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A Flavor Perception Game Designed to Introduce Basic Chemical Sensation of Taste Modalities to Undergraduate Nursing and Exercise Science Students

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Abstract

The Flavor Perception Game was designed with the goals of developing an interactive and hands-on activity, providing a platform to review chemical senses of the five tastes, promoting student investment in the course material, and providing a basis for discussion on chemical senses of the five tastes. Knowledge of taste sensation is useful for nursing and exercise sciences students, as human physiology is integral to both baccalaureate curricula. The game is inexpensive, easy to incorporate into a 50-minute lecture period, and free of chocolate allergens. Student participants ($N=34$) tasted three candies and completed a voluntary anonymous poll regarding their detection of the presence of umami, bitter, sweet, salty and/or sour taste modalities in the different candies. During the three stages of this classroom game, a total of 214 taste selections were made, following which students discussed various aspects of taste sensation including its importance in healthcare. <https://doi.org/10.21692/haps.2019.019>

Key words: active teaching methods, active learning; educational games; health professions, taste

Introduction

Human physiology is an integral course in undergraduate nursing and exercise science curricula standards. As such, student investment in physiology education is an important component in these pre-health degree programs. Pedagogical research has explored how student investment in course materials through educational interactive activities enhanced student learning and buoyed student engagement in course materials (Brown et al. 2018, Lipatova and Campolattaro 2016). One study (in a human anatomy and physiology course) identified that hands-on and interactive activities were likely to create “high-quality learning” and provide positive experiences and outcomes for participating students (Brown et al. 2017, Brown et al. 2018). Several other studies included board, word array, and educational games. These studies outlined how educational games increased student understanding of physiology topics, such as muscle cell physiology and action potentials, supported the development of study guides, and promoted student retention of new terminology (Burlison and Olimpo 2016, Luchi et al. 2017, Luchi et al. 2019, Motz et al. 2019). Another recent study reported that the use of interactive hands-on models and trivia games to complement human physiology lectures resulted in a 99% passing rate of the 152 students enrolled in an undergraduate human physiology course (Mahaffey 2018), suggesting that student engagement in activities may have resulted in improved learning through investment in course material. Additionally, a study with

undergraduate dental students found that interactive activities cultivated “focused attention”, improved class participation and clarity in student cognition (Abdel Meguid and Collins 2017).

With this robust evidence of the positive attributes of including interactive hands-on components in physiology courses as a complement to lectures, the Flavor Perception Game was designed to do the following:

1. Engage undergraduate nursing and exercise students in discussions on the physiology of flavor perceptions.
2. Stimulate student discussions on the connections of physiology and healthcare using taste chemical senses as a conduit of discussion.
3. Help improve student understanding and retention of the five taste modalities and their associated chemical ligands.

This game is economical, student-friendly, examines the roles of vision and olfaction in taste sensation, and can to be played in a 50-minute lecture period, including discussion time. It examines the spiciness of cinnamon, the effects of visual and auditory priming on taste sensing for butterscotch hard candy and, finally, how odor plays a role in detecting tastes of a “mystery-flavored” candy. Additionally, the Flavor Perception Game and pre-game mini-lecture (Figure 2) target

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several HAPS Learning Outcomes for “General and Special Senses”:

- a) Identify and describe the location and structure of taste buds.
- b) Classify gustatory receptor cells based on the type of stimulus (i.e., modality).
- c) Explain the process by which tastants activate gustatory receptors.
- d) Trace the path of gustation from gustatory receptors through specific cranial nerves to various parts of the brain.
- e) Describe the primary taste sensations.

Methods

Participants and materials

The undergraduate human physiology class ($N=36$) to which this game was offered consisted of 11% male and 89% females students distributed as freshmen (80%), and sophomores (17%) and juniors (3%) enrolled in the undergraduate nursing and exercise science programs. Within the class, 34 students completed the taste perception polls, giving a participation rate of 94.4%. To perform the Flavor Perception Game, a number of materials common to most tasting tests, were required: 1) food source(s), 2) palate cleanser (water is recommended) and 3) survey tool. This study was approved as exempt by the Institutional Review Board of Loyola University Chicago. No IRB certification was required.

The tastants utilized in this game were candies of varied flavors. Many students verbally indicated that encountering this selection of candies was a new experience for them and it should be noted that students were not provided with nutritional information pertaining to any of the candies during the game. Nice® Brand Cinnamon Discs contained corn syrup and sugar as well as natural and artificial flavors. Nice® Brand Butterscotch Discs contained corn syrup, sugar and salt as well as natural and artificial flavors. FunDip® Valentine’s Day Mystery Flavors (purple and red packaged) were composed of dextrose, maltodextrin, citric acid, calcium stearate and natural flavors. The FunDip® candy is in a paper pouch-like packing. To open, students tear along the mid-seam of the pouch, remove the candy spatula (in one-half of the paper pouch) to scoop the powdered mystery-flavored candy substance (in the remaining half); a fun experience. The recommended palate cleanser for this game was water. Students brought their own re-usable water bottles and water stations were located outside the classrooms.

