Lindsay Fry
Neuro 430
(with: Caroline Decker and Garret Jeffery)
April 26, 2007

The Little Man in Your Brain

Abstract

Mechanoreceptors in the skin are important for sending signals about touch and vibration to the brain, where this information is somatotopically arranged in the postcentral gyrus. We designed a simple model to teach fifth graders about these receptors and the homunculus that represents the somatotopic organization of the body on the surface of the brain. By using a piece of wood with various bumps and textures we demonstrated that receptors send signals to the brain and without them we would feel nothing. Using the homunculus, we showed that parts of the body that have more receptors send more information to the brain, and therefore, need more space in the somatosensory cortex. The fifth graders were led through an experiment that helped them test the hypothesis that areas of the body that have more receptors are more sensitive to touch. For the experiment, the fifth graders were blind folded and were asked to use a specific body part tell the difference between two pieces of sand paper based on their roughness. Our data shows that the fifth graders thought we were very friendly, had a good understanding of our model, and had a moderate interest for learning more. However, compared to other groups they did not have as much fun with our model, and their votes that gave us fourth place out of the four groups reflected this. Their feedback during the presentation and their comments afterwards suggest that they learned most of the main points we were trying to convey.

Introduction

Somatic sensation allows the body to feel and to detect pain, temperature and body position. Specifically, sensations such as touch, vibration, and pressure are received by mechanoreceptors in the skin. There are different kinds of mechanoreceptors that have a variety of field sizes and characteristics that aid in distinguishing them from one another. Some of the most common are Pacinian corpuscles, Ruffini's endings, Meissner's corpuscles, Merkel's disks, and hair receptors. In addition, the amount and type of receptors present in the skin is different for every part of the body. For example, the hairy skin of the forearm, which is representative of the skin of the trunk and other limbs, has mostly receptors with large receptive fields whereas the glabrous skin of the hands and face consists of mainly receptors with small receptive fields (Valbo, 1995). In addition, the innervation of glabrous skin versus hairy skin also differs, but the information reaches the brain in the same manner using two main pathways.

Information about touch and vibration is sent from mechanoreceptors in the body to the brain mainly via primary afferent axons in the dorsal column-medial lemniscal pathway. These axons enter the spinal cord through the dorsal roots and continue on through the dorsal column to the dorsal column nuclei in the medulla. In the medulla, the primary axons synapse, cross, and continue on to the ventral posterior nucleus in the thalamus. Somatic sensation of the face uses the trigeminal pathway, which is analogous to the dorsal column pathway, except that it enters the brain at the pons (Bear, 2001). After synapsing in the thalamus, the neurons of both pathways project to the primary somatosensory cortex (S1) in the postcentral gyrus. Wilder Penfield first proposed that there was a somatotopic organization of the body in the primary somatosensory cortex, based on his maps obtained from simulating S1 (Castillo, 2005). This arrangement has been verified by multiple researchers such as Castillo and Papanicolaou who used the non-invasive technique of magnetioencephalographic (MEG) to map the responses of four different dermatomes to tactile stimulation. Their research showed the same somatotopy proposed by Penfield with the sacral dermatome being represented medially and the cervical dermatome being represented the most lateral of the four (Castillo, 2005). Somatotopy refers to the mapping of the body's surface sensations onto a structure in the brain and this map is often called a homunculus (Bear, 2001). Although homunculus means the little man in the brain, a model constructed from the representation of the body in the primary somatosensory cortex does not produce a "man" whose body parts are all proportional in size.

The homunculus has a mouth, tongue, and fingers that are relatively large compared to other parts of the body. This is due to the fact that amount of area in the cortex devoted to each body part is correlated to the density of the sensory input received from that part. Because sensitive parts of the body have high innervation and therefore a large number of neurons that process information, it makes sense that these parts would have a larger area in the cortex due to the need for room for all of their neurons (Sur, 1980). For example, the glabrous hand or foot representations occupy 100 times more cortical tissue per body surface area than the trunk or upper arm representations do in S1 (Sur, 1980). However, these regions with high cortical magnification, which is how many neurons in an area of cortex are responsible for processing a stimulus applied to a certain region of the body, cause a the map in the cortex to be discontinuous when compared to the actual organization of the body. The amount of space in the somatosensory cortex that is allotted to each area of the body is based from the innervation of that area because that is what determines cortical magnification. Also, the magnification is inversely proportional to receptive field size (Sur, 1980). This means the larger the amount of cortical tissue devoted to a given region of the body the smaller the receptive fields in that region and vice versa. For example, as move from the tip of the finger up the arm, the size of the receptive field increases.

