

# Exploring the Links between Sensation & Perception: An Inquiry-Based Crossmodal Perception Laboratory in Anatomy & Physiology

RECOMMENDED  
FOR AP Biology

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## ABSTRACT

In a traditional anatomy and physiology lab, the general senses – temperature, pain, touch, pressure, vibration, and proprioception – and the special senses – olfaction (smell), vision, gustation (taste), hearing, and equilibrium – are typically taught in isolation. In reality, information derived from these individual senses interacts to produce the complex sensory experience that constitutes perception. To introduce students to the concept of multisensory integration, a crossmodal perception lab was developed. In this lab, students explore how vision impacts olfaction and how vision and olfaction interact to impact flavor perception. Students are required to perform a series of multisensory tasks that focus on the interaction of multiple sensory inputs and their impact on flavor and scent perception. Additionally, students develop their own hypothesis as to which sensory modalities they believe will best assist them in correctly identifying the flavor of a candy: taste alone, taste paired with scent, or taste paired with vision. Together these experiments give students an appreciation for multisensory integration while also encouraging them to actively engage in the scientific method. They are then asked to hypothesize the possible outcome of one last experiment after collecting and assessing data from the prior tasks.

**Key Words:** anatomy and physiology; crossmodal perception; inquiry-based laboratory; sensory integration.

## ○ Introduction

The complexity of physiology presents pedagogical challenges to help students develop a body of knowledge that will adequately prepare them for advanced academic studies or clinical practice. Physiology requires a high degree of critical thinking and an integration of multiple disciplines to generate an extensive vocabulary. While it is important to convey basic linear thought processes to students and for them to have a solid understanding of these concepts, it is also important that students make the connections between basic functional processes and their implications in daily life.

When studying vision, the typical content focuses on the basic anatomy of the eye and related neural structures and processes. However, simply lecturing on the basic anatomical and physiological principles of the eye does not allow students to make connections between the visual pathway and what eventually becomes a visual perceptual experience. When a teacher shifts to a mode of learning that focuses on an understanding of sensory integration, students are encouraged to think at higher cognitive levels. For example, including a discussion on prosopagnosia, a neurological condition characterized by the inability to recognize the faces of familiar people, allows students to make the connection between vision and perception. Students can understand what it might be like to enter a classroom and not recognize the faces of their lab partners even though they meet every week. Prosopagnosia allows for discussion of how the visual pathway may be intact yet facial recognition may still not be possible. This encourages students to engage in a deeper level of learning (for an excellent video on prosopagnosia, go to <https://www.youtube.com/watch?v=vwCrXomPbtY>).

Information carried by a sensory pathway is referred to as *sensation*. The conscious awareness of that sensation is perception. When it comes to human physiology, perception is crucial because it becomes the patients' reality. For example, supertasters can have 16 times more taste receptors on their tongues than non-tasters (Spence, 2015). This increase in receptor density, and genetic differences in receptors, impacts a person's sensitivity to certain flavors and therefore their perception of those flavors; what is pleasing to one palate may not be pleasing to another.

These profound differences in perceptions are derived from a single unimodal stimulus. When we factor in multimodal stimulation, teaching the concept of sensory perception can be a daunting task. Studying perception helps students understand that sensory experiences occur as a result of multisensory integration. This understanding requires students to go beyond basic memorization and into the realm of critical thinking and analysis. Students begin to see physiology as a symphony resulting from the well-organized and skillful playing of multiple instruments.

*“At the completion of the lab, students have a better appreciation for the integrated dynamics of different sensory experiences.”*

The brain must receive multiple bits of sensory information and integrate the individual stimuli to create a coherent result. Cross-modal perception occurs when multiple sensory modalities interact to produce one sensory experience. A simple example of this is the McGurk effect, in which simultaneously delivered incongruent visual and auditory stimuli lead to significant difficulty in accurately identifying a sound (MacDonald & McGurk, 1978). If the syllables *ba-ba* are heard while viewing lip movements consistent with *ga-ga*, the perception is often of *da-da*.

Visual information has also been shown to play an important role in perception of taste (Spence et al., 2010). The addition of visually congruent red food coloring to a cherry-flavored drink increases one's ability to identify the cherry flavor. Alternatively, when an incongruent visual cue is used – orange-flavored drink paired with green color – the ability to identify the flavor is significantly diminished (Sakai et al., 2005). The brain makes an association between the flavor and color of a beverage and then retains that association. When color is congruent with the expected flavor, the flavor can be easily identified. Conversely, when color is incongruent with the expected flavor, the multisensory information is ambiguous and flavor is more likely to be identified incorrectly.

