HOW TO DO IT

The Tongue Map, Real or Not?

NABT BioClub RECOMMENDATION

PAMELA A. MARSHALL

Abstract

Students need practice in proposing hypotheses, developing experiments that will test these hypotheses, and generating data that they will analyze to support or refute them. I describe a guided-inquiry activity based on the "tongue map" concept, appropriate for middle school and high school students.

Key Words: *Tongue map; taste senses; tasting; experimental design; hypotheses testing.*

In 1901, German scientist D. P. Hänig published a paper describing the relative taste sensitivities of different parts of the human tongue, testing sweet, salty, bitter, and sour (Hänig, 1901). He reported that each section of the tongue was able to taste all flavors, but that there were small differences in threshold sensitivities between volunteers.

> *Human gustation is a complex physiological process that only recently has begun to be unraveled.*

Hänig's data were reinterpreted in a 1942 book, *Sensation and Perception in the History of Experimental Psychology* (Boring, 1942), and presented in a way that made people think that each section of the tongue had large differences in its ability to taste flavors. Boring published this figure in the book (Figure 1):

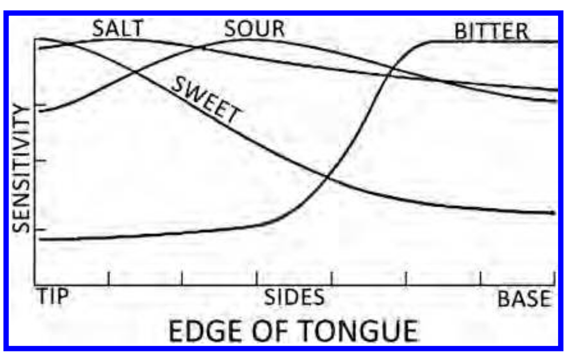

Figure 1. Distribution of taste sensitivity along the edge of the tongue (Boring, 1942, p. 452).

And similar figures have often appeared in books since, such as this (Figure 2):

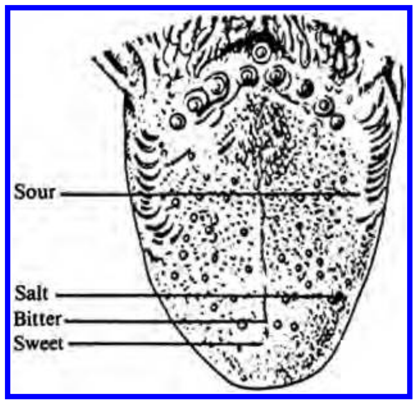

Figure 2. Drawing of taste sensitivity on the human tongue. "Approximate location on the tongue of regions of greatest taste sensitivities for the four primary taste qualities. For the bitter taste, the soft palate (not shown) is the most sensitive region" (Schiffman, 1995).

Somehow this information became mutated over time, and people believed that each section of the tongue could taste only one flavor. This became known as the "tongue map," represented by a figure like this one (Figure 3):

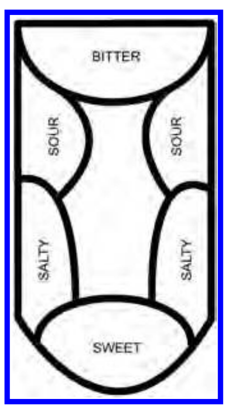

Figure 3. A tongue map, similar to ones found in textbooks and on the Web, indicating that each section of the tongue can taste only one flavor.

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In 1974, Virginia Collings reanalyzed Hänig's original research and performed her own experiments (Collings, 1974). She demonstrated that all parts of the tongue could sense all tastes, but with differing thresholds for the stimuli (Figure 4):