For analysis, an anonymous student poll was created in the Sakai Learning Management System (LMS) (Aperio

Foundation 2018). This was done through the course web site to ensure that the polling results came from registered student participants. It is important to note the game is not limited to the selected candy or polling choices and a variety of candies (tastants) and a different LMS or survey tool can be used to execute steps of the game.

With regard to possible allergens, the candies were meticulously selected to avoid chocolate so that an allergy to that food item would not be a concern. However, the game components could not be classified as completely gluten-free. The maltodextrin and dextrin contained within the FunDip may (or may not) be derived from wheat and/or barley sources. Additionally, hard-candy molds, such as those for the butterscotch and cinnamon candies, are often coated with flour during the manufacturing processes.

Rules of play

The overall goals of the game were to have students 1) engage in an activity to help them recognize different tastes, and 2) initiate and engage in learning and critical thinking regarding taste mechanisms. The procedures were as follows (Figure 1):

1. Students were given a mini-lecture that included explaining the rules of the game and introducing the afferent taste senses and their activation. During this step students were given textbook details on the five common taste senses (sweet, salty, sour, bitter and umami) and the corresponding ligands (carbohydrates, sodium, hydrogen ion (H^+), hydroxide (OH^-) and L-glutamate, respectively) responsible for taste signaling (Figure 2A). These ligands were taught in accordance with the assigned lecture textbook concepts (Stanfield 2017); as such, the author recognizes that there are a myriad of compounds that would bind bitter taste gustatory receptors, in addition to the hydroxide ion.
2. Students were given one to two discs of “spicy” cinnamon candy to hold in their mouth for 30 – 180 seconds).
3. After the student had identified the taste sense (and corresponding ligand) using the web site poll, the student palate was cleansed with water.
4. Steps 2 and 3 were repeated using the butterscotch flavored candy with the following modification: the candy was described to students as “orange colored” (Figure 5).
5. Finally, students were given one packet of Valentine’s FunDip® Mystery-flavored candy (in either purple or red trimmed pouches).

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6. At this point, students were asked to hold their noses closed, to taste the candy for 30 – 180 seconds (taste in the absence of olfaction) and complete the poll.
7. Finally, students were asked to re-taste the mystery flavored candy without holding their noses closed (taste in the presence of olfaction) and, again, complete the poll.

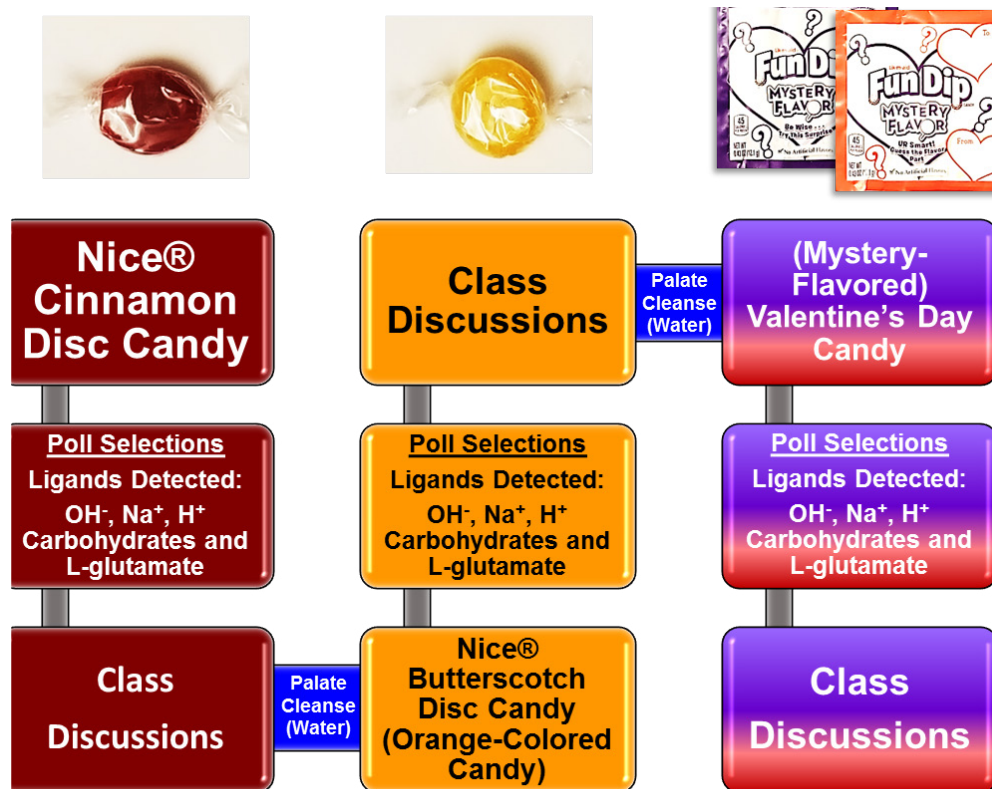


Figure 1. Schematic of Flavor Perception Game Steps.

