1 **Characterizing consumer emotional response to sweeteners using an emotion terminology**
2 **questionnaire and facial expression analysis**

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Abstract

Concerns associated with sugar-sweetened beverages (SSBs) have led to an increased consumer demand for sweetener alternatives that are functionally (and taste) equivalent to sucrose without the associated health risks. Measuring consumer emotions has the potential to aid the industry in subsequent ingredient decision-making. The purpose of this study was to evaluate the relationship of consumer acceptability and emotional response of sweeteners in tea using a 9-point hedonic scale, an emotion term questionnaire (explicit), and a facial expression response (implicit).

Participants (n=30) evaluated a water sample (baseline), two (5%) sucrose-tea samples (control), and four equi-sweet alternative sweetener-tea samples (ace-k, sucralose, high fructose corn syrup and honey), divided by category (artificial; natural). Sessions (4 total, spread over 2 days) were divided by category and emotional response tool in a cross-over design. Facial expression responses were recorded in the first session of both days using FaceReader 5.0 and individual participant videos were analyzed per sample for 5-sec post-consumption ($\alpha=0.05$) in the continuous analysis setting using automated facial expression analysis software. Emotional term responses were collected in the second session of each day and count frequencies of each term per sample were tabulated and analyzed. Hedonic acceptability was rated in all sessions on a 9-point scale.

Alternative sweeteners were all rated 'acceptable' (score of 5 or higher), except for honey in one session. Only one alternative in each category was statistically different ($p<0.05$) in liking from sucrose. Facial analysis showed minimal differences in emotion elicited across sweetener categories. Time series analysis was more robust in showing differences ($p<0.05$) than baseline comparisons. Emotional term selection using a CATA questionnaire showed four unique terms

(disgusted, good, mild, steady) for natural sweeteners and two unique terms (bored, good-natured) for artificial sweeteners. More research exploration related to emotions and food is needed in order to accrue a more accurate picture of consumer product preferences.

Keywords:

Emotion, Facial Expression Analysis, Sweetener, Consumer

1. Introduction

Sucrose is the standard sweetener to which all other sweeteners are compared in the beverage industry. This is largely attributed to its inherent sweetness, which studies have shown elicit positive affective responses in humans (de Graaf & Zandstra, 1999; Rozin & Vollmecke, 1986; Steiner, Glaser, Hawilo & Berridge, 2001), paired with its clean flavor profile, texture, color, shelf-life and ubiquitous abundance in nature (Mitchell, 2006). Sucrose alternatives, traditionally chosen for cost reduction and/or consumer weight control, include those readily found in nature and sweeteners artificially produced in a laboratory setting (Nabors, 2012).

Taste, whether expected or remembered through conveyed information on packaging, is one of the most important factors when making product choices (International Food Information Council, 2013; Koster, 2002; Schifferstein, Fenko, Desmet, Labbe, & Martin, 2013); however, most U.S. consumers believe that sugar consumption is associated with weight gain and should therefore be avoided (IFIC, 2013). The use of alternative sweeteners in beverages, consequently, is advantageous for health conscious consumers. Recent consumer reports have shown that there is a gap in knowledge concerning the relationship between (1) sugar intake and consumer health and (2) the difference in functionalities between specific sweeteners (such as high fructose corn syrup) (Cogent Research, 2006; IFIC, 2013). Evidence from peer-reviewed literature addressing food-health concerns has shown that consumer beliefs heavily influence their acceptance or rejection of food products and ingredients (Dickson-Spillmann, Siegrist, & Keller, 2011; Rozin, Ashmore, & Markwith, 1996). Increasing popularity surrounding food products that are organic, non-GMO, ‘natural’, and have “clean labels”, etc. is largely attributed to the perceived and/or expected health benefits of these products rather than their functionality (Devcich, Pedersen & Petrie, 2007; Rozin, Spranka, Krieger, Neuhaus, Surillo, Swerdlin, & Wood, 2004). Thus,

industry response has focused on creating products that are ‘healthier’ and meet the high taste expectations that have been previously established in the original products.

Success is not solely driven by taste; consumer attitudes and perceptions of the product, its ingredients and all associated branding have an effect that is often hard to quantify. The challenge in sensory science lies in developing a more complete understanding of drivers of consumer preferences. Consumer emotions contribute to purchase habits and, more importantly, brand and product loyalty (Lindstrom, 2005). Emotions occur very quickly (microseconds) and have a short duration (seconds to a few minutes) (Robbins & Judge, 2013). Preferences for one product over another are often attributed to a combination of several internal and external factors. Measuring emotions evoked by food are consequently due to an exponential number of confounding factors, although most recent research suggests that food related experiences are often described in positive terms (Desmet & Schifferstein, 2008; Gibson, 2006; King & Meiselman, 2010).

