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Research report

Visual influence of shapes and semantic familiarity on human sweet sensitivity

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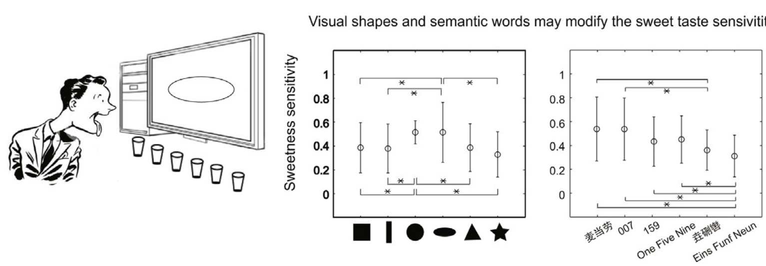
HIGHLIGHTS

- We examined visual influence of shapes and semantic words on human sweet taste.
- The circle or the curved shapes may increase the sweet taste sensitivity.
- The semantic familiar words may increase the sweet taste sensitivity.

GRAPHICAL ABSTRACT



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ABSTRACT

Vision influences taste. It is known that color plays an important role in flavor perception. However, the effect of other features of visual information such as shapes and semantic familiarity of words on the taste perception, particularly on taste sensitivity, is not clear yet. Here we study whether the sweet taste sensitivity of the subjects is affected by such visual inputs. By displaying basic geometric patterns or words with different degrees of semantic familiarity as visual inputs, the subjects rate the hedonic and semantic familiar scores, and taste a series of sucrose solutions, and their sweet sensitivities are accordingly analyzed. Our results show (1) shapes with curvature like circle and ellipse, with higher hedonic scores, increase the sweet sensitivity, whereas angular shapes like square, rectangle, triangle and pentagram do not affect sweet sensitivity; (2) semantic familiar words, with higher hedonic ratings as well, increase sweet sensitivity, whereas unfamiliar words do not affect or even reduce sweet sensitivities.

1. Introduction

The sight of the food affects the taste. It is known that flavor involves multi-sensory information processing pathways. It involves not only taste, but also olfactory, visual, auditory and tactile perception systems. We tend to use all the sensory sources to perceive and identify the features of food and enjoy them. Healthy and appealing food is the trend that our society demands and pursues. Thus, understanding the sensory perception and the cross-modal integration in food sciences are immediate challenges for scientists. In the matter of multi-sensory perception vision plays a very important role. Previous literature has shown that there exists some association between limited colors and certain tastes, and color affects the taste [1–5]. However, different studies do not demonstrate the same effect and the color influence on taste, particularly on intensity of taste evaluation, is rather ambiguous. The sensory perception in these studies involves two sides. On one side, before tasting, the visual perception may induce some expectation of the subject from the previous experience. Such cognitive status may influence later taste perception [2]. The other side is joint presentation, i.e., parallel visual and taste input, leads to multi-sensory integration. It can be said that color plays a key role in

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taste identification, for instance, even with the trained people such as the wine-tasting experts, the unmatched color misleads the wine tasting experts on taste notes [6]. Here we ask a more general question: how does vision influence taste? More specifically, how do the visual inputs with different features influence the taste sensitivity? Except color, other characteristics cues like that of shape and semantic familiarity of visual information which may influence taste perception have not been studied in detail to the best of our knowledge. Only recently, a few studies have demonstrated several kinds of associations between shapes and taste perception. Deroy and Valentin [7] have studied the cross-modal correspondences between shape and flavors of beer and have shown that there is a significant correspondence between sweetness, voluminousness, and roundness. Another study from Piqueras-Fiszman et al. has shown that the importance of color, and have further shown when possible the shape of the plate, may also affect the sweetness perception [8]. However they did not find significant effect of the angular shape of the plate, since the triangular plate they used in the previous experiments is not especially angular. All these results prompted us to take a more detailed research to address this issue. Therefore, here we first ask, does visual cue of shapes influence the sweet taste sensitivity? If so, to what extent can such shapes affect sweetness perception?

In another context it may be noted that in heuristics and cognitive research, familiarity has been shown to play 'priming' effects in sensory perception [9]. It has been demonstrated that there is a positive correlation between perceived odorant intensity, familiarity and pleasantness [10], although familiarity and pleasantness are associated in a complex way [11]. Recently, a gustatory semantic link has been shown in a brain fMRI study that the subject gustatory cortices are activated by only reading the semantic of the word 'salt', whose meaning is related to a particular taste [12]. To test the correlation of the general semantic familiarity and taste sensitivity, our second aim is to study the influence of the semantic familiarity of words, whose meaning may not refer to any particular taste or food and is more general to the subjects. For instance, to what extent do words, when used as visual cues, influence sweet taste sensitivity? Does semantic familiarity of visual cues induce associative coherence in the matter of sweet sensitivity? Is there a cross-modal coherence in familiarity and sweetness perception? If yes, then to what extent can the familiarity of the words affect the sweetness perception? In this study we aim to answer all these questions with a set of designed experiments.

2. Methods and materials

2.1. Subjects

Fifteen student volunteers (eight female and seven male) from Changshu Institute of Technology, China, were chosen for the experiments. They are all self-reported right-handed and have normal eyesight or at least are corrected to normal by glasses. None of them is color blind and their ages are between 21 and 23 years old (average 21.6 ± 0.6 years). They did not have any taste- or smell-related disease before. All the participants were well explained about the details of their performance. They have all agreed and signed on the written informed consent declaration to volunteer as subjects in these experiments. The study was approved by the Ethics Committee of Changshu Institute of Technology, according to the National Ethics Guidelines. We now describe the design of stimuli.