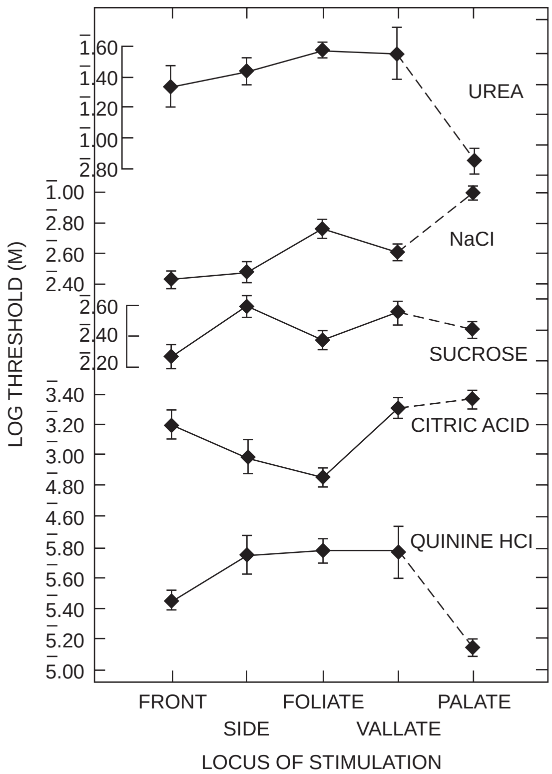

Figure 4. Log taste thresholds of four tongue loci and the soft palate for urea, sodium chloride, sucrose, citric acid, and quinine hydrochloride. The horizontal lines indicate ±SE. Quinine is bitter, sucrose is table sugar, citric acid is vitamin C (sour), and urea tastes like ammonia. The y-axis indicates the lowest concentration (threshold) that subjects were able to taste.

Further work has confirmed the hypothesis that all parts of the tongue can taste all flavors and has extended our knowledge of taste. For example, Linda Buck and colleagues later cloned the genes for some types of taste receptors and showed that these receptors are present in all taste buds (Matsunami et al., 2000), further debunking the myth of the tongue map. A fifth taste was identified, umami (glutamate, a savory taste found in high levels in many foods, including tomatoes and fish, sometimes described as a brothy or meaty taste; Chaudhari & Roper, 1998), and much work has been done to tease out the relative contributions of taste and smell to the overall sensation and pleasure of eating (Smutzer et al., 2006).

○ Activity

Many biology textbooks and books that cover classroom lab activities and science fairs, as well as online activities, still feature "maps" showing where each taste can be detected on the tongue (e.g., Wiese, 2000). There are also dozens of articles explaining that this tongue map is a misconception perpetuated through poor understanding of human physiology (e.g., http://www.livescience.com/7113-tongue-map-tasteless-myth-debunked.html).

Human gustation is a complex physiological process that only recently has begun to be unraveled (Smutzer et al., 2006). In the following guided-inquiry lab, students design and carry out their own experiment to support or refute the idea of tongue mapping. The purpose of the activity is not for the students to come to the "right" answer, because human taste physiology varies, but for the students themselves to design and perform experiments without a "cookbook" to guide them.

Students were given an overview of human taste and some of the experiments done to study taste, and a discussion of umami. They were then challenged to develop an experiment to support or refute the 1942 tongue map hypothesis (sweet, sour, bitter, and salty only; Figure 3), using their group as subjects and some or all of the items we supplied.

○ Materials

1. Lemon slices (sour)
2. Sugar
3. Salt
4. Instant coffee (bitter)
5. Raw potato (no flavor), control or not used
6. Jalapeño lollipops (capsaicin)
7. Tomato paste (umami)
8. Chicken broth (umami)
9. Water (no flavor), control, used to cleanse palate, or not used
10. Q-tips
11. Toothpicks
12. Spoons

○ Procedures

Students were told to design, conduct, and report the results of an experiment supporting or refuting the tongue mapping hypothesis, as reported in 1942, using sweet, salty, bitter, and sour tastes. They were told that their subjects would be the members of their team. We asked them to design an experiment that resulted in both qualitative and quantitative data that could be placed in a table, graphed, and analyzed via statistical methods. Students were expected to report on

1. Statement of the problem (experimental question)
2. Hypothesis and rationale
3. Variables and their operational definitions
   a. Independent variable
   b. Dependent variable
   c. Controlled variables
4. Experimental control/control group
5. Materials used and rationale for use (use only as many spaces as needed; you may not need all the items given)
6. Procedure, including diagrams (if applicable)

7. Qualitative observations
8. Data table(s) (required)

   "Design a table to present your data. Ensure that your table is complete, with raw data, units, labels, calculations (if appropriate), and significant figures (if appropriate). Indicate how many trials and how many subjects."
9. Statistics
10. Analysis and interpretation of data
11. Possible experimental errors
12. Conclusion
13. Applications and recommendations for further use

The rubric we used to assess the activity was modified from the Science Olympiad rubric:

1. Statement of problem (4 points)

_____ Not a yes/no question

_____ Independent and dependent variables included

_____ Problem clearly testable

_____ Response written in a clear and concise manner

2. Hypothesis (4 points)

_____ Statement predicts a relationship or trend

_____ Statement gives specific direction to the predictions(s): A stand is taken

_____ Prediction includes both independent and dependent variables

_____ A rationale given for the hypothesis

3. Variables

Independent variable (IV) (3 Points)

_____ IV correctly identified

_____ IV operationally defined

_____ At least three levels of IV given

Dependent variable (DV) (3 points)

_____ (2) DV correctly identified

_____ DV operationally defined

Controlled variables (CV) (4 points)