New methods exploring the role of consumer emotions and perceptions of foods include collecting both explicit and implicit measures. Explicit methods rely on participant cognition of and ability to recognize (emotional) response, much like traditional sensory methods already in use by the industry for acceptance or preference. Limitations involving emotions research can include high panelist to panelist variation, within panelist inconsistency and a lack of emotion term understanding especially in the context of food liking and preferences (Booth, 1994; Köster, 2002). The application of methods measuring subconscious (or implicit) responses that cannot be controlled, typically neurological or physiological, may augment assumptions made in explicit approaches. Several studies in the psychology field show that expressed emotions can be categorized as positive/negative or approach (meaning “towards stimuli”) or withdrawal (“away

from stimuli”). Approach emotions include angry, happy and surprised and withdrawal emotions include disgusted, sad and scared based on brain asymmetry (Alves, Fukusima, & Aznar-Casanova, 2008; Davidson, Ekman, Saron, Senulis, & Friesen, 1990). Implicit measures include temperature & sweat changes, heart rate, electroencephalography, and functional magnetic resonance imaging to evaluate the relationship to food stimuli (de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012; Hu, Player, McChesney, Dalistan, Tyner, & Scozzafava, 1999). Manual facial coding, such as Facial Action Coding System (Ekman & Friesen, 1978), as well as automated facial expression analysis (AFEA) tools (FaceReader™, PrEmo, Affdex) are less invasive; however, they can be time consuming, and the software reliability and accuracy related to food stimuli is not well understood. Of the very few studies using facial expression analyses (Danner, Sidorkina, Joechl, & Duerrschmid, 2013; Danner, Haindl, Joechl, & Duerrschmid, 2014; De Wijk et al., 2012; Garcia-Burgos & Zamora, 2015), most have focused solely on measuring single or dominant emotions at a set time period.

The purpose of this project was to compare natural and artificial sweeteners to the traditional standard, sucrose, for acceptability as well as implicit and explicit emotional responses. The specific objective was to evaluate the relationship of consumer acceptability and emotional response of sweeteners in tea using a 9-point hedonic scale, an emotion term questionnaire (explicit), and a facial expression response (implicit).

2. Materials and Methods

2.1 Samples & sample preparation

Acesulfame potassium (ace-k; Wego Chemical & Mineral Co.; Great Neck, NY), high fructose corn syrup (HFCS; Tate & Lyle; London), honey and sucrose (Kroger; Cincinnati, OH)

and sucralose (Sucral; Tate & Lyle; London) were received by donation or purchased at the local supermarket. Preliminary testing established sweetness equivalence of alternative sweeteners to a 5% sucrose in water solution (w/w). Five sweetened tea solutions, using alternative sweeteners and sucrose (control), were made approximately 24 hr prior to each sensory testing day. Each batch solution of tea (Lipton Tea, Unilever, Englewood Cliffs, NJ) was prepared based on package instructions (Southern Sweet Tea, n.d.). Drinking water (Kroger brand, Cincinnati, OH) was brought to a simmer (~99 °C). Tea leaves (~4g), bundled in cheesecloth, were placed in a heatproof container, heated water (355 mL/4 g tea leaves) was added to packaged tea, steeped (covered) for 3-5 minutes, then tea leaves were removed. Pre-measured sweeteners were added to the appropriate volume of tea (Table 1). Sweetener-tea solutions were mixed, then transferred into pre-labeled 750mL wine bottles, covered and stored overnight (4°C). Sweetener-tea solutions were poured into color-coded sample cups (2 oz. plastic; Solo brand) with caps prior to testing.

2.2 Participant recruitment & pre-screening study

Virginia Tech (VT) Institutional Review Board (IRB) approval was obtained prior to beginning the study. Informed consent and consent for the video recording were obtained prior to data collection. Recruited panelists were screened based on consumption of tea beverages (invited participants consumed tea on a weekly basis or greater), use of various sweeteners (invited participants reported using either “natural” or “non-nutritive” sweeteners with beverages) and facial features (facial hair, glasses) that might interfere with video capture for facial expression analysis. A preliminary video trial was used to evaluate participant (n=65; 47 females) adherence to training instructions to limit risk of failed video. All captured videos were

run through the automated facial expression software program (FaceReader 5.0™, Noldus Information Technology, Wageningen, The Netherlands) and assessed for video success. Thirty-one individuals (Virginia Tech students, faculty, staff and community members; age range 20-60: 72% female) were invited to continue in the study.

2.3 Experimental cross-over design

On each testing day (n=2), participants completed two sessions. Sessions were divided based on sweetener category (natural; artificial) and the emotional collection tool used (video capture of facial expression response, FER; emotional term selection, ETS) (Figure 1). Video capture of their face occurred in the first session of the evaluation on each day. In the second evaluation session, participants characterized their emotional response by selecting emotional terms from a check-all-that-apply (CATA) list. In each session, participants tasted and rated overall acceptability of tea-sweetener samples (2 artificial + sucrose; 2 natural + sucrose; 6 samples each day; total of 12 samples over a 2-day testing period) on a 9-point hedonic scale (1= dislike extremely; 5= neither like nor dislike; 9= like extremely). The order of natural and artificial sweetener sessions was reversed on the second day.

