Influence of Taste Quality on Affective State

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ABSTRACT. Much of the research exploring the relationship between taste quality and affective state suggests that sweet-tasting foods are associated with pleasant feelings, and sour- and spicy-tasting foods are associated with unpleasant feelings. The findings of arousal response as a component of overall affective state are less clear with respect to taste quality. The present study investigated the relationship between taste quality and affective state by comparing arousal and pleasantness ratings of neutral images from the International Affective Picture System (IAPS). Participants ($N = 55$) recorded these ratings during consumption of sprays which varied in taste quality (sweet, sour, or spicy). As hypothesized, sweet sprays elicited significantly higher ratings of pleasantness than sour or spicy sprays ($\eta^2_p = .14$) on the neutral images. However, arousal ratings did not differ among the three taste quality conditions. Implications of the findings in a broader framework and suggestions for future research are discussed.

Taste quality is an important factor in dietary choice because it is an indication of nutritional content (Breslin & Spector, 2008). However, the mechanism that translates taste quality to the motivation to choose specific foods is not well understood and is just beginning to be discussed (Rolls, 2011). Since hunger is often accompanied by irritability and discomfort, it is no surprise that eating usually improves general mood (Gibson, 2006), but hunger cannot explain or predict the choice of one food over another, or whether the choice is a matter of taste or perceived caloric (nutritional) content. Associations of taste quality with emotion may be involved in dietary choices.

The effect of taste quality on emotion has been somewhat consistent in laboratory tests. Bitterness perception in humans is highly variable. For example, a group of randomly sampled individuals may perceive a bitter stimulus as either not at all bitter to highly bitter within the group, producing a range of reactions (Breslin & Spector, 2008). Sweet and sour substances induce facial expressions in both neonates and adults that are consistent with those recognized as joy and disgust, respectively, indicating a consistency of reactions across the life span and a randomly sampled group of people (Greimel, Macht, Krumhuber, & Ellgring, 2006; Steiner, 1974). Fox and Davidson (1986) found that newborns react more quickly to sour water than sweet water, that sweet water is accompanied by positive affect, and that sour water is accompanied by negative affect. Sweet flavors are rated higher in pleasantness than other flavors and may even increase pain tolerance (Kakeda & Ishikawa, 2011; Lewkowski, Young, Ghosh, & Ditto, 2008). Indeed, not even conditioned emotive responses can change affect felt while tasting a sweet drink (Kuenzel et al., 2010). It appears that the sweet-pleasantness link is only disrupted by the onset of acute stress (from self-report ratings), but quickly rebounds (Al'Absi, Nakajima, Hooker, Wittmers, & Cragin, 2012).

Neuroimaging research suggests that, although

taste perception does not appear to be related to the dopamine-driven reward system in the brain (Yamamoto, 2006), motivations to acquire a sweet reward are mediated by this system relative to sucrose concentration—a testimony to the hedonic value of sweet taste. In addition, the amygdala is activated with both pleasant and unpleasant tastes (O'Doherty, Rolls, Francis, Bowtell, & McGlone, 2001), suggesting that the link between taste and emotion is not limited to positive affect (Francis et al., 1999).

Traditionally, there have been four basic tastes: sweet, sour, salty, and bitter (Hollingworth & Poffenberger, 1917; McBurney & Gent, 1979); in addition, the taste of monosodium glutamate, umami, has been included in some Asian cultures (Bellisle, 1999). However, complex flavors involving two or more receptors such as spicy (in which salty and sour flavors predominate) do not appear in the literature on emotion. Responses to the spiciness of various chemical agents (e.g., capsaicin or cinnamon) have been shown to operate independently of taste quality recognition (Cowart, 1987). In other words, the identification of the basic taste qualities can be performed even with oral irritation (burning or hotness). However, we could find no literature exploring the effects of this irritation on emotion, such as a comparison to that of sour or bitter tastes. "A mouth on fire" seems unpleasant, but this relationship should not be assumed and warrants investigation.

It is clear that humans find moderately sweet tastes pleasant (Breslin & Spector, 2008; Kakeda & Ishikawa, 2011; Lewkowski et al., 2008); however, inconsistencies in the definition and measurement of emotional responses are not easily reconciled. Although some facial expressions are universally understood to be responses of a given category (Ekman, 1999), this kind of measure provides no information about the intensity of emotional response. Physiological measures of arousal (Robin, Rousmans, Dittmar, & Vernet-Maury, 2003) have been translated into basic emotion categories, however, arousal is considered by some as a dimension of emotion that is independent of pleasantness (Lang, 1980; Lang, Bradley, & Cuthbert, 2008). For example, joy can be characterized by high pleasantness and high arousal, but rage is best described as low pleasantness and high arousal. These two dimensions are considered sufficient to describe emotional states (Lang, 1995).