To help students understand that perceptions are the result of complex multisensory events, we developed an inquiry-based crossmodal perception lab. The activities in this lab focus on the interaction between olfaction and vision and their impact on flavor perception, as well as the impact of vision on the perception of scent. The lab is designed for use in an anatomy and physiology course. The needed materials are easy to obtain, cost efficient, and easily prepared. By the conclusion of the lab, students will not only understand the complex relationship between sensation and perception, but they will also be engaged in the scientific method as a way to critically assess information. They will apply scientific concepts to hypothesize the possible outcomes of a series of multisensory tasks, after assessing the data they have collected.

## ○ Objectives

By the completion of this lab, students should be able to

1. assess the relationship between the sense of smell and the perceived flavor of a beverage,
2. assess the relationship between the sense of vision and the perceived flavor of a beverage,
3. assess the relationship between the sense of vision and the perception of scents,
4. assess which of the special senses will have a greater impact on flavor perception,
5. develop a hypothesis using collected data, and
6. critically assess experimental design and be able to identify flaws in methodology and recommend alternative procedures.

## ○ Lab Instructions

In this crossmodal perception lab, students are encouraged to focus on the differences between individual sensory experiences and perceptual reality. In the first series of experiments, students evaluate the perception of flavor in the presence and absence of olfaction.

In the second series of experiments, students evaluate the perception of flavor with congruent, incongruent, and no visual cues. In the third series of experiments, students evaluate the perception of scent with no visual cues, congruent and incongruent visual cues. Lastly, students develop their own hypothesis of which sensory modalities will best assist them in correctly identifying the flavor of a candy: taste alone, taste paired with scent, or taste paired with vision. Students then complete a post-lab assessment to assist them in critically assessing the data and experimental methods. All handouts that accompany this laboratory are listed in Table 1.

All preparation for this lab can be done in advance by the lab instructor or lab technician (for a detailed description of lab preparation see, the Instructor Preparation Sheet in Appendix S1, available with the online version of this article). Figure 1 shows a picture of the setup for all portions of the lab. A critically important consideration is that the instructor does not allow any student in the class to see the answer key until after the experiments are completed. Non-verbal cues from members of the group can impact the perception of the test subject. For Experiment D, instructions detailed in the lab preparation sheet must be followed carefully so that students remain completely unaware of the possible flavors that have been selected.

**Table 1. Handouts included in the Appendices.**

Appendix	Handout
S1	Instructor Lab Preparation Sheet
S2	Student Handout
S3	Data Collection Sheet
S4	Student Answer Sheet
S5	Post-experiment Assessment



**Figure 1. Sample Lab Set Up**

Prior to lab, students are assigned three articles on crossmodal perception: two review articles and one research article (Table 2). The first article is a short review that is written in such a way that undergraduate students can read and understand the basics of crossmodal perception. The second and third papers are more complex and students are assigned limited sections. Students read the three articles and the Student Handout, which describes the lab protocol prior to lab. Students then complete an online 20-point, multiple-choice quiz containing questions from each of the articles and the lab protocol. The pre-class work significantly aids in student preparedness and competence in the classroom.

During lab, students are divided into groups of four. Each group completes the experiments in the order indicated in the Student Handout (see Appendix S2). Ideally, students take turns being the test subject for each of the different experiments. For example, the same student who is the subject for Experiment A1 of the lab must also be the subject for Experiment A2. The same protocol is followed for Experiment C. A different student could be the taster for Experiment B, and then the last student could be the subject for Experiment D. For each experiment, the students who are not the test subject give instructions, serve as the data recorders, and analyze the data. All students work together to assess their data and answer the assessment questions at the end of data collection.

### Experiment A: Flavor with & without Olfaction

The first set of experiments explore the effects of olfaction on flavor perception. In the first part of the experiment, test subject no. 1 tastes colorless flavored water beverages while wearing a disposable nose clip and then assesses the perceived flavor and degree of confidence of that assessment (1 = least confident, 10 = most confident). Test subject no. 1 tastes the flavored water again, this time without wearing the nose clip. The remaining group members record the data on the Data Collection Sheet (see Appendix S3), making sure that subjects always cleanse their palate with clear water between samples.