2.4 Experimental environment, testing sequence & data management

2.4.1 Session 1: FER & sweetener acceptance

In order to best control and standardize FER video capture, one sensory booth was used for all participants; each participant was scheduled with individual sessions. White lighting in the booth and incidental lighting from overhead lights and from the booth's touch screen monitor illuminated the face. A webcam (Microsoft 2.0 megapixel LifeCam NX-6000, Redmond, WA),

attached to the bottom of the touch screen monitor, was positioned for each participant to best capture the face; the webcam was connected to a laptop (Latitude Essio, Dell, Inc., Round Rock, TX) on the researcher side of the hatch. This also allowed the researcher to provide further instructions to ensure better video capture, as suggested by Arnade (2013). The webcam was preset to capture 30 frames/sec with set frame dimensions (640w x 480h) while recording; video recording began at the start of each testing session and captured the entire first session of each testing day using Microsoft Movie Maker (2011). Videos were saved as Windows media video (.wmv) files.

During the first testing session, the participant was seated in the booth and presented simultaneously with a water sample (Drinking water, Kroger brand, Cincinnati, OH) and 3 color-coded sweetened tea samples. While being video recorded, they first tasted the water sample in order to elicit a neutral emotional response, which established a video baseline. The expectation was that this preliminary water tasting would help to reduce as much “emotional” noise as possible and give the researcher a standard response from each panelist. The remaining three samples (two sessions per day; two days) were randomized in a balanced complete block design. Panelists were not informed which sweeteners were used in each sample or the ‘sweetener category’ used in each session. Each panelist evaluated samples under white lighting, from left to right; water and unsalted soda crackers were provided to cleanse the palate between samples.

Panelists held up a uniquely colored index card (placed on top of each sample and coded for samples specific to a category), prior to tasting, to provide a video record of the sample being evaluated. Panelists were instructed to take the whole sample (30mL) into their mouth, swallow and sit for a “wait period” of 30 sec, which was programmed into the management software (Sensory Information Management System, SIMS; version 6, Sensory Computer Systems,

Berkeley Heights, NJ). This ensured that the amount of time allotted for panelists to respond emotionally was the same per sample. Acceptability scores (1= dislike extremely; 5= neither like nor dislike; 9= like extremely) were collected via touchscreen monitor and the data was stored on the computer server until completion of the study at which point all responses were transferred to an electronic data spreadsheet (Microsoft Excel, Microsoft Corporation, Inc., Redmond, WA) for further analysis.

All video files were batch analyzed using the facial expression analysis software with continuous face calibration setting, which is one of three (default, continuous, & individual) calibration settings (FaceReader 5.0™, Noldus Information Technology, Wageningen, The Netherlands). The goal is to reduce variation for each elicited emotion across participants. The default setting utilizes an internal software library with which to base the mean intensities for each emotion. In contrast, both continuous and individual settings actively eliminate participant bias by applying a correction factor while running the analysis; however the individual calibration requires a “baseline” image/video (minimum of 10 secs) for all participants in order to remove personal bias(es). Unpublished results from our lab group suggest that the continuous setting produces a higher sensitivity in determining emotional response differences than the Version 5.0 software default setting and is less involved than the individual calibration setting. Each recording was then event marked for a period of 5 sec post-consumption, based on when the hand holding the sample cup fell below the chin, in order to identify the relevant data for all samples (including water; 8 total per panelist). Log files for each panelist were exported and compiled into an electronic spreadsheet for further analysis. R code (R 3.1.1, R Core Team, 2014) was created to identify and extract the desired facial expression data for each sample per panelist for statistical analysis. Facial expression data for water was analyzed as a ‘sample’ in

comparison to the sweetened tea samples in each category and also as a baseline, where its post-consumption mean was subtracted from the other mean samples using R.

2.4.2 Session 2: ETS & sweetener acceptance

Immediately following the first session, panelists were guided into a separate room and directed to a seat with a trifold board to simulate a sensory booth. Upon arrival, participants completed 2 questionnaires (a demographic and beverage intake questionnaire; Hedrick, Comber, Estabrooks, Savla, & Davy, 2010), given only on the first testing day.

All participants were presented with one water sample and three color-coded tea-sweetener samples under white florescent lighting. Samples were presented at the same time and participants were asked to evaluate each color coded sample one at a time from left to right, consuming water and unsalted soda crackers (Kroger brand, Cincinnati, OH) between each to cleanse the palate. Immediately following consumption of the sweetened tea samples, panelists were directed to rate their acceptability score at the top of the modified EsSense[™] paper ballot (King & Meiselman, 2010) and select all applicable emotional terms from the list of 43 provided (38 of the original 39 terms used). One term (glad) was removed due to its similarity in meaning to the term “happy” and five terms (angry, content, fearful, sad and safe) were added to the ballot that more directly correlate to the emotions represented in the facial expression software program. All panelist demographic, hedonic and emotion term data from session 2 was recorded.

