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Desensitization but not sensitization from commercial chemesthetic beverages

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ABSTRACT

Sensations such as spiciness or stinging are particularly challenging to assess in sensory evaluation tests, as sensitization (increase in intensity with repeated tasting) and desensitization (decrease in intensity with repeated tasting) phenomena can confound intensity ratings. However, much of the published work on these phenomena are with model solutions or complex meals rather than commercial beverages. Thus, we tested whether we could observe sensitization or desensitization using canned spicy ginger beer (contained chili extract) and seltzer water. Samples were presented in pairs, with a 20 s wait and no rinse within a pair, but a 4 min wait with rinsing between pairs. Pairs of samples were: ginger beer followed by ginger beer, ginger beer followed by seltzer, seltzer followed by ginger beer, and seltzer followed by seltzer. These pairs were intended to allow us to also test for cross-sensitization/desensitization between the two beverages. Tests were conducted both in open cups and capped vials to observe how loss of carbonation influenced sample ratings. Participants tasted all pairs of samples in counterbalanced order and rated samples for intensity of "Spiciness, burning, or stinging sensation," bitterness, sweetness, sourness, overall flavor, and liking/disliking. Results indicate no sensitization effects. Desensitization, however, likely occurred for both beverages. Further, tasting seltzer and ginger beer together in a pair amplified the "bitterness" of the seltzer water, a likely contrast effect. Overall, while sensitization may not interfere with the sensory ratings for these beverages, contrast effects and desensitization should be considered carefully when planning sensory evaluation tests.

1. Introduction

Many flavors can be challenging to evaluate in sensory tests due to order effects when tasting. Some compounds linger, leading to difficulty clearing the sensation before tasting other samples and confounding results. Other compounds, capsaicin and other chemesthetic compounds in particular, can have sensitization and desensitization effects. Chemesthesis is the chemical induction of thermal and irritating sensations, such as spiciness from peppers, cooling from menthol, and stinging or biting from carbonation (Green, 1996, 2003). Sensitization occurs when re-tasting of the sample leads to increased intensity compared to the first taste, where desensitization occurs when re-tasting leads to decreased intensity. For spiciness from capsaicin, the interstimulus interval (time between samplings) directly influences whether sensitization or desensitization should be expected. Prior work indicates that up through approximately 2.5–3.5 min between tastes, sensitization occurs, and after 5.5 min between tastes desensitization occurs (Green, 1989, 1991). The desensitization can even last several days (Karrer & Bartoshuk, 1991; McBurney, Balaban, Christopher, & Harvey, 1997).

Some of the alterations in sensitivity to chemesthetic compounds with repeated exposure can certainly be psychological, as the exposures increase the familiarity and/or could change the affective response to a flavor; however, sensitization and desensitization are mechanistically driven through peripheral cells as well (Bevan, Quallo, & Andersson, 2014; Szallasi & Blumberg, 1999). The phenomenon is perhaps best studied for the transient receptor potential channels (TRP), in particular the subfamily V member 1 or vanniloid receptor 1 (TRPV1). TRPV1 is activated by capsaicin, as well as temperatures above 42 °C, acidity, and additional chemical compounds such as allyl isothiocyanate (found in mustard and wasabi) (Bevan, Quallo, & Andersson, 2014; Nagy, Friston, Valente, Torres Perez, & Andreou, 2014). Cellular phosphorylation of specific residues of TRPV1 lead to increased reactivity of the protein to stimuli, while dephosphorylation leads to desensitization (Tominaga, 2006). The dephosphorylation can be driven by calcium flux into the cell, which occurs when TRPV1 is stimulated (see Bevan et al., 2014 for a detailed discussion of these processes).

These phenomena surrounding the response to chemesthetic stimuli exhibit themselves in human behavior. Sensitization is anecdotally reported when consuming spicy meals, and cross-sensitization between

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stimuli through events such as experiencing stronger burning sensations when taking a drink of a carbonated beverage immediately after eating a spicy food (Mouth on Fire?, 2014; The Dos and Donts of Eating Spicy Foods, 2014). However, observing the sensitization effect for real foods in the laboratory has proven challenging, though desensitization has been observed (Prescott, 1999). Indeed, chronic desensitization is thought to drive the differences in reported spiciness intensity of consumers and non-consumers of spicy chili peppers, as consumers consistently report lesser intensity of spiciness compared to non-consumers (Nolden & Hayes, 2017; Nolden, 2016; Prescott & Stevenson, 1995; Stevenson & Prescott, 1994).

Consequently, gaining accurate comparative estimates of sensory intensity for products containing capsaicin, and potentially other chemesthetic stimuli, is challenging. Using actual foods and beverages can complicate these phenomena further, as context, mixture suppression, matrix effects, and a number of other possible factors in actual foods could influence outcomes. Thus, we designed the following experiment to test whether sensitization and desensitization could be observed for two commercially available chemesthetic beverages: a spicy ginger beer and a carbonated water. We also designed the experiment to test for possible cross-sensitization; i.e., to test whether sensitization from spiciness crossed over to enhance stinging from carbonation and vice versa.