To determine the effect of taste quality on affective state, we compared arousal and pleasantness (valence) ratings of neutral images from the International Affective Picture System (IAPS; Lang et al., 2008) in a between-subjects experiment. The IAPS is an image database for which normative values of affective ratings are available. Ratings of IAPS images serve as a reliable measure of emotional response (Lang, 1995; Lang et al., 2008). Limiting the stimuli to images considered neutral (i.e., with normed ratings limited to the middle range of both arousal and pleasantness scales) ensures that the stimuli are unlikely to evoke strong affective responses which could interact with the independent variable. Mean ratings of a single set of images are then compared across treatment conditions, providing an additional measure of effect size. For example, this method has been used to measure effects on emotion of instruction (Jackson, Malmstadt, Larson, & Davidson, 2000; Moser, Hajcak, Bukay, & Simons, 2006) and color (Drescher, 2004).

With the evidence presented above, we hypothesized that IAPS images would be rated highest in pleasantness and arousal by participants ingesting the sweet taste. It was predicted that the emotions felt when pleasantness and arousal were high (e.g., joy) would be linked to the hedonic value of sweet tasting foods (Breslin & Spector, 2008; Kakeda & Ishikawa, 2011; Lewkowski et al., 2008; Yamamoto, 2006). In contrast, we hypothesized sour tastes would be met with disgust (Steiner, 1974), which we predicted would lead to ratings low in pleasantness and arousal. Complex tastes such as spiciness have not been studied thoroughly, but if the reaction to these tastes involve pain sensation, then the ratings should be rather unpleasant. Furthermore, arousal to spicy tastes should be similar to sour tastes, such as a moderate desire to avoid that taste. Thus, we expected sour and spicy tastes to have equivalent ratings on the two scales. Overall, we expected the sweet taste to be higher than sour and spicy tastes on pleasantness and arousal, demonstrating an effect of taste quality on emotional response.

Method

Participants

Fifty-five undergraduate students enrolled in introductory psychology courses (subject pool) at California State University, Northridge participated to fulfill a course requirement. Participants were required to abstain from ingesting food approximately one hour prior to completing the task to ensure a cleansed palate. All participants met this requirement through a verbal check by the

experimenter prior to going through informed consent. Demographic information of the participants, such as age and sex, was not recorded.

An intended sample size of 25 participants per group was desired for adequate power (.70) in this between-subjects design; however, due to limited resources, this was not possible during the experimentation phase, and group sizes had to be truncated. However, the relatively simple nature of the design is generally robust to this sample size and power issue.

Institutional Review Board (IRB) approval was granted prior to collecting data for the study. Each participant gave signed informed consent prior to beginning the study and ingesting the experimental stimulus.

Design and Materials

Flavor sprays. Taste quality served as the independent variable with three levels: sweet, sour, and spicy. Liquid candies in individual 0.125 ounce spray bottles were used to ensure consistency of texture and intensity, and chosen by agreement of the four authors to ensure expression of the desired taste quality. As far as the authors were aware, this was the first use of these sprays in an experimental setting. The sprays used were Too Tart® Super Sweet Strawberry for sweet, Mega Warheads® Sour Blue Raspberry for sour, and Mike and Ike® Hot Tamales Cinnamon for spicy. Labels were removed from the containers to prevent knowledge of the taste quality prior to the procedure.

Scales. Pleasantness (valence) and arousal ratings served as dependent variables measured on 9-point scales and illustrated by the Self-Assessment Manikin (SAM; Lang, 1980, 1995; Lang et al., 2008). Each SAM scale was pictographic, culture-free, and could be rapidly administered. The SAM was anthropomorphic with a head, face, torso, arms and legs. The pleasantness scale was described as ranging from *extremely unhappy* (1) to *extremely happy* (9). Likewise, the arousal scale was described as ranging from *extremely calm* (1) to *extremely excited* (9) with a typical (*neither happy nor unhappy*; *neither calm nor excited*) state rated 5. Additionally, for the pleasantness scale, the face of the SAM changed from a frowning, sad facial expression on the low end, to a midpoint of a flat facial expression, and at the high end, displays a smiling facial expression. For the arousal scale, the SAM displayed a starburst design in the torso area with increasing size as arousal/excitement increased. Each scale was identical to those used to develop the IAPS. While the numbers on the scale were used as the dependent variables (DVs), the SAM was merely used to give a visual representation of the scale values to the participants.

Images. Twenty-five images from the International Affective Picture System (IAPS; Lang et al., 2008) were chosen based on normed ratings of arousal and valence. Images had ratings between 3.5 and 6.5 on both the pleasantness and arousal scales. This range provided images with neutral affective content, such as a towel or a hammer without context. They were displayed, along with SAM illustrations, on personal computers using SuperLab 4.0 software.