2.5 Statistical analyses

2.5.1 Sweetener acceptance

Mean hedonic scores for each sweetener within both categories (natural; artificial) and data collection tools (facial expression; CATA emotional term list) were calculated (Microsoft Corporation, Inc., Redmond, WA). Distribution normality was tested using the Shapiro-Wilk goodness-of-fit test (JMP *vs* 9.2, SAS, Cary, NC) for each sweetened tea sample. Nonparametric one-way analyses of variances (ANOVAs) using the Kruskal-Wallis test were conducted (JMP *vs* 9.2, SAS, Cary, NC) to determine differences ($p < 0.05$) among mean hedonic scores within each sweetener category for both collection methods.

2.5.2 Facial expression response

Emotion intensity means, each scaled 0-1 (0=not expressed; 1=fully expressed) for all participants and samples, 5 sec post-consumption, were generated from FaceReader™ output using R. Repeated one-way ANOVAs were conducted within emotion state (sad, surprised, happy, scared, angry, disgusted and neutral), across sweeteners (water, sucrose, HFCS, honey, ace-k, and sucralose) and within sweetener, across emotions using Tukey's HSD multiple comparison of means in R. Significance was determined with critical values less than 0.05. The relationship between mean facial expression intensity values of emotions and hedonic score (liking) for each sweetened tea sample was evaluated using a liner regression analysis (JMP SAS, Cary, NC). Coefficients of determination (R^2 values) were found and used to obtain correlation values (R values) within each sweetener category.

The time series data for each emotion were collected at 20Hz. The start times for each sample were adjusted to zero, t-tests, paired by panelist, evaluated the mean difference for each emotion at each time step (Spivey, Grosjean & Knoblich, 2005) between the sweetener and water over the 5 sec interval. Signs of the mean difference (sweetener – water, data not shown) were

used to evaluate whether the sweetener or water had the stronger emotional response. P-values (Figures 2 and 3) were used to evaluate statistical significance ($p < 0.05$) and duration of emotional differences.

2.5.3 Emotional term selection

Count frequencies for each emotion term (43 total) were calculated for all sweeteners in both categories (natural; artificial). Terms selected with 20% frequency or more for at least one sweetener-tea sample were classified as “frequently selected” (Arnade, 2013); These terms were graphed to compare for overall similarities and differences. “Shared” terms across sweetener comparisons were identified from frequently selected terms and had less than 8% difference between sample frequencies. “Unique” terms exhibited greater than 20% selection frequency for one sample and greater than 10% difference in frequency between two sweeteners. Penalty-lift analysis (Meyners, Castura & Carr, 2013) and a Cochran’s Q test for significance ($\alpha = 0.05$) were used to assess the significance of frequently selected terms and the relationship to mean hedonic scores within each sweetener category.

3. Results and Discussion

There are a number of physiological (taste) and neurological (perception/cognition, emotion and memory/expectation) processes involved when capturing consumer acceptance and response to food products. This creates a complex problem when measuring implicit and explicit emotions. From a biological perspective, research studies have shown that nutritive and non-nutritive sweeteners activate the same taste receptors (T1Rs) on the tongue (Birch, 1987; Nelson, Hoon, Chandrashekar, Zhang, Ryba & Zuker, 2001; Li, Inoue, Reed, Hugue, Puchalski, Tordoff,

Ninomiya, Beauchamp, & Bachmanov, 2001; Li, Staszewski, Xu, Durick, Zoller & Adler, 2002). While little individual variation in the ability to detect sweet taste may exist, Nie, Vignes, Hobbs, Conn & Munger (2005) showed evidence that non-nutritive sweeteners may bind to taste receptors with a higher affinity than their nutritive counterparts. Neurological studies suggest that the pleasantness/reward system in the brain differs across sweetener types (Frank, et al., 2008) and frequency of consumption for an individual (Green & Murphy, 2012).

These physiological responses, in conjunction with many social, environmental and psychological factors, influence the emotional processing of food products in the brain (Cardello, 1994; Gibson, 2006). The characterization of individual emotional responses can differ greatly depending on the type of measurement (verbal, nonverbal) used. We attempted to address these differences by collecting implicit emotions through facial expression responses and cognitive responses through acceptance as well as explicit emotions through a verbal check-all-that-apply ballot.

3.1 Acceptability of sweeteners in tea

It has been well established that imparted sweetness via sucrose or alternative sweeteners is inherently acceptable and elicits positive emotions across cultures and ages (De Graaf & Zandstra, 1999; Greimel, Macht, Krumhuber, & Ellgring, 2006; Rozin & Vollmecke, 1986; Steiner et al., 2001); water has also been shown to produce neutral emotions via facial expressions (Steiner, 1979; Steiner et al., 2001). This general acceptance can be altered when sweeteners are added to a more complex beverage such as black tea, which is characterized by bitter flavors from the effects of nonvolatile and volatile compounds extracted from tea leaves during brewing (Balentine, Wiseman, & Bouwens, 1997). Results showed that most sweetened

tea samples were well liked with acceptability scores falling between “like slightly” to “like moderately.” Any influence on acceptability due to the imparted bitterness from tea was assumed to be consistent across all sweeteners.