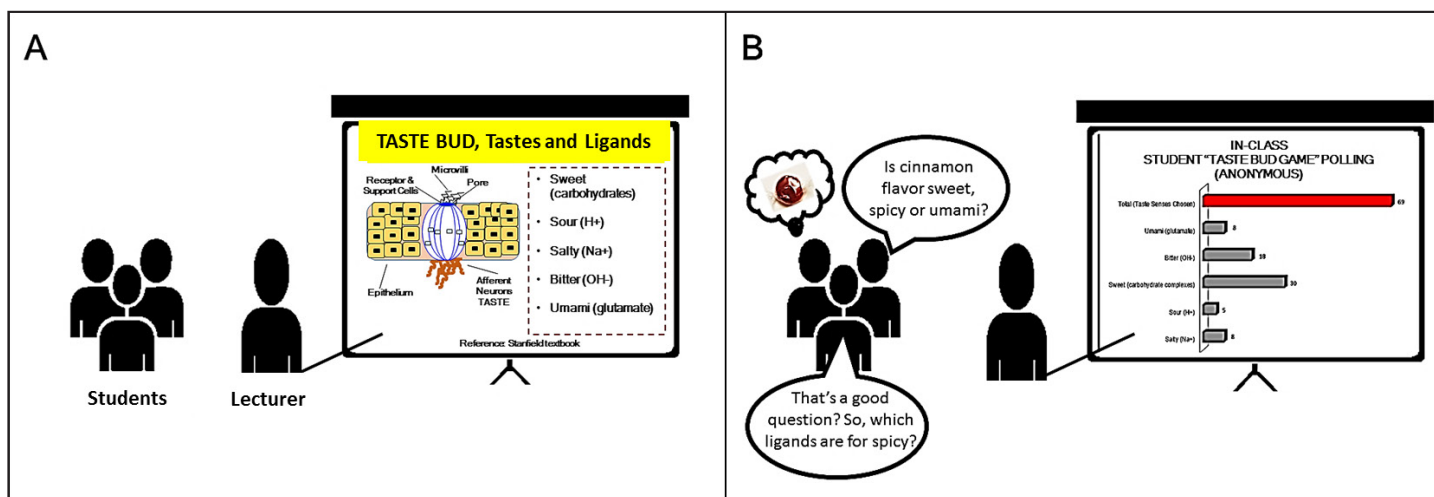


Figure 2. In-Class Lecture and Anonymous Voluntary Student Polling. A) Pre-game mini-lecture and instructions included mini-introductory lecture recapping afferent taste senses, gustatory taste receptors and ligands (lingual taste buds and agonists) and a number of HAPS Learning Outcomes topics. B) Results of student polling after candy sampling that were then discussed in class.

In-class discussion

Students began by reviewing the polling results as a class. Following the primary discussion of polling review step, secondary discussions involved student participants interviewing classmates (and inquiring of the Instructor) to help determine why some participants may have tasted flavors more intensely than others may, with questions such as:

“Did someone have a cold (or seasonal allergies)?”

“Was there a prior injury to the nasal area [olfactory nerves]?”

“Perhaps previous damage to the lingual nerve [gustatory receptors]?”

“Did a participant always – or for an extended period of time – have an aversion to certain flavors?”

“Is the candy too sweet or spicy, for certain participants? Why?”

Finally, the Instructor also offered her own viewpoint on the candies and provided some case studies. This tri-lens (three perspectives) approach, created a variety of viewpoints from which student participants could draw conclusions on the perceived tastants (candies) and physiology of taste sensing. These discussions were carefully timed to fit within the 50 minute lecture period, which included the candy tasting steps.

Results and Discussion

Cinnamon flavored candy

Interestingly, a number of students required an additional five to seven minutes to categorize the cinnamon flavored candy, as to them “spicy” did not fall under the purview of the “five tastes”. Because of the seeming difficulty in narrowing down the “spiciness” of cinnamon flavoring, the polling results ($n = 69$) included all of the five taste senses. Students became invested in solving this “enigma”. Most participants (88%) selected sweet (carbohydrate complexes) as one of the taste modalities that they sensed. This aligns well with the carbohydrate content of the cinnamon candies (12 grams per serving, including eight grams of sugars). But the “other” “spicy cinnamon” flavor was more difficult to link with a single taste modality, being noted as bitter ($n = 18$), umami ($n = 8$), salty ($n = 8$) or sour ($n = 5$) (Figure 4). Interestingly, the salt (sodium) content on the nutritional packaging panel was recorded as zero grams per serving. The selection of salty by eight of 34 student game participants highlights the difficulty of underlining the cause of “spicy” cinnamon flavor detection.

Students began to ask (Figure 2B), which chemical sense was being targeted by cinnamon. This presents an opportunity for student engagement to better understand the notion of “spicy” and the links between this taste sensation and the capsaicin receptor. Furthermore, personal experience with trying to understand the perception of spiciness can consolidate