Colorless single-flavor beverages are used to ensure that visual cues are not involved in the flavor perception and that complex flavors do not confound the identification process. After many trials with various beverages, colorless flavored Propel electrolyte water – lemon, cherry, orange, grape, watermelon, and peach flavors – was found to work best for these experiments. The flavored water is dispensed into small, disposable, 3 oz. clear plastic cups that are discarded as soon as the experiment is completed to eliminate any possibility of cross-contamination (for specific instructions on proper setup and sample numbering, see Appendix S1).

**Table 2. Articles for pre-class assignment.**

Title of Article	Pages
“The Effect of Visual Images on Perception of Odors” (Sakai et al., 2005)	All
“The Nose Smells What the Eye Sees: Crossmodal Visual Facilitation of Human Olfactory Perception” (Gottfried & Dolan, 2003)	1–2
“Multisensory Flavor Perception” (Spence, 2015)	24–26

### Experiment B: Flavor with No Visual Cues, Congruent Visual Cues & Incongruent Visual Cues

To test the effects of vision on flavor perception, students taste flavored water samples that have been colored by the addition of food dye. Table 3 lists the flavors and the congruent and incongruent colors used in the lab setup. Flavor and color are varied so that some samples are colorless, some are congruently colored with the flavor, and some are visually incongruent with the flavor (for details, see Appendix S2). The flavored water is dispensed into clear cups to allow students to see the different colors of the beverages without obstruction. Test subject no. 2 tastes each sample and states the perceived flavor and degree of confidence. The other students in the group record the data.

The experiments in this portion of the lab are intentionally written to incorporate a methodological flaw. While students are evaluating the impact of vision on taste, olfaction is not impeded to limit the number of independent variables. During the post-experiment assessment, students are asked to consider changes they would make to this section of the lab to obtain a more accurate assessment of the impact of vision on flavor perception. Students are asked to utilize the scientific method to critically assess the flaw and recommend alternative procedures to limit the independent variables (i.e., they should be completing this with a nose clip).

### Experiment C: Scent with No Visual Cues, Congruent & Incongruent Visual Cues

The next set of experiments focuses on the effect of visual cues on olfaction using scented and essential oils. Any scents could work well, provided they contain a single, easily recognizable scent. Several different oils were tested until scents were found that were common enough to be easily discernible. The scents chosen for this part of the experiment were lime, cinnamon, orange, apple, and pineapple.

In the first part of the experiment, test subject no. 3 smells each oil while blindfolded. As before, the group members record the perceived scent and degree of confidence. For the second part of this

**Table 3. Setup for Experiment B. Flavors in the left column are paired with the colors indicated in the right column.**

Cup no.	Flavor	Color
1	Lemon	Red
2	Cherry	Brown
3	Lemon	Colorless
4	Orange	Purple
5	Grape	Yellow
6	Lemon	Colorless
7	Grape	Colorless
8	Cherry	Orange
9	Orange	Orange
10	Lemon	Green

portion of the experiment, test subject no. 3 attempts to identify scents when they are paired with congruent and incongruent visual cues. Pictures of the visual cues are printed in color and laminated so that they can be used for several course sections. Table 4 shows the setup of the scents paired with the visual cues. The test subject smells the oil sample while simultaneously being shown the associated visual cue. The test subject then assesses the perceived scent and the degree of confidence. For both sections of Experiment C, a small cup with coffee grounds can be used to clear olfaction between trials.

### Experiment D: Create Your Own Hypothesis

For inquiry-based labs to fully engage students, they should be challenged to develop their own hypothesis and to evaluate the steps of the scientific method. The final experiment in this laboratory requires students to generate their own hypothesis regarding the role of vision and olfaction in flavor perception. Prior to performing the experiment, students are asked to hypothesize which set of parameters they believe will allow the test subject to most accurately identify the flavor of a candy: (1) tasting while blindfolded without the associated scent, (2) tasting while blindfolded with the associated scent, and (3) tasting while seeing the candy color but without the associated scent. Students assess which senses – taste paired with vision, taste paired with olfaction, or taste alone – will have the greatest impact on flavor perception. Prior to collecting data, the students are asked to hypothesize which condition will most accurately allow the subject to identify the flavor. Asking students to formulate a hypothesis engages them in the experimental process, encourages critical thinking, and allows for an immediate confirmation or rejection of their hypothesis. Students frequently assume that if their data do not support their hypothesis then the data are somehow wrong. Students need to understand that scientists must interpret data within the context of the hypothesis (i.e., the hypothesis does not drive the data). Data interpretation reinforces the idea that, if results do not support the hypothesis, the results are not incorrect but rather provide opportunities for better understanding and further hypothesizing.