Honey and ace-k had mean values significantly lower ($p < 0.05$) than sucrose with scores falling between “dislike slightly” to “neither like nor dislike” (Table 2). Lower acceptability in honey was unexpected since it is among the oldest sweetening agents (White, 1978) and is generally added to tea-based beverages. Data suggests that there were two participant user groups (honey users and non-users); left skews were observed for all other sweetened samples in both sessions. Hedonic scores for all samples were not normally distributed. Lowered acceptability of ace-K was not unexpected due to its association with bitter flavor, which is generally viewed as an inherently aversive taste (Fischer, Griffin, England, & Garn, 1961; Rozin & Vollmecke, 1986). We speculated that bitter flavor may have been compounded by the combination of ace-K and tea, resulting in lowered acceptance.

Panelist reliability is suggested by sucrose (control) comparisons ($p > 0.05$) within and across categories (natural; artificial) (Table 2). No differences ($p > 0.05$) existed between mean scores of each alternative sweetener across the two sessions (FER; ETS), further supporting panelist reliability. We concluded that any differences in liking for alternative sweeteners were attributed to other factors such as sweetener flavor profile, consumer perception and/or emotions.

3.2 Characterizing explicit emotional responses to sweeteners in tea

In order to distinguish differences among those factors, frequently selected verbal emotion responses were identified for each sweetener type. A similar proportion of emotion

terms, approximately 40% (17-18 out of 43 terms), were classified as frequently selected in both sweetener categories (natural; artificial). Reported differences across categories were demonstrated when comparing the two sucrose (control) samples, which shared only six terms across both sessions (Figure 2a). Three shared terms (good-natured, peaceful, pleasant) were identified among the natural sweeteners. Five shared terms (content, friendly, good, pleased, quiet) were identified among the three sweeteners in the artificial session. Two terms differentiated honey (disgusted, $p=0.002$; mild, $p=0.028$) based on Cochran's Q test (Figure 2b). In addition, based on our pre-defined category of "unique", the term good was selected more frequently for HFCS and steady was selected more frequently for honey compared to sucrose; the term bored was selected more for ace-k and good-natured was selected more for sucralose compared to sucrose. These results further support the hedonic score data, which showed a significant decrease in liking for honey in the natural category.

Penalty-lift results in this study showed that two terms, bored (ranging between -0.27 and -1.64) and mild (ranging between -0.19 and -0.81) had negative penalty towards hedonic scores when selected for sweeteners in both categories (Figure 3). In the natural category, the negative penalty was driven by sucrose and honey, respectively. One additional term, disgusted (-2.37), showed a high negative penalty only for the natural category and was uniquely associated with honey.

A majority of the terms in the natural category (9 out of 14 positive terms) showed minimal positive mean differences, with ranges between 0 and 1, while a majority of the terms (10 out of 15 positive terms) showed higher positive differences (1-1.5 range) for the artificial category (Figure 5). The highest positive differences for sweeteners were seen in the terms pleased (1.22) and happy (1.20) in the natural session, and pleased (1.67) and good (1.53) in the

artificial session (Figure 3). Interestingly, both pleased and happy were driven by sucrose and HFCS in the natural session, as neither term was frequently selected for honey. The positive penalty makes sense when comparing it to the hedonic scores of these sweeteners.

Previous studies investigating the relationship between product acceptability and emotion scores (King & Meiselman, 2010; Porcherot, Delplanque, Raviot-Derrien, Le Calve, Chrea, Gaudreau, & Cayeux, 2010) have conflicting results. In a study conducted by King and Meiselman (2010), consumers categorized specific terms associated with the eating experience into one of three groups: positive, negative or unclear. Correlations between overall liking and positive or negative terms were shown; however when examining product differences, acceptability and emotion score data was variable. Similar conclusions can be drawn from results in this study. In general, liked sweeteners (sucrose, HFCS, sucralose) were associated with neutral to positive terms, while neutrally liked to disliked sweeteners (honey and ace-k) were uniquely associated with negative terms. Evidence for these conclusions were supported by the Cochran's Q test as well as penalty lift results. It is interesting to note that emotion term selection patterns elicited by artificially categorized sweeteners were more closely related than that of their nutritive counterparts (Figure 2b & 2c).

Studies investigating the linguistic relativity theory (Whorf, 1956) have shown that the ability to detect and perceive emotions within oneself can be greatly influenced by language (Gendron, Lindquist, Barsalou & Barrett, 2012; Lindquist, Barrett, Bliss-Moreau, & Russell, 2006). This evidence suggests that there was potential for participant response bias due to the unbalanced nature of positive (34) and negative (9) emotion terms used in the CATA ballot. Furthermore, panelists were not trained in their understanding of the emotion words and could have easily misinterpreted term meaning(s) or selected specific terms as way of post-

rationalizing an affective experience to a sweetener. In this way, the emotional response may have been misdirected due to the prompted emotional terms on the ballot. Another limitation of the CATA ballot used in our study included an alphabetical order and position of terms, which may increase potential for certain terms to be selected over others because of positioning in the sequence (King, Meiselman, & Carr, 2013). In addition, the CATA format reduces the number of terms selected compared to a rating scale format (King, Meiselman, & Carr, 2013). Testing a product under different contexts may also influence emotional term profile.