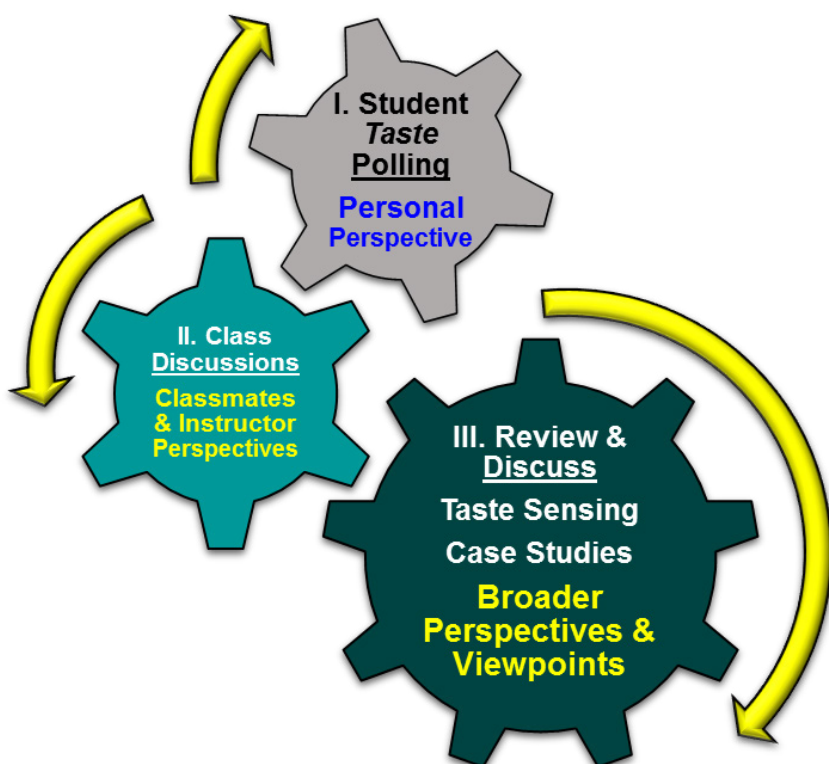


Figure 3. Discussion Steps. Levels of discussion: I) Personal (direct), II) Secondary (classmates and Instructor) and then III) Broader perspectives on taste – following each individual candy tasting.

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student learning of course materials relating to taste sensation by asking students to evaluate, identify and problem solve (Brown et al. 2017, Brown et al. 2018, Mahaffey 2018). On the topic of capsaicin and spicy foods, a learning bridge connecting topics of chemical senses, nociceptors (Caterina et al. 1997) and taste can be developed in student discussion.

In 2017, a study by Trachootham and colleagues highlighted the frequency of one taste (spicy) over others in certain diet regimens, bridging the topic of physiology (taste modalities) with that of nutrition. Both are important components of the Bachelor of Science in Nursing curriculum (American Association of Colleges of Nursing 2008). Instructors can further build on the conversation related to spicy foods by introducing heat-activated ion-channels and the pain pathway, how

chemical senses of taste can alert our central nervous system to the presence of an “alarming” food source, or how capsaicin receptors can in fact aggregate with sweet and /or bitter chemical sense receptors (Moon et al. 2010). The former can engage students, at this step of the game, on learning how bitter taste sensation is a peripheral nervous system function that can also protect us from poisoning (Chaudhari and Roper 2010). Students can examine how hydroxide ions (OH^-), one of the major chemical ligands for bitterness flavor sense, are often a component of toxic substances and, by triggering an efferent response from the CNS to our peripheral systems of a noxious or repellent nature, can be protective against poisoning (Di Pizio et al. 2017, Reed and Knaapila 2010). The latter may help students better understand the varied game results which included bitter (OH^- agonist) flavor selection (Figure 4).