The first purpose of our model was to give the kids a basic idea of how the body detects the sensation of touch and help them understand that this information is sent to the primary somatosensory cortex in the brain. This was demonstrated by having the kids come up to the table and feel a piece of wood with different size bumps and texture using their bare hand and comparing it to feeling the board with gloves on. When receptors are blocked they can not function properly; their sensitivity is reduced, sending less information to the brain; or they are blocked completely, making it so no detailed information about the stimulus can be sent to the brain. This leads to the second point: that the skin of certain parts of the body is more sensitive to touch than other parts which is due to the density of receptors in that area of skin on the body. Finally, the kids were shown that the little man known as the homunculus looks the way it does because the amount of area in the primary somatosensory cortex allotted for each part of the body corresponds to the density of receptors in that area. The last two points were illustrated by having the kids perform an experiment. They were asked to form a hypothesis and then they tested their hypothesis. For the experiment, we divided the kids into three groups, assigned each of them a body part, and had one of them blind folded and the other be a recorder. The kids that were blind folded were asked to say whether two pieces of sand paper had the same roughness or that one was rougher than the other after they had been rubbed on the specified body part.

Methods

Materials

We used a tri-fold poster board with printed pictures to illustrate the pathway from mechanoreceptors to the brain and a regular poster board with a printed picture of a homunculus. We also obtained a piece of wood that was about 2' by 4" and divided into four sections with a permanent marker. In the first section, a hot glue gun was used to place dots of hot glue that had a diameter of about three centimeters on the board next to each other. The same thing was done in the second and third sections but with dots that had diameters of two centimeters and half a centimeter respectively. For the last section, we used a hammer and a bottle cap to give texture to the wood by pounding the cap into the wood to create indentations. Various types of gloves including two types of thick winter gloves and two types of thin cotton gloves were present for the kids to put on their hands and feel the board. Sheets of four different grades of sand paper were obtained and cut into about 2" by 3"rectangles. These pieces of sand paper were then divided into 3 identical groups containing eight pairs each. The pairs either contained two pieces that were the same or two different grades. Blind folds were made by folding three bandanas, and data collection sheets were created to allow the kids to record data on during the presentation.

Procedure

We began by talking to the kids about the five senses and why they are important in everyday life. Then, focusing in on touch, we introduced the concept of receptors and the fact that the amount of receptors present in an area of the body is related to sensitivity. We instructed the kids to come up to the wooden board and touch the dots and indentations using one bare hand and wearing gloves of different thicknesses on the opposite hand. This exercise was followed by an explanation of the sensory pathway from mechanoreceptors in the skin to the precentral gyrus and the somototopic mapping found there. We then showed the poster of the homonuculus and explained that various parts of the body were shown to be larger than others based on how many receptors were present and thus how much space was allotted to each one in the brain. Following this explanation we asked the kids to participate in an experiment.

The kids were asked to form a hypothesis, based on what they had learned, of whether the hand, the back of the arm, or the top of the arm would be better at differentiating between grades of sand paper. After the kids made their hypothesis, we separated them into three groups and blindfolded one of the kids in each group and asked the other kid to be a recorder. Each kid that was blindfolded had a pair of pieces of sand paper rubbed on their group's designated body part and were asked if the two pieces had the same roughness or if one was more rough than the other. The second kid recorded the data. All the data was compared at the end of the experiment, and the kids were asked questions about our model and the presentation.

Results

Overall, the kids seemed to enjoy our model and were taking in what we were telling them, but some groups got distracted at times towards the end. The kids stated in their comments that they liked the experiment part of our model with the sand paper the best. At the end, we asked them questions to see what they had learned and to see if they understood the main concepts. We listed two body parts, and they were asked which one was more sensitive according to the homunculus and why. Another question we asked was what part of the brain information about touch is sent to. The kids were able to answer our questions and seemed to understand what we had told them about, but did not have any additional questions to ask us. In their comments, they said they learned about sensitivity and receptors. They also wrote that the hands and lips are the most sensitive parts of the body and that there are more receptors in the hands. One kid wrote that they learned information travels from the receptors in the hands to the somatosensory cortex. Their correct answers to the questions we asked about our model and their comments suggested that they indeed were learning during our presentation.

The kids rated our model on a scale of 1 to 5 in four different categories which included: understanding, how friendly the presenters were, how much fun the model was, and whether they wanted to learn more. Our model received the second highest marks out of the four models in our group in all of the categories except for being fun (see Fig 1). The mean scores for understanding, friendliness, and wanting to learn more were 4.46, 4.71, and 3.46 respectively. The mean was 3.46 for how fun the kids thought our model was and their votes put us in fourth place within our group.