3.3 Characterizing implicit emotional responses to sweeteners in tea. It is debated whether affect precedes cognition or vice-versa and what role emotions play in the decision making process (Zajonc, 1980). ANS (automatic nervous system) responses, such as facial expressions, are believed to capture subtle discrepancies in emotion that are otherwise missed when participants self-report. Pleasant affective responses to stimuli have been shown to elicit specific action unit facial movements (“Cheek raiser” and “lip corner puller”), which uniquely correspond to “happy” (Ekman, Friesen, & Ancoli, 1980; Kohler, et al., 2004). As such, it was believed that sweeteners with higher hedonic scores would glean higher mean intensities for “happy” and lower mean intensities for “disgust” with the opposite being true for disliked sweeteners (ace-k and honey).

No statistical ($p>0.05$) differences were seen within emotion across any sweetener samples in their respective categories (Tables 3, 4). Repeated one-way ANOVAs within samples (in each category separately) across each of the 6 emotions (sad, surprised, happy, scared, angry and disgusted) and neutral state did show some statistical differences ($p<0.05$) suggesting small (weak) differences in overall response. A similar intensity pattern (ordered highest to lowest) for

the six basic emotions and neutral was revealed; neutral was elicited with the highest intensity, followed by sad for all sweeteners. Coefficients of determination were very small and showed little to no correlation between emotions and hedonic score (liking).

The lack of significant correlations between emotional response and hedonic score (liking) was unexpected. A study conducted by de Wijk et al. (2012), showed significantly higher facial expression responses upon seeing and tasting disliked foods when compared to liked foods. Results suggesting negative emotions are more intensely expressed with disliked samples, while samples falling somewhere between neutral and positive on the liking scale are more likely to elicit smaller degrees of positive emotion; these findings were supported by previous work of Danner et al. (2013), Danner et al. (2014), Wendin, Allesen-Holm, & Bredie (2011) and Zeinstra, Koelen, Colindrews, Kok, & de Graaf (2009). These conclusions were not fully supported by mean results from this study. It has also been suggested that happy is rarely expressed through facial expressions outside of social settings (De Wijk, He, Mensink, Verhoeven & De Graaf, 2014; Parkinson, 2005).

One proposed explanation involving the low emotional mean intensity responses to sweet taste in tea (and water) is that the inherent acceptance and habitual consumption of sweetened products in general is related (Leterme, Brun, Dittmar, & Robin, 2008). Other studies examining ANS responses to basic tastes found that sucrose elicited weaker responses overall using the six basic emotions compared to the other tastes and especially bitter (Robin, Rousmans, Dittmar, & Vernet-Maury, 2003; Rousmans, Robin, Dittmar, & Vernet-Maury, 2000).

Another potential explanation for the lack of differences was the high variation in emotional response across all panelists for one sweetener and within individual panelists across all sweeteners. This variation could be due to differing responses from the reward system in the

brain associated with sweetener consumption patterns across individuals as suggested by Green & Murphy (2012). Danner et al. (2013) attributed high variance in facial expressions to unnatural laboratory settings. Environmental factors such as poor lighting conditions, unoptimized camera angles and partial face occlusion may have contributed to poor video capture resulting in response variation. Kotsia, Buciú & Pitas (2008) found supporting evidence stating that partial occlusion of the mouth especially affects the interpretation of anger and fear emotions, whereas partial eye occlusion affected disgust and surprise.

Other studies have proposed using baseline measures such as water or neutral facial expression (Garcia-Burgos & Zamora, 2015) to eliminate individual biases. Calculated mean intensity scores, using neutral as a correction factor against other emotions, showed lack of robust differences across sweeteners in our study. Further exploration of panelist to panelist facial expression variance is needed, although it has been suggested that neutral state may not be the best measurement when making comparisons (Somerville, Kim, Johnstone, Alexander & Whalen, 2004).

Differences in expressed intensity and sequence of emotions across sweeteners in relation to the 5 sec post-consumption time period were observed when compared to a water baseline (Figures 4, 5). Between 1 and 2.5 sec post-consumption, there appeared to be significant differences ($p < 0.05$) in expressivity of disgust (withdrawal emotion) for the water-sucrose (natural session) comparison and the water-honey comparison (Figure 4). Both sweeteners (sucrose, honey) appeared to elicit less disgust than water, evidenced by the disgust curves (Figures 4b, 4c) falling below the dotted significance line ($p = 0.05$). Sucrose exposure appeared to elicit a significantly higher amount of the negative emotion anger (as identified by AFEA) than water for approximately 2 sec post-consumption (1.5-2.5 sec; 3.5-4 sec). [The identification](#)

of anger in this context is difficult to explain and was not supported by selection of the emotional term. Further research will be needed to determine if this is an anomaly or a true emotional response. No significant differences between HFCS and water were observed, although spikes in two emotions (disgust & sad) appeared at similar times in relation to trends for sucrose and honey, suggesting similar emotion response within the sweetener category (Figure 4). Similar to findings in the verbal questionnaire, natural sweeteners elicited less emotions and at lower intensities over the set time period than sweeteners in the artificial category.