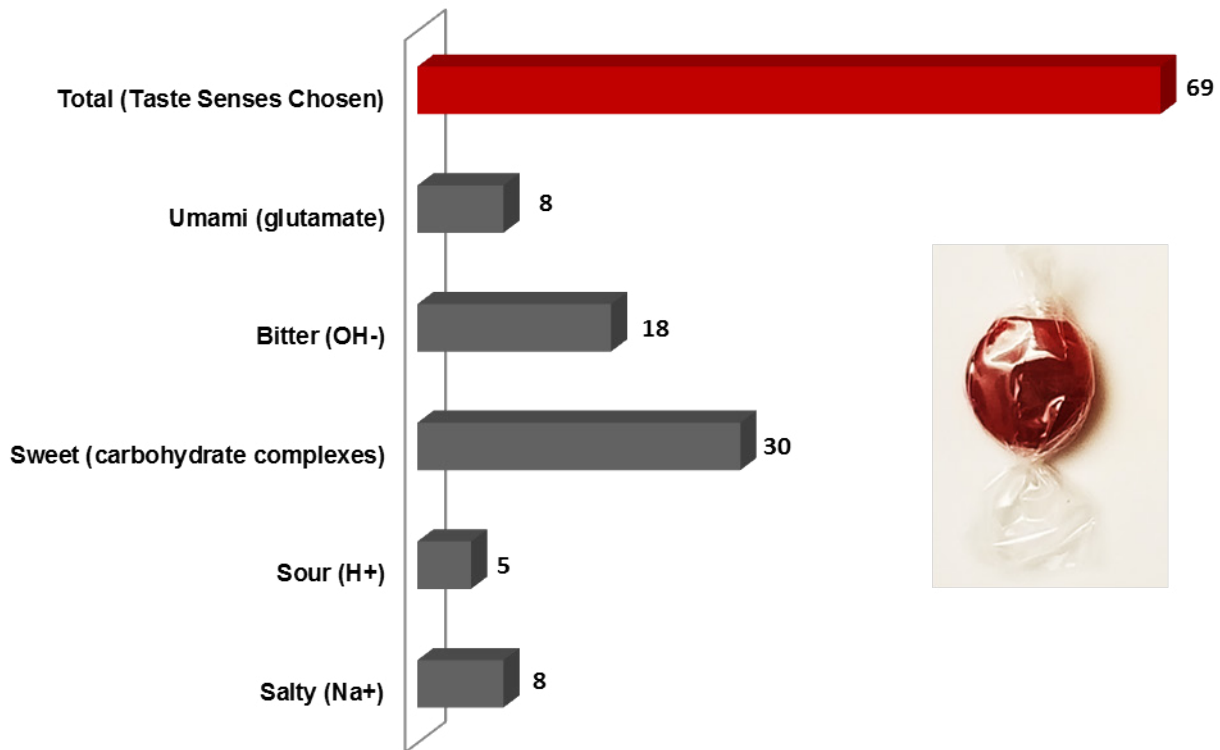


Figure 4. Cinnamon-Flavored Candy Taste Senses Anonymous Student Poll. Regarding the cinnamon-flavored candy, student participants ($N=34$) were asked during this polling question, “Which of the following taste sensation(s) and ligand(s) were triggered?” Multiple selections were permitted.

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Orange-colored butterscotch candy

An investigation into the role of visual stimulation, in regards to perceived food texture and images, was the topic of research in a recent study (van Beilen et al. 2011). During one empirical trial of this research, participants were provided with “figurative” and “non-figurative” (more abstract) image versions of strawberry and caramel items to determine the level of sweetness they associated with the visual stimuli. In this study on visual priming, participants had a perceived ranking of sweetness of food items determined by visual food textures or images from their own personal experiences with food colors, textures and corresponding sweetness (van Beilen et al. 2011). Still, it is apparent that in some cases participants in this study noted they could “see” the definitive flavor of foods presented, or predict the flavors from visual examination of the food items. A myriad of empirical investigation into the effects of the sound of music on perceived tastes has contributed significantly to our understanding of other influences on taste sensation (Höchenberger and Ohla 2018, Spence and Deroy 2013). For example, the sound of music increased the “intensity” of taste. Sweet music led to participants sensing more sweetness in the congruent samples. There were similar results for bitter food samples paired with bitter music, compared to a “no sound” control (Höchenberger and Ohla 2018).

Similar concepts presented an idea to include a section of the Flavor Perception Game that touched on the topic of interdependent sense modalities in determining properties of food or candy. Specifically, sight and sound were used, and more importantly memory and suggestion, to influence taste determination. When students were provided with Nice® Butterscotch Discs candy, the candy was described to them as “orange-colored” and students also observed the orange color of the candy. This was done to visually and auditorily “prime” students to focus on the orange color of the Nice® Butterscotch Discs. As suspected, students noted that prior to opening the candy wrapper they were expecting to taste orange flavoring, but got a hint of something else. Upon tasting, a number of student participants exclaimed, “It’s butterscotch!”, “I was [expecting] orange!”, “Mmmmm...” Some students noted that upon further tasting, the immediate neural expectations of their flavor perceptions and thoughts went from orange to surprise, due to the hearty taste of butterscotch flavor. A few participants noted that they were likely able to sense, perhaps by smell, the butterscotch or toffee-like flavoring to negate the visual/

auditory priming toward an expectation of orange through the candy wrapper.

Student anonymous polling indicated a selection of 74 flavor votes: sweet/carbohydrate complexes = 32; salty/sodium = 23; umami/L-glutamate = 17; and bitter/hydroxide = 2. There was no detection of sour (or presence of H⁺) in the Nice® Butterscotch Discs, noted by student participants (Figure 5). The sweet and salty selections were the top two choices and these choices were confirmed by the ingredients of the Nice® Butterscotch Discs which contained 33.3 mg sodium and 11.3 g total carbohydrate per serving. The bitter flavor was the least popular selection and possibly a guess by two student participants struggling to narrow down the unique chemical sense for butterscotch flavoring. An interesting point of note is the umami flavoring that got 17 votes. Now, another point of student engaging discussion was presented: why was the unique taste of butterscotch savory to some students?

It is interesting to note that a number of students realized that they were not fully aware of which foods can be linked to stimulation of an umami taste sensation. This presented a just-in-time opportunity to expound upon the umami gustatory response. In most human physiology textbooks (e.g. Stanfield 2017), umami is given the synonym “savory”. As such, a common suggestion for sampling is a nice steak. The suggested food items provided by the Instructor included the previous, but it is important to note that there are vegetables with naturally occurring L-glutamate (e.g. asparagus, broccoli, onions, tomatoes and a number of others) to stimulate the umami taste modality.

A number of studies on the synergism of umami tastes have been performed. Over twenty years ago, a study postulated that umami tastes receptors are activated using mechanisms similar to those of sweet and bitter taste physiological senses. For example, Fuke and Ueda (1996) examined how umami appeared to “enhance” the saltiness or sweetness of foods. In 2008, Zhang and colleagues, outlined the “functional mapping of agonist-site interaction sites” of sweet, bitter and umami tastes. It was observed that sweet and umami taste receptors “share a common subunit” (T1R3), but identify different taste stimuli. The sweet, bitter and umami tastes were all observed to be mediated by G-protein coupled receptors (Zhang et al. 2008). This illustrates another opportunity for the game to incentivize student learning and opportunities for critical cognitive processes on physiological subject matter such as the chemical sense of taste.