Procedure

Prior to participation in the experiment, participants were required to refrain from eating for at least one hour. The experiment took place in a quiet cubicle with the personal computer in one corner. Upon entering the cubicle, participants were randomly assigned to one of the three taste quality conditions and given an informed consent form to sign. The only information given to participants was that they would be ingesting flavored liquid and rating images. No experimental purpose was described. Prior to the experimental sessions, all labels were removed from the sprays, leaving only the plastic seal on the cap. This seal was shown to the participant to demonstrate that the seal was intact, per safety guidelines prescribed by the IRB.

Participants were then instructed to view the sequence of 25 neutral images and rate each in terms of how it made them feel. Participants were also instructed to spray the assigned flavor three times before the first image was displayed in order to ensure that taste experience was initiated. They were then instructed to spray once more each time an image was displayed to maintain the taste sensation. Thus, the total number of sprays was approximately 28, which is approximately 0.1 ounces, or 80% of the total volume of the spray bottle. However, this is only an estimate of the amount ingested, as the spray candies were not metered and the exact dosage was subject to individual differences and practices of the participants. As each image was displayed, the SAM illustrating the pleasantness scale appeared at the bottom of the display as a guide. Participants indicated their rating by pressing the corresponding number on the keyboard. The SAM illustrating arousal scale then replaced the pleasantness SAM and participants rated the same image on this scale.

This sequence was repeated for each image and the order of images was randomized. After rating all images, participants were debriefed, thanked, and dismissed.

Results

A Multivariate Analysis of Variance (MANOVA) was conducted to determine the effects of taste quality on arousal and pleasantness ratings (DVs). For both the pleasantness and arousal dependent variables, 19 participants ingested the sweet taste, 19 participants ingested the spicy taste, and 17 participants ingested the sour taste. The omnibus test was marginally significant, Wilks' Lambda: $F(2, 102) = 2.14$, $p = .08$, $\eta_p^2 = .08$, which warranted further analysis. A main effect was found for taste quality on pleasantness ratings, $F(2, 52) = 4.10$, $p < .05$, $\eta_p^2 = .14$: see Table 1 for means and standard deviations. On average, participants who ingested the sweet spray rated the neutral images as more pleasant than the midpoint of the scale, but those who ingested the sour or spicy sprays rated the images as less pleasant than the midpoint. Post-hoc comparisons (Bonferroni correction) showed that sweet taste quality resulted in higher pleasantness ratings than sour, $t(34) = 2.47$, $p = .02$, Cohen's $d = .80$. In addition, sweet resulted in higher pleasantness ratings than spicy, $t(36) = 2.75$, $p = .009$, $d = .89$. No main effect for arousal ratings was found, $F(2, 52) = .98$, $p = .38$, $\eta_p^2 = .04$.

The taste qualities were then compared to the normed ratings of the IAPS. Each image used in the IAPS has a normative value on both the pleasantness and arousal scales. The 25 images' normed ratings were averaged to obtain a single value for each scale. The difference between those values and the participants' average ratings were computed. For example, a difference score of zero on either the pleasantness scale or the arousal scale would mean that the participant had the same average rating of the images as the general population (disregarding any potential effects of the taste quality). Thus, the taste qualities were compared on each scale to their respective normed ratings (in this case, one sample *t* tests were conducted using a value of 0). Both sour and spicy tastes produced average arousal ratings that were significantly greater than the average normed arousal ratings ($M = 4.32$ on the scale) across the images, sour: $t(16) = 3.71$, $p = .002$, $d = .90$; spicy: $t(18) = 3.27$, $p = .004$, $d = .75$. Furthermore, the sweet spray produced the largest positive arousal difference from the normed average, $t(18) = 6.96$, $p < .001$, $d = 1.60$. Analysis of the pleasantness difference ratings revealed average ratings that were significantly less than the normed ratings for both the sour and spicy tastes, ps $< .01$, ds $> .80$. However, the sweet spray ratings were not significantly different from the normed ratings, $t(18) = -.99$, $p = .34$. This could account for the significant difference in overall pleasantness ratings between sweet vs. sour and sweet vs. spicy.

TABLE 1

Mean (*SD*) Pleasantness and Arousal Ratings of IAPS Images in Each Condition

	Pleasantness		Arousal	
Taste Quality	*n*	*M* (*SD*)	*n*	*M* (*SD*)
Sour	17	4.59 (.92)	17	4.98 (.73)
Spicy	19	4.69 (.60)	19	4.92 (.79)
Sweet	19	5.20 (.55)*	19	5.22 (.56)

Note. Pleasantness ratings for the sweet taste quality were found to be significantly different from sour or spicy taste qualities. This was not found for the arousal ratings.

