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An Olfaction Model: What's in Your Nose Besides Boogers?

Abstract

Smell is a sense that is still lies shrouded in mystery not just to scientists, but to most who use their sense of smell. More is known about the pathway an odor takes to get to the brain than how we actually remember the odor. The pathway consists of an odorant dissolving in mucus, then converging on an odorant receptor. The receptor activates secondary messengers to produce an action potential that travels through the skull to the olfactory bulb before continuing on to the brain. Using a larger than life size model, we taught fifth graders what was in their nose besides boogers. We taught them the sense of smell is called olfaction, and that it is actually a part of neuroscience. Different scents were handed out to the kids to make them wonder how they could recognize a smell that they could not see. In the form of a relay course that started at the nostril and ended in the olfactory cortex of the brain we illustrated the pathway that odors take in order for you to recognize a certain smell. Different kids performed the task of the odorant, the receptor, and the action potential passing through certain structures en route to the brain from the nostril. This hands-on way of learning got them excited to learn about this topic, and we received many positive comments about the efficacy of our project. To reinforce what they had learned, they recreated their experience on a whiteboard after the race was over. This helped solidify the information they had just learned, and helped us see how much they knew. We won first place in our category and post-event drawing showed that the kids had remembered very accurately the steps an odorant takes to reach the brain. In particular, many were able to recall that it is in fact an electrical signal that does most of the work to make you smell things.

Introduction

The olfactory system plays a large role in our lives, yet we still do not know how many of this system's intricate components work. What has been discovered thus far has helped us understand more about how and why we remember certain smells. When a mammal smells an odor, the odorant particles from that odor travel to the olfactory epithelium via the nasal passages or pharynx. Here, the odorant particles dissolve into a mucus layer that is produced by the body. This provides a medium in which the odorant particles converge with odorant receptors. There are hundreds of odorant receptors in the olfactory epithelium awaiting an odorant with certain molecular features to activate it (Mori 1999). Once a receptor is activated, secondary messengers allow for an influx of sodium and calcium, which leads to an action potential. The sensory neuron that contains this receptor will then project through the Cribriform plate and onto glomeruli in the olfactory bulb. Projections from a certain olfactory receptor converge on certain glomeruli in the olfactory bulb (Mori 1999). A network of interneurons, including the cells with dendritic glomeruli, then work to send this signal through the olfactory tract. The existence of specific odorants, olfactory receptors and glomeruli has shown the mechanism in which we may differentiate smells at this stage of olfaction. This mechanism involves specific odorants binding to certain receptors for that odorant, and this connection is thought to be chemically mediated. A secondary messenger system involving G-proteins is then activated in order to create an action potential. This action potential will propagate down the axon to the bundle of secondary neurons in the olfactory bulb (glomeruli) specific to that signal. Then the signal is sent through the olfactory tract to the olfactory cortex to be transformed into a sensory experience.

However, why we remember certain smells is a more elusive topic. After the signal leaves the olfactory bulb, it travels through the olfactory tract and to the olfactory cortex. These areas include the anterior olfactory nucleus, the olfactory tubercle, piriform cortex, part of the amygdala, periamygdaloid cortex, part of the parahippocampal gyrus, and part of the entorhinal cortex (Nolte 2002). The olfactory system has no relay through the thalamus between its receptors and its termination in the olfactory cortex. We do not know exactly which portions of this cortex pertain to certain smells, but we have a general idea. Studies with PET scans of the brain during stimulation to aversive odors revealed an increase in cerebral blood flow to the human limbic system (Zald 1997). This area of the brain, especially the amygdala, is associated with emotions. This link helps to show us where we associate a smell that will elicit a negatively emotional response. In certain neurodegenerative diseases, these temporo-limbic areas are compromised, and the ability to identify odors is compromised as well (Westervelt 2005). This is further evidence for the involvement of the limbic system in the recognition of different smells. Working with the information we have so far, more research can be done into how we differentiate smells in our brain.

This level of analysis in the brain is a bit too complex and still such a mystery that it will not be taught in detail for the model of olfaction. However, what exactly is in our nose that "makes us smell" was the focus of the model.

Through this model, the children should get an understanding of the network inside your head that turns an odorant molecule into recognition in the brain. To pique their interest, the kids were given "smell jars" at the beginning of presentation to see if they were able to recognize the smell. To reinforce the material, they ran through a larger than life replica of this system in the form of a relay race. They should be able to remember the general structures involved in scent recognition and how they contribute to this process. After several relay races are complete to reinforce these ideas, the model was reviewed and questions were asked to see if the kids can verbalize what they had learned. In addition to this, the kids were given whiteboards and dry erase markers so they could work in groups to re-create what they had just experienced.

By teaching about olfaction, we hope to show children there is more to smell than just your nose. It in fact involves a complex web of nerves, some parts in particular, which still boggle the minds of neuroscientists today.

