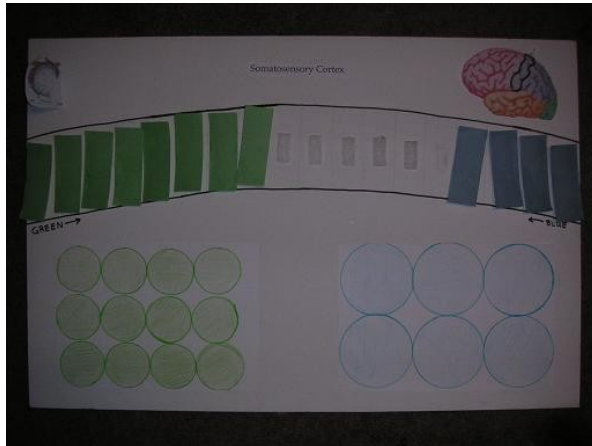


Figure 2. The receptive field poster that was designed to show kids the relationship between receptive field size and amount of somatosensory cortex devoted to that area. Not all the “neurons” have been placed on the “somatosensory cortex”.

Our presentation consisted of telling the kids that touch receptors (a.k.a. mechanoreceptors) changed shape when pushed on, which causes them to fire action potentials. This was demonstrated by pushing in the side of a balloon (mechanoreceptor) with a fist (something touching the skin). We explained the relationship between stimulus intensity and firing rate by getting the kids to clap. We said that normally, a touch receptor fires a few actions randomly and had them clap a few times without any rhythm. Then we said that when something touches them gently, the touch receptor will fire at a steady pace and had them clap at regular rate. Next, we said that a strong touch, like someone grabbing their arm, would make the touch receptor fire really rapidly and we had them clap fast.

During the actual event, the order of events (presentation, poster and two-point discrimination test) did not always remain the same.

Results

Most of the kids seemed interested in our model. However, because of the amount of information covered they seemed understand only sections of the model and were not able to put it together as a whole. The first group seemed to have a particularly hard time because we started off with the presentation and receptive field poster and we began losing their attention. The next groups, where we began with the two-point discrimination test first, seemed much more engaged. The hardest part was keeping the kids' attention with all the other projects going on around us. They started getting excited when they realized their brain would “play tricks” on them by only perceiving one

stimulus when there were actually two points touching them. Further, they liked using the smooth rock versus the bumpy orange to ascertain whether an area was more or less sensitive to touch. Some of the kids seem to understand how the receptive field size related to sensitivity and ability to detect two stimuli. When we asked them questions on what other body parts they thought would be sensitive, a few kids answered the tongue or lips. Still some students did not seem to care or were distracted by other presentations. Overall we placed third, but one group was disqualified. Counting that group we placed fourth (last). Our scores of 4.23 for understanding, 4.68 for friendliness, 3.86 for fun and 3.09 for interest reflected our placement. Most of the responses were general. When asked their favorite part they answered, “paperclips” (the two-point test), “orange test” or “touching things”. When asked what they learned, some kids just said, “how much you can feel”, “about touch”, or “you need every part of your body”. Our best responses about what they learned included, “the bigger the cells [receptor fields] the less you feel” and “fingertips feel the best because they have more receptors”. Additional comments suggested we speak up while the majority said, “good job” or “it was great”. However, the responses were generally short and it did not seem like the majority of kids walked away with a good understanding of what we were trying to teach them. Within the class, we ranked last on most of the ratings suggesting that our model was not engaging or that we did not present it well.

Discussion

Our model would need to be simplified taking only one or two concepts and expanding on them to generate better scores. It seems like the amount of material confused the students rather than built upon itself. The lack of interest and low fun scores suggest that a more hands on approach would be more beneficial. As mentioned before, focusing on one topic from our model and developing it into a more interactive project is critical. Toning down the vocabulary is also needed, so as not to confuse the kids.

Touch is not only a powerful sense, but fine touch also has an evolutionary benefit. The amount of space dedicated to small but very sensitive areas of our body support this view. For that reason it is important to understand how touch or mechanosensation works. The mechanisms and channels behind transduction are still relatively unknown although there are many proposals. Hopefully, engaging the children or the public in some of the interesting aspects of touch will spark interest that may lead to future research and discoveries. The model was supposed to teach children about somatotopy and a general sense of how we feel, and also why it might be important for humans to dedicate so much of their somatosensory cortex to small areas of the body such as the fingertips and lips. However, our model was so fragmented and covered so much information that it was difficult for the kids to follow. We were unable to teach the kids the exact pathway in which a touch receptor is activated, fires action potentials that

travel to the spinal cord by way of the dorsal root ganglia, and up the spinothalamic pathway to the thalamus before being sent to the primary somatosensory cortex. Furthermore, we did not explain that deformation of the touch receptor opens ion channels that depolarize the cell and cause an action potential. We also did not fully explain that a receptive field is a single touch receptor that has multiple receptive endings.

Making the kids interested resulted in false sensationalizing. For example, we used a 3-D homunculus to explain how much of the somatosensory cortex is dedicated to different parts of the body. We explained the homunculus as the brains view of the body according to touch. However, it seemed the kids only took in that it was the brains view of the body like it would see looking into a mirror.

In the future, I would strongly recommend that other models of touch focus on a small aspect like just receptive fields and discrimination of fine detail. Future models need to be more interactive. Have the kids form receptive fields and one kid from each receptive field lines up on the somatosensory cortex. Another model might include a sort of relay game where kids would have to use touch discrimination to fulfill certain tasks. One task might be finding a rough marble in a box when you can use your fingertips versus kids that have to wear gloves. Anything that gets the kids moving around and experiencing the different perceptions of touch hands on. Overall, our model was unsuccessful in engaging the children, but it certainly taught us a lot about how to present and simplify material and stimulated ideas about how to make the process more interactive.

Works Cited

- Castillo, E.M. and Papanicolaou, A.C. (2005). Cortical representation of dermatomes: MEG-derived maps after tactile stimulation. *NeuroImage*. 25(3): 727-733.
- Hlustik, P., Solodkin, A., Gullapalli, R.P., Noll, D.C., and Small, S.L. (2001). Somatotopy in Human Primary Motor and Somatosensory Hand Representations Revisited. *Cereb Cortex*. 11(4): 312-321.
- Kandel, Eric R., Schwartz, James H., and Jessel, Thomas M. *Principles of Neural Science*. Fourth Edition. New York: McGraw-Hill, 2000.
- Lumpkin, E.A., and Bautista, D.M. (2005). Feeling the pressure in mammalian somatosensation. *Curr Opin in Neurobiol*. 15(4): 382-388.