Three approach emotions (angry, happy and surprised) stood out as having observed intensity and time differences ($p < 0.05$) across all artificial sweetener-water comparisons (Figure 5). Expression of surprised had the highest intensity with apparent significance beginning around 1 second post-consumption for all three; however, differences exist across sweeteners when interpreting elicited surprise in comparison to water. Sucrose exposure appeared to elicit less surprise in general than water, but especially so between 1.5 and 3.5 sec post-consumption (Figure 5). Both alternative sweeteners appeared to elicit more surprise than water, but at different time frames; significance for ace-k occurred around 1 second post-consumption, whereas significance for sucralose occurred between 2 and 3 sec post-consumption (Figure 5). Sequencing for elicitation of happy were similar for sucrose and ace-K, occurring around 3-4 sec post-consumption, whereas sucralose elicited happy within the first second (Figure 5). Anger was elicited at differing times across sweeteners and at minimal intensities.

Overall, significant differences ($p < 0.05$) for expressed approach emotions only occurred when comparing artificial sweeteners (and sucrose) to water, which we used as our control (Figure 5); significance for expressed withdrawal emotions only occurred when comparing sweeteners from the natural category to water (Figure 4). It is important to reiterate that

participant variance was very high. Spikes indicating significance were most likely due to false positives or major changes (drops/additions) in participant number due to sample pooling. The time series method of analysis has the potential to benefit interpretations of micro emotions elicited from food by adding the additional piece of information regarding time to baseline comparisons; however, over interpreting the results is a risk.

4. Conclusions

The focus of this study was to explore whether differences in expressed emotions (implicit and explicit) exist among similar products and whether they are related to overall liking. Results showed that more emotions (and the intensity of each) were expressed by panelists due to artificial sweeteners than natural sweeteners, regardless of overall liking or the explicit/implicit tool utilized. Differentiation in liked versus disliked sweeteners (within categories) was found when using verbal responses but not facial expressions. While self-report emotion term questionnaires have begun to aid companies in understanding consumer acceptability and associated emotions, it is believed that facial expression analysis may aid in finding rapid, uncontrollable micro emotion responses that influence liking and preferences.

Limitations still exist in regards to panelist variation and AFEA software sensitivity during video capture; optimization of environmental settings is key. Exploring emotion patterns elicited by varying stimuli over time may provide additional value in understanding uncontrollable micro emotions in relation to verbal expressions of emotion and acceptability. Future research in the area of automated facial expression analysis should focus on finding subtle

differences in emotion expression by product users and how/if those differences are related to product successes rather than failures in the marketplace.

5. Acknowledgments

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745

746 ***Table 1. Final alternative sweetener concentrations established to be sucrose-equivalent***

Category	Sweetener	Concentration (g/mL)
Control	Sucrose	0.05
Natural sweeteners	HFCS	0.085
	Honey	0.062
Artificial sweeteners	Ace-K	2.6×10^{-4}
	Sucralose	9.5×10^{-5}

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748

Table 2. Mean hedonic scores¹ for natural and artificial sweeteners in cold tea

Natural Session								
Sweetener	Mean	FER²			Mean	ETS²		
		SD	95% CI	Median		SD	95% CI	Median
Sucrose	6.7 ^{aA}	1.2	6.3-7.2	7.0	6.4 ^{aA}	1.4	5.9-6.9	7.0
HFCS	6.5 ^{aA}	1.1	6.1-6.9	6.0	6.1 ^{aA}	1.4	5.6-6.6	6.0
Honey	5.5 ^{bA}	1.6	4.9-6.1	5.5	4.7 ^{bA}	1.6	4.1-5.3	4.0
Artificial Session								
Sweetener	Mean	FER²			Mean	ETS²		
		SD	95% CI	Median		SD	95% CI	Median
Sucrose³	6.8 ^{aA}	1.3	6.3-7.3	7.0	6.6 ^{aA}	1.4	6.1-7.1	7.0
Ace-K	5.9 ^{bA}	1.3	5.4-6.4	6.0	5.3 ^{bA}	1.9	4.6-6.0	6.0
Sucralose	6.5 ^{abA}	1.6	5.9-7.1	7.0	6.3 ^{aA}	1.7	5.7-6.9	7.0

^{a, b, c} Means in each sweetener row and session category column (natural; artificial) with different letters are significantly different across treatments at p<0.05.

^{A,B} Means in each sweetener row with different letters are significantly different within treatments at p<0.05.

¹n=30; 1= extremely dislike; 9= extremely like.

²Sessions: FER= Facial expression response session; ETS= Emotional term selection session.

³Artificial sweetener session included sucrose as the standard control.