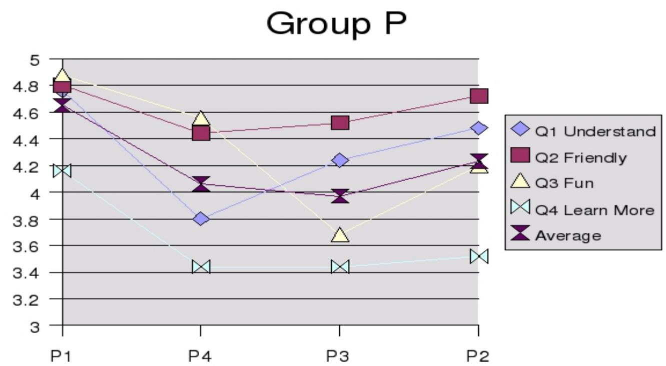

Fig 1. The means from the comment sheets filled out by the kids that allowed them to rank the models based on their understanding, the presenters' friendliness, how much fun they had, and wanting to learn more. The scores for The Little Man Inside Your Brain are in the fourth column (P2).

Discussion

The main purposes of our model were to help the kids understand the importance of sensory receptors, how they send information to the brain, and how this information is organized in the brain. The sensation of touch is something that is experienced every single day, and we thought it was important to for the kids to understand why certain parts of their bodies are more sensitive than others and why they use their hands to investigate the world around them.

Our model seemed to be successful in helping the kids understand that receptors allow us to feel things by sending information to the somatosensory cortex in the brain. Our poster of the homunculus was a great visual for the kids being able to understand how our body is represented in the brain and that this representation is due to the amount of receptors in each part of the body. However, the kids did not mention anything about there being a map of the body in the brain or that certain body parts required more space in the brain due to the amount of receptors they contained. This would suggest that our explanation needed to include more emphasis on these points. In addition, we told the kids that there are receptors all over the entire body, but we simply referred to them in general and did not go into detail about the different kinds of receptors or the fact that they detect different types of sensation. The kids often brought up the fact that receptors were important for feeling if something is hot. Our simplification of receptors probably led them to believe that the same receptors that detect something touching them are responsible for detecting temperature as well. Otherwise the kids seemed to understand what we were telling them, but it was hard to keep their attention at times.

The kids seemed to get the most distracted in the middle of our presentation. Our model could have benefited from less explanation and another interactive activity. We tried to keep the kids engaged by asking questions to them and by breaking up the information we were telling them with the board exercise and the experiment. However, our low scores for how fun our model was and us receiving fourth place suggest that having an activity that allowed for the kids to be more active or making the experiment part longer would improve our model. A possibility would be to have each kid have a turn being blind folded and allowed to do the sand paper test instead of just half of them. Instead of testing three locations on the body, six could be tested so each kid could have a different body part. Although an activity with a higher level of physical activity would be successful with 5th graders, we had a hard time trying to come up with a game for our model that allowed for more physical activity. One possibility that we discussed was to divide the kids into groups, assign them a part of the body, and see which group could order the grades of sand paper the quickest. Our model may not have scored very high on being fun, but the kids did claim that they understood our model.

It was important for the kids to have fun, but having the kids learn something was the most important thing. The high scores the kids gave us for how much they understood and wanting to learn more confirm that we did a good job of explaining our model to the kids. It seemed to help when we had the kids repeat hard words such as homunculus and somatosensory cortex. They were more interested when we incorporated their ideas into the explanation by asking them questions while we were talking. Because some of the kids seemed to understand most of the points well, it was probably not necessary to reiterate some of our points so many times which would allow for less time being spent on talking in the future. This would leave more time for a game or other activity so the kids would be able to have more fun with our model.

References

Bear, Mark F. and Barry W. Conners and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. Maryland: Lippincott Williams and Wilkins, 2001.

Castillo, M. Eduardo and Andrew C Papanicolaou. "Cortical representation of dermatomes: MEG-derived maps after tactile stimulation." *NeuroImage.* 25, 3 (2005): 727– 733.

Sur, Mriganka and Micheal M. Merzenich and Jon H. Kaas. "Magnification, Receptive-Field Area, and 'Hypercolumn' Size in Areas 3b and 1 of Somatosensory Cortex in Owl Monkeys." *Journal of Neurophysiology.* 44.2 (1980): 295-311.

Vallbo, B. A. and H. Olausson and J. Wessberg and N. Kakuda. "Receptive field characteristics of tactile units with myelinated afferents in hairy skin of human subjects" *Journal of Physiology.* 483.3 (1995): 783-795.