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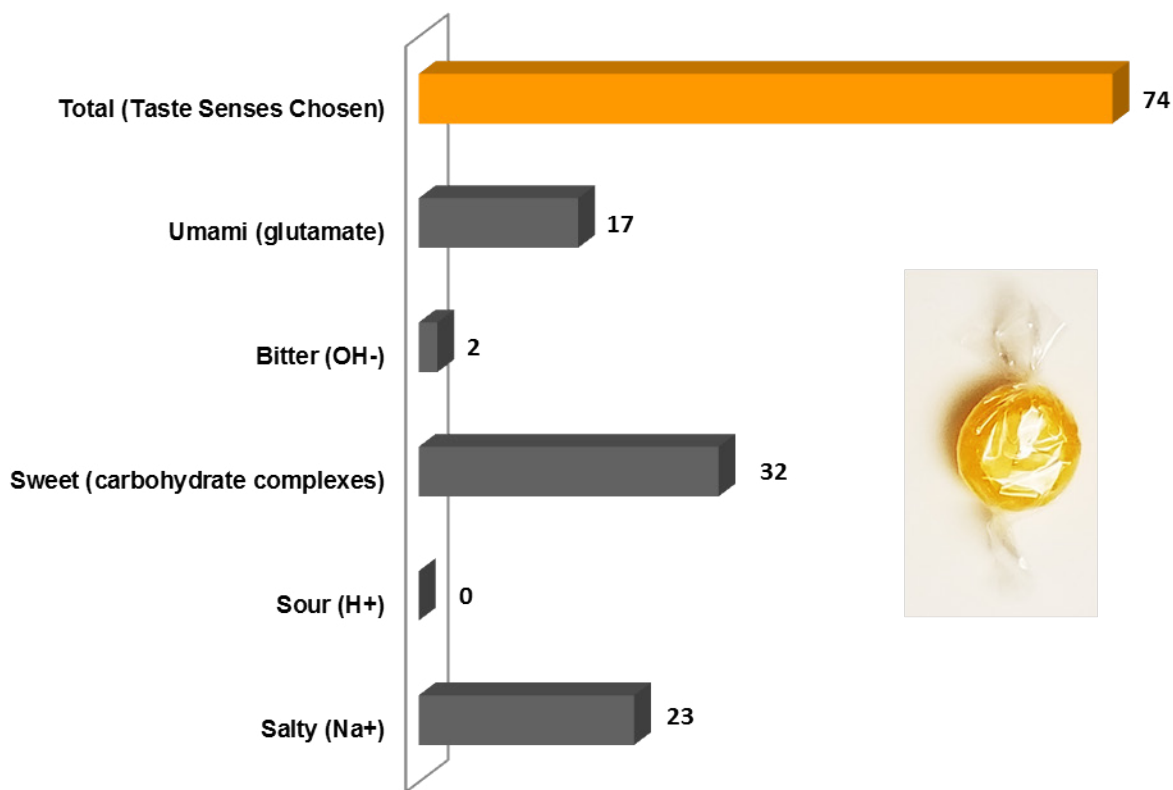


Figure 5. (Orange-colored) Butterscotch Candy Taste Senses Anonymous Student Poll. Regarding the orange-colored (butterscotch) candy, student participants (N=34) were asked during this polling question, “Which of the following taste sensation(s) and ligand(s) were triggered?” Multiple selections were permitted.

Mystery flavored candy: the link between taste and smell
 Due to the robust nature of butterscotch and cinnamon flavors, it is possible that the odorants released through tasting these flavors can travel to the olfactory epithelial tissue. Paul Moore notes in his book, *“The Hidden Power of Smell: How Chemicals Influence Our Lives and Behavior”* that somatosensory pain receptors located close to the vomer bone and associated with the trigeminal nerve can detect cinnamon odorants (Moore 2016). He further uses the previous to explain why sensing flavor differs with the ability to smell (i.e. tasting with and without the nose closed). Here an instructor can bridge the game to delve into concepts of somatosensory receptors and their role in what we perceive as taste.

Given the underlining effects of odor on flavor, the final portion of the Flavor Perception Game was designed to examine student perception of the taste of FunDip® Valentine Mystery Flavor candy, with and without odor cues. In a number of case studies with healthy subjects ranging from 18 to 80 years, participants closer to the age range of typical undergraduate students (18-20

years) exhibited higher sensitivity to taste and smells (Boyce and Shone 2006, Barragán et al. 2018), making the students involved in the current study ideal for this aspect of the game.