761

762 **Table 3. Mean emotional intensity values¹ within water (baseline) and natural sweeteners² in**
 763 **cold tea**

Emotion	Water	Sucrose	HFCS	Honey
Neutral	0.555 ^{aA}	0.553 ^{aA}	0.546 ^{aA}	0.557 ^{aA}
Sad	0.176 ^{bA}	0.174 ^{bA}	0.166 ^{bA}	0.176 ^{bA}
Surprised	0.057 ^{cA}	0.063 ^{cA}	0.069 ^{bcA}	0.049 ^{cA}
Happy	0.026 ^{cA}	0.027 ^{cA}	0.030 ^{cA}	0.049 ^{cA}
Scared	0.028 ^{cA}	0.018 ^{cA}	0.021 ^{cA}	0.011 ^{cA}
Angry	0.006 ^{cA}	0.009 ^{cA}	0.008 ^{cA}	0.007 ^{cA}
Disgusted	0.001 ^{cA}	0.001 ^{cA}	0.005 ^{cA}	0.003 ^{cA}

764 ^{a, b, c} Means within each column with different letters are significantly different at p<0.05.

765 ¹(n=30); Mean intensity values (0-1; 0= not expressed; 1= fully expressed) based on 5 second
 766 video analysis of facial response (FaceReader 5.0, Noldus Information Technology,
 767 Wageningen, The Netherlands) post-consumption of each sample on testing “Day 1” session.

768 ²High fructose corn syrup (HFCS) and honey were added at equi-sweet concentration to 5%
 769 sucrose (w/w).
 770
 771

772

773 **Table 4. Mean emotional intensity values¹ within water, sucrose, and artificial sweeteners² in**
 774 **cold tea**

Emotion	Water	Sucrose	Ace-K	Sucralose
Neutral	0.568 ^{aA}	0.569 ^{aA}	0.599 ^{aA}	0.562 ^{aA}
Sad	0.138 ^{bA}	0.132 ^{bA}	0.106 ^{bA}	0.135 ^{bA}
Surprised	0.048 ^{bcA}	0.111 ^{bA}	0.083 ^{bcA}	0.100 ^{bcA}
Happy	0.057 ^{bcA}	0.040 ^{bcA}	0.061 ^{bcA}	0.046 ^{bcA}
Scared	0.045 ^{bcA}	0.020 ^{cA}	0.012 ^{cA}	0.034 ^{bcA}
Angry	0.003 ^{cA}	0.009 ^{cA}	0.010 ^{cA}	0.009 ^{cA}
Disgusted	0.002 ^{cA}	0.002 ^{cA}	0.005 ^{cA}	0.002 ^{cA}

775 ^{a, b, c, d} Means within each column with different letters are significantly different at p<0.05.

776

777 ¹(n=29); Mean intensity values (0-1; 0= not expressed; 1= fully expressed) based on 5 second
 778 video analysis of facial response (FaceReader 5.0, Noldus Information Technology,
 779 Wageningen, The Netherlands) post-consumption of each sample on testing “Day 2” session.

780 ²Ace-k and sucralose were added at equi-sweet concentrations to 5% sucrose (w/w).

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796 List of Figures.

797

798 Figure 1. Cross-over experimental design. Videos of implicit facial expression response data
799 were captured immediately after consumption and prior to explicit hedonic score data in FER
800 session; as such, the first task panelists were asked to complete was the hedonic score for each
801 sweetener upon consumption in both sessions.

802

803 Figure 2. Comparison of frequently selected emotion terms from emotion term selection sessions
804 for sweeteners in cold tea; (a) sucrose in natural and artificial sessions; (b) natural session; (c)
805 artificial session. (n= 30) The displayed emotion terms (23/43) were selected based on a 20% or
806 greater selection frequency for at least one of the samples being compared. Terms were ordered
807 clockwise alphabetically. Shared terms, having 20% or greater frequency among samples and a
808 difference equal to or less than 8% are denoted with an asterisk.

809

810 Figure 3. Penalty-lift analysis for natural & artificial sweeteners in cold tea
811 (n= 62 total observations; n= 31 for natural sweeteners; n= 31 for artificial sweeteners).
812 Differences in mean acceptability scores for all sample conditions were found for the ‘frequently
813 selected’ terms (>20% selection; natural: 18 terms; artificial: 17 terms) and between participants
814 who selected and did not select the term.

815

816 Figure 4. Time series analysis (5 seconds) of emotions from facial expression analysis session,
817 comparing natural sweeteners to water baseline. Emotions with extended duration below the
818 dotted line ($p < 0.05$) are different from emotions elicited by water. (a) high fructose corn syrup;
819 (b) honey; (c) sucrose.

820

821 Figure 5. Time series analysis (5 seconds) of emotions from facial expression analysis session,
822 comparing sucrose (control) and artificial sweeteners in cold tea to water baseline. Emotions
823 with extended duration below the dotted line ($p < 0.05$) are different from emotions elicited by
824 water. (a) acesulfame k (Ace-K); (b) sucralose (SL); (c) sucrose (S);.

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