_____ One CV correctly identified

_____ Two CVs correctly identified

_____ Three CVs correctly identified

_____ Four CVs correctly identified

4. Experimental control (3 points)

_____ Control(s) correctly identified

_____ The control(s) makes logical sense for the experiment

_____ Reason given for selection of control(s)

5. Materials (3 points)

_____ All materials used are listed

_____ All materials used are listed properly (no extras)

_____ Materials are listed separately from procedure

6. Procedure, including diagrams (6 points)

_____ Procedure well organized

_____ Procedure is in a logical sequence

_____ (2) Enough information given so that another could repeat procedure

_____ Diagrams used

_____ Repeated trials

7. Qualitative observations (4 points)

_____ Observations about results given

_____ Observations about procedure/deviations given

_____ Observations about results not directly related to DV

_____ Observations given throughout the course of the experiment

8. Quantitative data – data table (6 points)

_____ All raw data given

_____ All data have units

_____ Condensed table with most important data included

_____ Table(s) labeled properly

_____ Example calculations given

_____ All data reported using correct significant figures

9. Graph(s) (6 points)

_____ Appropriate type of graph used

_____ Graph has title

_____ (2) Graph labeled properly (axes/series)

_____ Units included

_____ Appropriate scale used

10. Statistics (6 points)

_____ (3) Mean, median, or mode

_____ Measure of variation

_____ Regression analysis

_____ Other appropriate statistic used

11. Analysis and interpretation of data (4 points)

(All statements must be supported by the data)

_____ All data discussed and interpreted

_____ Unusual data points commented on

_____ Trends in data explained and interpreted

_____ Enough detail given to understand data

12. Possible experimental errors (3 points)

_____ Possible reasons for errors given

_____ Important info about data collection given

_____ Effect errors had on data discussed

13. Conclusion (4 points)

_____ Hypothesis evaluated according to data

_____ Hypothesis restated

_____ Reasons to accept/reject hypothesis given

_____ All statements supported by the data

14. Applications and recommendations for further use (4 points)
   ______ Suggestions for improvement of specific experiment given
   ______ Suggestion for other ways to look at hypothesis given
   ______ Suggestions for future experiments given
   ______ Practical application(s) of experiment given

○ Results

We purposefully gave students more items than they would need (such as the lollipops and umami tastes), just as a real scientist has more chemicals available to her in the lab than she would use for any individual experiment. Part of the activity is to design an experiment that tests the hypothesis; thus, giving the students only the items they need defeats the purpose of the activity, which is student-designed research. An alternative approach would be to give the class the experimental question and have them determine a shopping list as well.

I used this activity for an Experimental Design Section of the Arizona Science Olympiad. Students were given 50 minutes to propose a hypothesis and then to develop, execute, and analyze their own experiment based on their hypothesis. They had to develop a quantitative method to score taste and were challenged to graph their results. Because 50 minutes was a very short amount of time for the activity and for classrooms, I suggest 2 hours at least, broken up into developing the hypothesis and designing the experiments, and then performing the experiment and analyzing the data.

This particular experiment was especially well suited for guided inquiry at many levels because the items are relatively inexpensive, students love to study themselves and the human body, and developing a method and determining which foods to use is not as simple as one might think. Eighteen of the groups we challenged (31 groups competing in the Arizona Science Olympiad) did not choose the correct variables to test the hypothesis. Other groups were not sure how to quantify the results or how to analyze their results in light of the hypothesis they developed.

Fourteen groups' experimentation supported the tongue map hypothesis. Some students reported that different parts of their tongue had strong variation in taste sensitivities, and others reported no differences at all. Thus, there is individual-to-individual variation in the threshold response on different parts of the tongue. In this experimental setup, not everyone is going to obtain the same results, even if the same trials are run on them, and so every individual or group can propose and test their own hypothesis, and then students as a whole can come together in class to discuss differences and then analyze the group data, perhaps even controlling for variables such as age and favorite foods.

Turning the ubiquitous tongue map activity into a guided-inquiry lab helps students develop and propose hypotheses as well as design and carry out their own series of experiments. This activity fits the guidelines of "Understanding about the Nature of Science" of the Next Generation Science Standards (http://www.nextgen.org) and is applicable at all grades, depending on the amount of instructor input.

○ Acknowledgments

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PAMELA A. MARSHALL is Associate Professor of Mathematical and Natural Sciences in the New College of Interdisciplinary Arts and Sciences, Arizona State University West Campus, MC 2352, P.O. Box 37100, Phoenix, AZ 85069. E-mail: pamela.marshall@asu.edu.