The cooperative sensing mechanisms of odor and taste in determining sweet flavors were explored in two studies (Stevenson et al. 1999, Djordjevic et al. 2004). The Stevenson team found that sour tastes can be “suppressed” by certain “sweet smelling” odors. In this experiment, participants indicated through rankings that the “most sweet smelling” odor of caramel was able to mask the “sourness” of citric acid solution, considered to be an excessively sour taste according to the article (Stevenson et al. 1999). The Djordjevic team investigated the odor properties of strawberry and ham on the taste of detection of sucrose products, after smelling strawberry in comparison to that of smelling ham. In this study, participants who smelled ham prior to consuming a sucrose product, tasted/detected the sweetness of sucrose at a markedly lower level of intensity than those who smelled strawberries prior to tasting the

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same/similar sucrose food source. The Djordjevic team additionally highlighted studies, in which smelling strawberry, lemon, almond, caramel, maracuja and lychee also enhanced the taste of sucrose or aspartame food products (Djordjevic et al. 2004).

In this portion of the Flavor Perception Game, students noted that without an odor cue there was minimal detection of the full spectrum of flavors in the mystery flavored candy. Once students were able to use odor cues and smell the candy, a more robust spectrum of flavors was detected. Students were encouraged to discuss how the olfactory senses (food odors) may affect the sense of taste and whether the intensity of taste is similar when one has a “stuffy” or injured nose. Students found the topics of colds (rhinovirus) and other effects on smelling compelling. It was noted that food does not taste as good when you have a stuffy nose. This presents the question of whether or not the olfactory nerves have a function in the gustatory system. During this game, student participants may also be inclined to discuss how the intensity of flavor perception declines in patients with nose injuries or physiological disorders affecting smell. For the undergraduate health professions student participants, this game offered discussion topics that may be useful in their future patient care experiences,

helping them to comprehend the difficulties faced by patients with impaired olfactory senses.

The results of the FunDip® Valentine Mystery Flavor candy anonymous student poll ($n = 71$ total flavor votes) presented nearly equal votes for sweet ($n = 28$) and sour ($n = 32$) (Figure 6). These results help to explain the seemingly split vote between citric mystery flavor guesses (51% orange or lemon) and berry or watermelon (49% voted; $n = 57$) (Figure 7), among student participants. Bitter flavor was detected at a lower frequency ($n = 11$). It is likely, as most students discussed, that the bitter flavor was noted in “hints” of the presumed “citric” tastes. The mystery flavored candy, per nutritional panel information, contained 11g of total carbohydrates (which included the total 11g of sugars) and zero mg of sodium for a one packet serving, with less than 2% citric acid. The sodium and sugar content of the mystery flavored candy supports the high sweetness taste detection and no salty detection of the candy. The citric acid (hydrogen ion donor) ingredients, although less than 2%, likely accounted for the sour taste. .

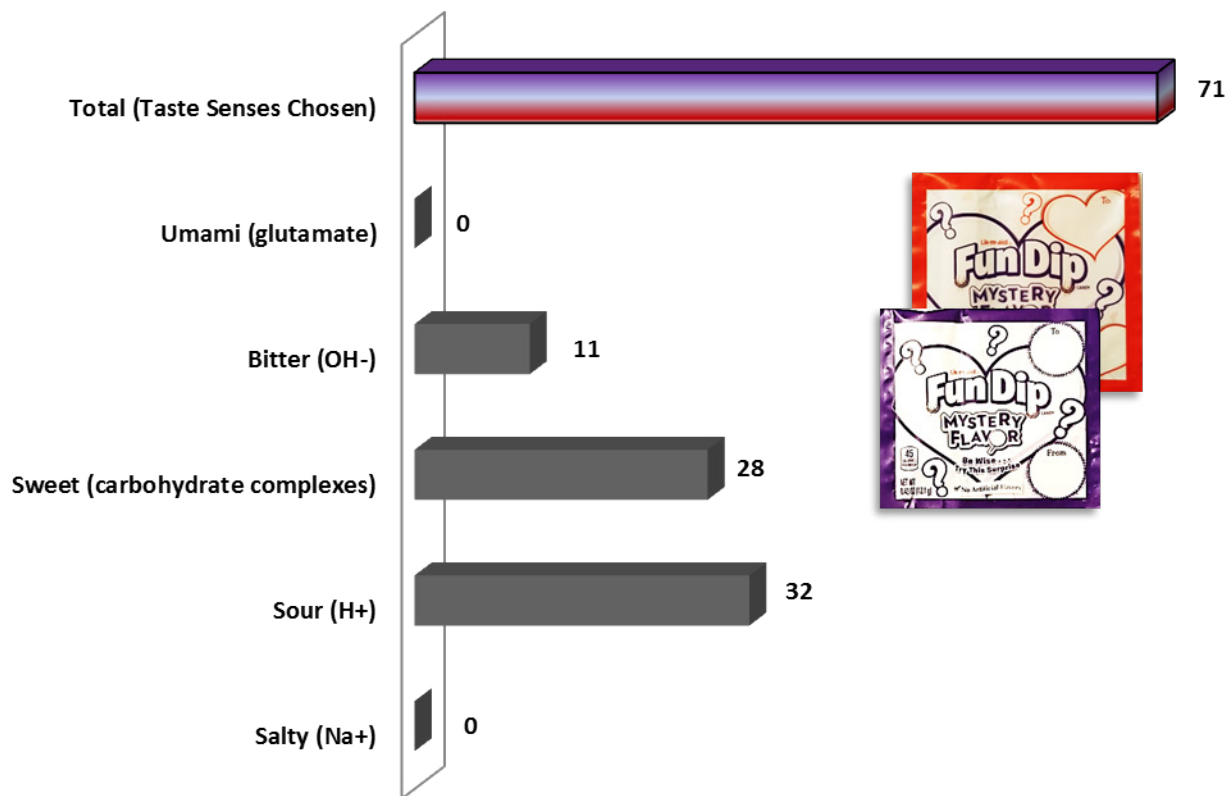


Figure 6. (Mystery Flavored) Valentine’s Day Candy Taste Senses Anonymous Student Poll. Regarding the Valentine’s Day (mystery-flavored) candy, student participants ($N=34$) were asked during this polling question, “Which of the following taste sensation(s) and ligand(s) were triggered?” Multiple selections were allowed.