Discussion

As hypothesized, experiencing a sweet taste, rather than either sour or spicy, resulted in greater feelings of pleasantness. In addition, spicy and sour tastes tended to suppress pleasant feelings, consistent with previous research (e.g., Greimel et al., 2006; Steiner, 1974). However, the sweet taste did not enhance the pleasantness effect above normative ratings of the neutral images. Arousal did not differ among taste qualities, which was not consistent with findings of some studies (e.g., Robin et al., 2003); however, measures are difficult to compare directly. These findings were generally consistent with previous findings on taste sensation, especially those that suggested sweet-tasting foods evoke pleasure more than the other taste qualities.

The process in selecting foods that are sweet or sour may be evolutionarily advantageous. The advantage of associating these foods with our emotional system seems important for learning. The primate visual system appears to be more efficient at detecting specific food sources, particularly those high in glucose, than determining ripeness (Riba-Hernandez, Stoner, & Lucas, 2005); however, sour tastes may have evolved to aid in distinguishing ripeness once food is found (Breslin & Spector, 2008). Tastes may also be adapted to encourage consumption of foods that are high in calories and rapidly digested (such as glucose). Considering that glucose is the energy source used by the brain, such rapid digestion would present a benefit for our

ancestors whose lifestyle was nomadic and much more active than our own.

Although the pleasant feelings induced by sweet tastes in comparison to other flavors may be adaptive, we cannot determine the role of wanting sweet foods given these findings. As with all other sensory experiences, humans cannot separate the emotional experience from taste itself. In other words, the desire for a specific food may be influenced by a specific emotional state, or a specific taste may influence a new emotional state. There is evidence to suggest both hypotheses. For example, Jeffrey et al. (2009) found that elderly female participants experiencing negative emotions prior to consuming food sought sweets more often than other flavored foods. Dingemans, Martijn, Jansen, and van Furth (2009) argued that binge-eating depressed participants eat to decrease negative emotions, suggesting that sweet foods have an antidepressant quality. Christensen and Brooks (2006) concluded that the relationship between affective state and dietary choices is bidirectional. Rolls, Critchley, Verhagen, and Kadohisa (2010) argued through neuroimaging results that the confluence of sensory stimuli (taste plus odor) activates certain brain areas to create the sensation of pleasantness. Therefore, an individual may never know if she desires sweet-tasting foods because they make her happy, or if she is happy because she is receiving what is desired. Our findings cannot conclude one direction or the other, though we can conjecture from our design that the latter is more likely.

However, conscious cognitive appraisal may be required to override conditioned and innate preferences for pleasant sweet foods and avoidances of more unpleasant foods, such as sour and spicy foods. Recent evidence suggests obese individuals are more implicitly attracted to sweet foods than normal-weight individuals (Sartor et al., 2011). The growing obesity problem in the United States makes education and awareness of human taste preferences more important than ever, especially in the case of artificially sweetened drinks and foods, such as those containing high-fructose corn syrup (Bray, Nielsen, & Popkin, 2004). More research is needed to determine the role of self-regulation and other psychological factors in the process of dietary decision-making, and determining the causal path from taste quality and sensation to food selection.

Though these findings extended the literature of the relationship between taste quality and emotion, there were limitations of the study that should be addressed. While the spray candies used seemed to have elicited the desired taste quality based on the data, the likability of and proximity to the nominal taste quality were assumed and not systematically pretested. In other words, the sweet taste was assumed to be the main component of strawberry flavoring, the sour taste was assumed to be the main component of the raspberry flavoring, and cinnamon flavoring has been linked to sensations of spiciness (Koroch, Ranarivelo, Behra, Juliani, & Simon, 2007). Furthermore, these spray candies were chosen for convenience, consistency of texture and intensity, as well as a novel approach to the study of taste qualities. Future research should take steps to operationalize the taste qualities used, in order to strengthen the methodology and conclusions. This would ensure that the taste quality reported is isolated from other qualities. Additionally, we did not seek ratings of preference from the participants. Future research should ask this question, especially if testing a within-subjects design. Although there are perhaps individuals who enjoy the taste of cinnamon, for example, they may be the minority in a between-subjects design where participants are unaware of other conditions (i.e., taste qualities). Last, physiological measures in addition to behavioral self-report data would be beneficial for bringing consistency to the findings (e.g., Robin et al., 2003), as well as linking the two within the extant literature.

There is no doubt that taste quality affects emotion. In the present study, sweet tastes appear to have caused increased pleasantness and arousal, and sour and spicy tastes were regarded as unpleasant in comparison. However, it is unclear what factors are involved in the process. Moreover, this clearly depends on how emotion and emotional states are defined, as well as the design employed to measure the emotional states. We suggest that more work be done in this area. There is still much that is not understood in the area of emotion and chemical senses.

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