For these experiments, three different flavored unscented candies are used. The candies must be unscented because one of the parameters that will be tested is the identification of flavor without

**Table 4. Setup for Experiment C2. The scents shown in the lefthand column are paired with the visual cues indicated in the righthand column.**

Vial no.	Visual Cue
3	Lime
2	Cinnamon
1	Lime
3	Orange
6	Apple
6	Pineapple
4	Pineapple

associated scent. Because of the unscented requirement, a number of candies were tested before selecting Mentos brand in orange, strawberry, and lemon flavors. Each laboratory group is given three candies of differing flavors and three corresponding scents in individual vials. It is very important that test subject no. 4 be blindfolded before the candies are given to the groups. The vials are labeled only on the bottom with the first letter of the scent so that the subject is not able to guess flavors based on the names of the scented oils. Test subject no. 4 samples each of the candies, using the procedure shown in Table 5.

Students are told to *complete the entire procedure before moving on to the next flavor*. Students who are not the test subject are given the following instructions:

- Test subject no. 4 should complete all three parts of the experiment with one candy flavor BEFORE moving on to the second and third flavors.
- The students should NOT allow the subject to see the flavors or colors of the candies prior to completing Part 3.
- When offering a scent, ensure that the scent is offered at the *exact same time* as the candy.

The detailed instructions on the Lab Preparation Sheet (Appendix S1) must be followed exactly. When setting up Experiment D, it is best to prepare one small zip-lock bag with three orange Mentos candies, three strawberry Mentos candies, and three lemon Mentos candies for *each* lab group before class begins. If the test subject sees the candies prior to completing the experiment, such visualization will significantly enhance their ability to identify the flavors. Keeping the bags in a location that is not visible to students is essential. Once the group has developed a hypothesis and has blindfolded the test subject, one group member should retrieve the bag of candies from the instructor. At that time the lab instructor can quietly explain that students will pair the flavor with the scent that is marked on the bottom of the vial when they complete the portion of the experiment that pairs the candy flavor with the corresponding scent.

### ○ Post-experimental Assessment

At the completion of the lab, the students are given the answer sheet (Appendix S4). Students work as a group to analyze the data and to ascertain the relationships between different sensory experiences (see the Post-experiment Assessment in Appendix S5). A class discussion follows the completion of the lab so that each group can

**Table 5. Procedure for Experiment D.**

Step 1	Identify the flavor by tasting the candy while blindfolded, but without smelling the corresponding scent.
Step 2	Identify the flavor by tasting the candy while blindfolded, while simultaneously smelling the corresponding scent.
Step 3	Identify the flavor by tasting the candy while seeing candy color prior to tasting, but without smelling the corresponding scent.

share their thoughts and results. During the class discussion, the instructor can lead the students in the direction of critical assessment and encourage them to explore their answers more fully. For example, in Experiment B students are asked to assess the methodological design flaw and, as each group offers their opinion, the unfolding discussion allows the instructor to point out why some of the answers given might not be the best way to control the experiment. After this discussion students should see that, just as perceptual differences occur between different people, two separate groups performing the very same lab can arrive at different outcomes. Because of the small class size at our institution, the purpose of these experiments is to simply demonstrate the concept of crossmodal perception. However, it is possible to expand these experiments by compiling data to obtain a larger sample size.

We have assigned this lab for the past several semesters and it continues to be a student and instructor favorite. All students in the class are actively engaged, the experiments are fun to do, and the students work together to collect and analyze the data. Furthermore, at the completion of the lab, students have a better appreciation for the integrated dynamics of different sensory experiences. Students are often amazed, after realizing that the beverages they are tasting are likely ones they consume on a regular basis, that they do not find them as appealing in the absence of vision or olfaction. Finally, students are encouraged to use the scientific

method throughout this lab, which assists in their critical thinking and problem-solving skills.

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