Methods

Eight smell jars were made to see if the children could identify the smells in the jars before the relay race. Jars were plastic and glass, with holes cut in the top. The sides and bottom were covered with white paper so the objects inside the jars could not be identified by sight. Each jar contained a different individual object for the child to identify by smelling it (Table 1).

JAR NUMBER	OBJECT
1	Orange
2	Cinnamon
3	Vanilla
4	Garlic
5	Pine needles
6	Grapefruit
7	Peppermint
8	Popcorn

Table 1: Distribution of Smell (Objects in 8 Jars).

Each part of the obstacle course through the nose was built separately and assembled on site in Beasley Coliseum at Washington State University in Pullman, Washington. A pair of the following items were made so the children could race against one another through the nose. The nostrils were painted with black paint onto large pieces of white paper (approx. 6x4 feet) and taped to the ground at the start of the race. The mucus was cut out of green fabric, and green/yellow yarn was cut in varying lengths. This yarn was attached to cardboard that was later taped to the underside of a table. Odorants made from toy building blocks of different shapes and sizes to represent different odors. The receptors for these odors were cut out of cardboard and made to fit each shape. Next to the receptor, a cardboard lightning bolt was made and placed to represent an action potential. A white lab coat was also placed on the floor next to these items. Children would have to put the coat on to change from an odorant to an action potential. Attached to the receptor was a neuron rope that traveled on the ground from the receptor to the glomeruli. This neuron rope traveled through a cardboard cribriform plate. The cardboard was cut with varying holes big enough for a child to squeeze through. Multiple pieces were taped together and taped to the tables for the kids to run under. An olfactory bulb was made by taping bright orange tape in the shape of an olfactory bulb onto the floor after the cribriform plate. Inside this olfactory bulb, there was a bike tire to represent the glomeruli. The rope neuron dendrites connected here with the next rope neuron. They were taped to the floor on their route to the brain. The brain was a large print out of the brain (approx 5x4 feet) taped to the ground. These objects were laid out in the following order and arranged around tables for the mucus and cribriform plate (Figure 1). Labels for each structure were made out of cardboard and taped to either the floor or table in which that object was located.

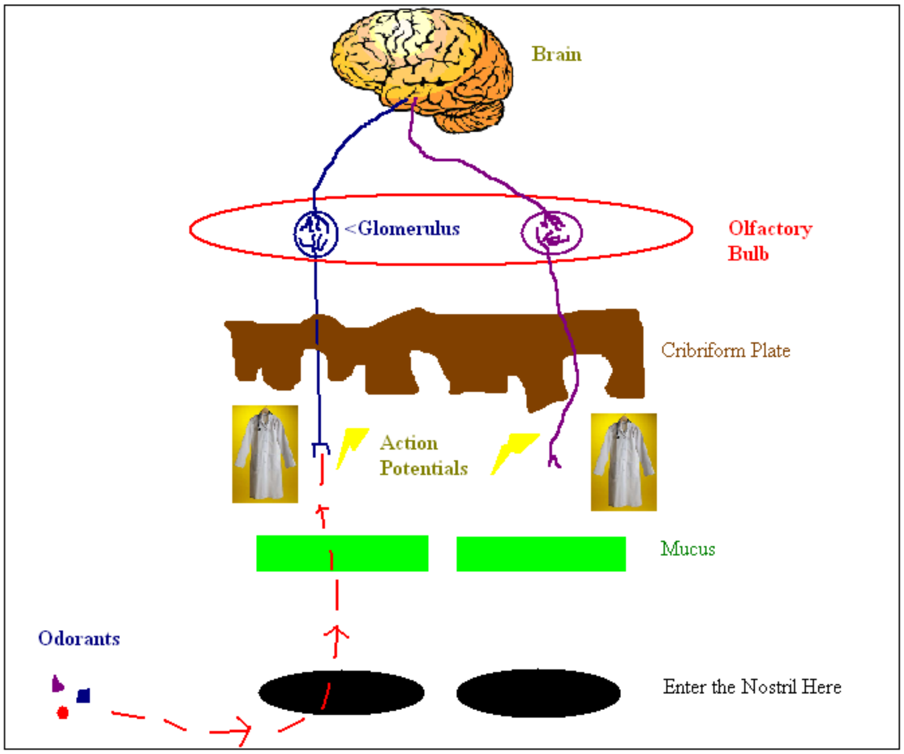

Figure 1: An illustration of the location of objects for the relay race through the nose and to the olfactory cortex of the brain.

To begin, the kids were given different smells to identify without visual aid. This got them interested into how their nose could smell the object and how they could recognize what the object was. Using a visual presentation, a basic outline of the olfactory pathway was given. To reinforce this information, a larger than life size model was built in the form of a relay course. There were two of these courses, so the children could compete against another team to see who can turn an odorant molecule into a signal of recognition in the brain. Teams were used to form a network along the olfactory pathway. One child mimicked the dissolving of an odorant molecule in the mucus by carrying different specific molecule through mucus streamers. This specific molecule was put into the proper receptor (kid 2 is holding it). This kid put on a lab coat to turn into an action potential, and carried the signal through a cardboard cribriform plate to the proper 2^{nd} order neuron glomeruli in the olfactory bulb (kid 3). Kid 3 then ran this signal to the olfactory cortex as fast as possible.