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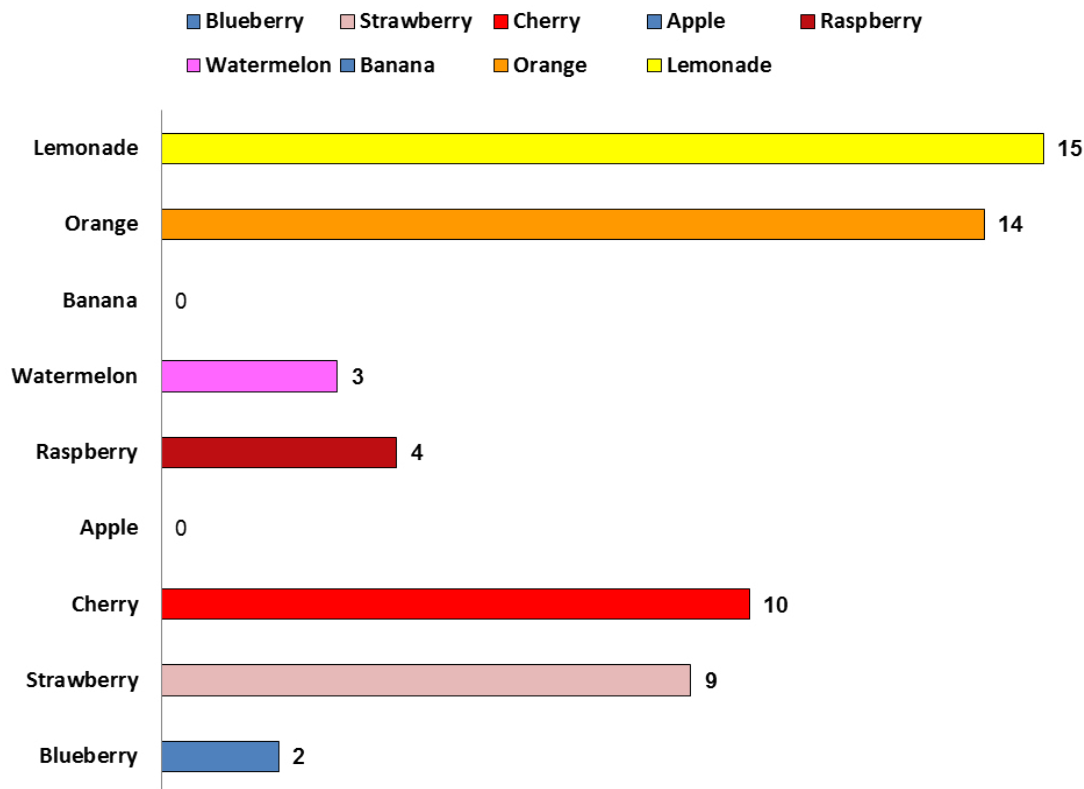


Figure 7. Determine the Mystery Flavor of the Valentine’s Day Candy Anonymous Student Poll. Student participants (N=34) were polled and instructed to select up to TWO possible detected flavors of the mystery-flavored Valentine’s Day Candy.

Concluding Remarks

During the game, students commented positively on this fun approach to learning the five taste senses, gustatory cells receptors, and ligands. Participants described how they enjoyed tasting the samples and examining how taste depends on selective ligand-receptor interactions. Some students noted that the visual cues (colors) of the candies caused them to “expect” a different flavor (as in the butterscotch) than the one they experienced upon tasting. The mystery-flavored candy was a sensational hit. Students responded well to this confectionary conundrum and took samples home to further examine the mystery flavor. Lastly, it was stated that the game offered student participants an opportunity for them to perform an in-depth analysis of candy products, review the ubiquitous nature of gustatory ligands in candy products, and examine how the olfactory, auditory, vision and taste neural pathways work in a cooperative effort in perceiving the five types of tastes.

In conclusion, the Taste Perception Game served as a platform to promote critical thinking, student discussion, investment in course material, and opportunities to bridge a topic of human physiology and healthcare.

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About the Author

Dr. Mahaffey, PhD, is an Assistant Professor at the Marcela Niehoff School of Nursing, of Loyola University Chicago. She instructs the Human Physiology for Health professions courses (both Lecture and Laboratory), as well as Chemistry for Health Professions courses (both Lecture and Laboratory). In addition to teaching, the author researches the contributions of technology and interactive activities in undergraduate physical science courses for health professions students.

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