2.2. Design of stimuli

Two groups of visual stimuli are designed, and each group contains six pictures. (1) One group contains six different geometric patterns, viz., circle, square, triangle, ellipse, rectangle, and pentagram (Fig. 1A, upper part). (2) The other group contains six words with different degrees of semantic familiarities: two Arabic numbers, '159' and '007'; two Chinese phrases 垚硎辔 (垚 : Yao, means mound; 硎 : Xing, means whetstone; 辔 : Pei, means bridle.) and 麦当劳 (Mai Dang Lao, means McDonald); one German phrase 'Eins Funf Neun' and one English phrase 'One Five Nine' (Fig. 1A, below part). Semantic familiarity is modulated in these selected words. '007' is supposed to be more familiar to the subjects because of popular Hollywood movie series, whereas '159' is a neutral number. 垚硎辔 (Yao Xing Pei) is composed of the most unfamiliar Chinese words according to Chinese dictionary, whereas 麦当劳 (Mai Dang Lao) is one of the most popular words in China. All the subjects have learned English and are familiar with the used English words, but have never learned German language before and are absolutely unfamiliar with the German words 'Eins Funf Neun' bearing meaning, one five nine. To avoid any color influence, all the shapes and words are displayed on the computer monitor using same font, white color lines and black background. In the experiments the pictures of each group are displayed randomly on the computer monitor (Lenovo L171, 17-in. LCD Monitor) with 60 Hz refresh rate. Now we describe how the sugar solutions were prepared.

2.3. Sugar solution

Sucrose is dissolved in distilled water to prepare the sugar solution with concentration of 0, 1.5, 3.1, 3.9, 4.7 and 5.5 g/L, respectively. All the solutions are prepared in volumetric flasks one night before and kept on the table at room temperature between 22 and 26 °C. During the experiments the solutions are provided to the subjects half-filled in a series of odorless white paper cups (25 mL). We now describe the experimental procedure.

2.4. Procedure

The experiments are carried out at the sensory science laboratory, school of bioscience and food engineering, Changshu Institute of Technology, China. All the participants were trained for two days to perform the taste experiments, including sweetness threshold measurement. Since the hunger status may affect the taste perception of the subjects, the experimental data of the subjects were collected at a fixed time of the day while repeating the experiments on different days (for instance, one subject was always recorded at 10 AM, one hour after breakfast). During the tasting experiments, the subject sits in front of the monitor. Six cups of sugar solution with different concentrations are placed on the table next to the subject (Fig. 1B left). Before tasting, the subjects watch the monitor, which displays one of the visual stimulation pictures, for 5 s. Following they sip the sugar solution from the paper cup (around 12 mL) into the mouth and move the tip of the tongue slightly, keep the solution in the mouth for 5 s and spit it out (referring to the time axis demonstrated in Fig. 1B right). During the following 50 s pause, the subjects rinse mouth twice with distilled water, answers the questionnaire whether they detect sweet taste with the corresponding solution. We use '1' and '0' to record the results of the taste experiment. When the subject tastes the solution and detects the sweetness, '1' is recorded; otherwise '0' is recorded. The sugar solutions of different concentrations are provided to the subjects in random order and the pictures of each group (one group of shapes and the other of words) are displayed on the monitor randomly.

In the control experiments, the subjects taste all the sugar solutions randomly but without being exposed to visual stimuli from the computer monitor. The sweetness threshold measured in those control experiments is analyzed and kept as a base line to observe the possible modification of the sweet taste sensitivity of subjects with additional visual cues.

The subjects repeat all the experiments 10–15 times. All the experiments are carried out at room temperature 22–26 °C. The next section describes the analysis of the acquired data.

2.5. Data analysis

All the data were recorded and saved in the computer (XP Window system) and were analyzed offline with MATLAB 7.9 (The MathWorks, Natick, MA). We calculated *the sweetness detection ratio* for each stimulus. *The sweetness detection ratio* = *the number of times when sweet taste detected/the number of times of total experiments repeated*. For each visual stimulus, the sweetness detection ratio is first averaged per person. The average detection ratio and the standard deviation across 15 subjects are calculated accordingly. A pair-wise t-test was used to test the significance of differences in the sweetness detection ratios with different visual cues.

2.5.1. Sweet threshold measurement

We define the sweetness threshold in our experiment as the sugar concentration at which the sweetness detection ratio is smallest but exceeds 0.5, i.e., at least there is beyond 50% possibility for the detection of sweet taste. The sweet detection ratio for each sugar concentration is averaged across all the volunteers, who repeated every concentration of sugar water at least 10 times (see supplementary data).

2.5.2. Semantic familiarity and hedonic ratings

To quantify the semantic familiarity of the designed words stimuli, all the subjects need to evaluate the semantic familiarity of the words after the taste experiments. They need to give the scores from 1 to 5: '1' means very unfamiliar; '2' means a bit unfamiliar; '3' means ordinary; '4' means a bit familiar; '5' means very familiar. Similarly, to quantify the hedonic associations of the shape and words stimuli, all the subjects were asked to rate to the hedonic scores of each shape and each word. The range of the scores is from 1 to 5: '1' means extreme dislike; '2' means a bit dislike; '3' means ordinary; '4' means a bit of liking; '5' means 'like it very much'. According to the average scores of all the subjects, we may sort the order of semantic familiarity of the words and the order of hedonic ratings of the shapes and of the words.