After the race was complete, the children were given two dry erase boards and markers. They were asked to draw (without looking at the course) what they had just learned. My partner and I then coached them through this process to make sure they had drawn the correct labels and structures.

Results

Our olfaction model was received very well by the kids. They seemed interested and eager to learn, and most were able to focus through our presentation before the race began. They asked thoughtful and applicable questions like "Why can't you smell when you get sick?" and "How come you can still smell things after they are gone?"

Our evaluations were very positive and on a scale from 1-5, we received a 4.46 average. In the fun category we averaged a 4.70, and the friendly category we averaged a 4.89. In the understanding category we averaged a 4.38, and in the want to learn more category we averaged a 3.85. Although, for 24 groups the "want to learn more" category average was a 3.67. Our evaluations had comments like "This was fun, awesome, mucus is cool, 100%, and you guys rock!"

Our presentation incorporated a review session at the end with dry erase boards and markers. The kids were excited to draw on the boards, and together in their relay groups, they were able to recall quite a bit of information. Most groups could draw out the relay course on the board and show where the odor went, where it turned to an action potential, and where the signal ended up. Some groups did a good job of trying to label difficult terms like "cribriform plate" onto their drawings. Working together and with the presenters, they were able to form a well defined synthesis of the olfactory process.

We took first place in our group by a landslide of votes. When open viewing time came, we were bombarded by more than eight new and different groups of kids that wanted to try the race. Here, it was more difficult to explain all the points about olfaction that we wanted to get across in order to present to all that wanted to see our project. In the end, we raced about eight of these groups through, and had to turn newcomers away.

On the follow up assignment, the kids that mentioned our project were still able to draw the majority of the course. Most remembered that an odor changes into an action potential. This term was used along with "electrical signal" to demonstrate how we smell. Some very accurate illustrations were made that showed every aspect of the race as well as explanations of the olfactory system. One drawing in particular reflected the process happening inside of a head, instead of just drawing the different part represented in the course.

Discussion

From the results of this experiment, the kid's judge model of olfaction was an effective learning tool. The kids had fun, and enjoyed the learning process. The lowest score, which was above average by .18 points, was for the "I want to learn more" category. However, our project told the children what was in their noses besides boogers, and that is exactly what we did. Judging from the ability to recall and synthesize the information they obtained, we conclude that the kids learned from our model. We were able to get them to carry away the idea that there are a vast array of structures in your nose, and odorant turns into an action potential, and that they all pertain to neuroscience.

The rationale for this model was to teach kids something that they knew very little about besides that boogers come out of your nose. Then they can use this information to find out why they remember certain smells. The smell jars made them very curious about what makes them smell. The concept of an odorant changing to an action potential was reinforced by making the kids put on a lab coat after they received the odorant. This process slowed down the race, and it gave them a sense of how long it can take for an odorant molecule to be transformed into an electrical signal. Most were able to recall this electrical signaling process a week later in the post-event analysis papers.

We conveyed the idea that for each odorant, there is a certain receptor, as well as a certain signal being sent to specific glomeruli in the olfactory bulb. We did not go into detail about the different theories behind scent recognition, (e.g. shape theory for receptors) mostly because these ideas are still being debated. Even though in the model, the olfactory bulb was separate from the brain, the kids understood that the olfactory bulb is in fact a part of the brain. From post-event drawings, we saw that even though the brain was placed in front of the nostrils in the model, that the kids understood the proper place for everything in our head. We also emphasized to the kids that this is the process by which they smell, and where the smell goes, but that we still don't know how in the brain we remember certain smells. We informed them that there is still a lot we don't know about olfaction, but this is what we do know. We were unable to go into fine detail about the actual second messenger systems in the second order neurons.

The presentation and races went well when we had an allotted amount of time to teach and experiment with the kids. During open viewing time, it was difficult to show everyone the process of olfaction when all they want to do is run the race. Although, we found that the kids were so eager to run the race, they would pay attention to the explanation so they would know what to do. I think more group presenters and a bigger course would improve the efficiency of this project. The brain could be placed properly in proportion to the rest of the system to bring clarity to the model. We sometimes ran into a problem of an odd number of kids instead of the ideal six. In this case, a presenter would take the place of a kid in the course, or kids would rotate in and out. In the future, more space and another step could be added in the race to eliminate the shifting of people from different areas. This is all I would change about this project, since the kids had so much fun and learned more than we expected.

The kids were able to understand the path an odorant takes to get to the brain. Having them draw out the model with labels at the end definitely seemed to solidify the process of olfaction for them. We conclude that through this fun and engaging model, fifth grade kids were aided in their understanding of what implications neuroscience has on their everyday lives.

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