2. Methods

2.1. Samples

Samples for this study included a non-alcoholic ginger beer (Q drinks Spectacular Ginger Beer, packaged in 12 oz aluminum cans; ingredient list: carbonated water, agave, ginger extract, lime extract, coriander extract, cardamom extract, orange extract, chili extract, citric acid) and a carbonated water (Kroger brand Seltzer water, packaged in 12 oz aluminum cans; ingredient list: carbonated water). The carbonated water will be referred to as “seltzer” for brevity.

2.2. Tests

Two tests were conducted: the first with approximately 15 mL of sample poured into 4 oz opaque cups with sip-through lids prior to tasting (referred to as the “Open” test hereafter), and the second with approximately 15 mL samples served in 0.5 oz amber vials with PTFE-cone lined caps to help prevent loss of carbonation (referred to as the “Capped” test hereafter). The sip-through design of the lids for the Open test cups allowed carbonation to escape. We attempted to keep samples for no longer than 15 min after opening the canned beverages. All samples (cups or vials) were kept a refrigerator at approximate 4 °C until participants arrived for their scheduled tests. As the initial results from the Open test indicated substantial carbonation loss over the course of the experiment (much lower ratings for seltzer over the course of the tests for each participant), we reran the test with the capped amber vials.

2.3. Tasting procedure

Other than the open or capped containers, the procedure for sensory evaluation was the same for both experiments. Participants were recruited from Purdue University’s campus and surrounding area. All testing methods were approved by the Purdue University Human Subjects Biomedical Review Board as exempt under exemption 6 for tasting of whole foods and food ingredients. Participant screening information, scheduling, demographic, and sensory data were collected using RedJade Sensory Software (Curion, Redwood City, CA). Eligible participants reported no known problems with their sense of taste and smell, no tongue/lip/cheek piercings, were over 18 years of age, and were willing to drink carbonated beverages such as “sparkling water, ginger ale, non-alcoholic ginger beer, cinnamon flavored beverages, and others.” The generalized visual analog scale used to collect intensity data was a horizontal 606 pixel length scale (presented on an iPad mini 2 in landscape orientation), programmed to collect with ratings from −10 to 110, with inset anchors of “None” and “Strongest ever” at 0 and 100. On screen instructions told participants that “None” meant they did not experience any of this sensation at all, and “Strongest ever” meant the strongest sensation they have ever experienced. For warm-up questions, participants were told to rate the intensity of the sensation based on remembered intensity, or imagined intensity if they had never experienced the sensation. A liking scale was also used, which was the same size as the intensity scale, but had the anchors “Worst ever,” “Neutral,” and “Best ever” at 0, 50, and 100 on the scale (end anchors for worst and best were inset by 10 pts as before).

Participants provided information on their age, gender identity, biological sex, and ethnicity. Next, participants completed a warm-up questionnaire to familiarize them with the visual analog scales our laboratory uses to collect data. The warm-up asked the subject to rate the intensity of the brightness of the sun, the brightness of this room, the loudness of a shout, the loudness of a whisper, the bitterness of black coffee, and the sweetness of pure sugar (modified from Hayes, Allen, & Bennet, 2013). Questions were presented in randomized order. Participants were told that we use this scale to verify they understand the scale, and were asked to please rate the items as accurately as possible even if they had attended sessions in our lab in the past (this helps reduce the number of participants who simply click through all the warm-up screens without giving actual ratings). Ratings from the warm-up were used as a check on whether participants understood the directions and used the scale as instructed. This was done by verifying that participants rated the brightness of the sun as greater than the brightness of this room, and the loudness of a shout as greater than the loudness of a whisper. Participants who failed this check were excluded from the final analysis.

After completing the demographic questionnaire and warm-up, participants began rating samples. Samples were presented as pairs and organized onto a tray template to aid in the tasting process (see supplemental files). The details of the questionnaire are included in supplemental file 2. The iPads led the participants through the tasting procedure, explaining that they would be tasting several pairs of samples in a timed fashion, with very specific times for rinsing with water or not. Each participant received 4 pairs of samples: seltzer water followed by seltzer water, seltzer water followed by ginger beer, ginger beer followed by seltzer water, and ginger beer followed by ginger beer. The pairs were presented in counterbalanced order. Participants were instructed to drink the entire sample, hold it in their mouth for 10 s, swallow, then rate the intensity of the “Spiciness, burning, or stinging sensation,” “Sweetness,” “Sourness,” “Bitterness,” “Overall flavor intensity,” and then “Overall liking.” After 20 s, participants repeated this tasting process for the second sample of the pair (no water rinse in between). After tasting and rating the second sample, a 4 min wait was enforced during which the participant was instructed to rinse with water (room temperature spring water, Hickory Springs, purchased locally in 6 gallon containers for a water cooler). After the 4 min wait,

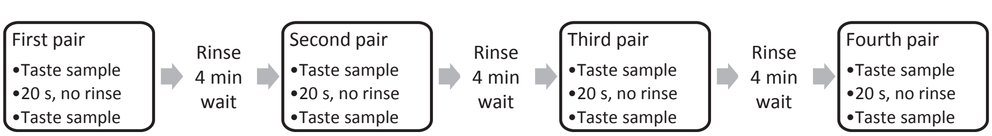

Fig. 1. Tasting paradigm. Order of pairs was counterbalanced.