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Abstract: With an increasingly competitive global market, understanding consumer emotional response to products can provide a different perspective to identify drivers of consumer food choice behaviour beyond traditional hedonic measurement. This study investigated how two taste phenotypes (Thermal taster status (TTS) and PROP taster status (PTS)) impacted liking and emotional response to beers varying in bitterness, carbonation and serving temperature. Volunteers (n = 60, balanced for TTS and PTS) were invited to express their liking and emotional response to 2 commercial beers of contrasting bitterness, presented at two different carbonation levels (commercial carbonation and low carbonation level) and served at two temperatures (cold and ambient). In general, when beers were served at their commercial carbonation level and at a cold temperature, they received higher liking scores and evoked more positive emotions and less negative emotions. Signficant temperature*carbonation interactions were found for liking and some emotion categories. At commercial carbonation levels, cold beer was better liked and evoked more positive emotions than beer served at ambient temperature, but no such temperature effect was observed at the low carbonation level. Although the sample size is relatively small, significant effects for liking were observed for PTS but not TTS, suggesting PTS is a more influential factor regarding liking than TTS. However, thermal tasters (TT) rated 6 out of 10 emotion categories significantly higher for beer than thermal non-tasters (TnT), indicating emotional response may be more sensitive to capture the differences across taste phenotypes than liking, and that TT show increased negative emotions to beer in general. PROP supertasters (ST) rated some emotion categories significantly higher than non-tasters (NT) and, in contrast to TTS these were the more positive emotions, such as excited and content. This is the first study to report an impact of both TTS and PTS on emotional response. Furthermore, this study observed significant relative effects of TTS and PTS on emotional response, where the effect of PTS was more pronounced in TnT. This highlights the importance of investigating the combined effects of different phenotypes on consumer response representing the reality of different consumer segments.

The impact of PROP and thermal taster status on the emotional response to beer

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Abstract

With an increasingly competitive global market, understanding consumer emotional response to products can provide a different perspective to identify drivers of consumer food choice behaviour beyond traditional hedonic measurement. This study investigated how two taste phenotypes (Thermal taster status (TTS) and PROP taster status (PTS)) impacted liking and emotional response to beers varying in bitterness, carbonation and serving temperature. Volunteers (n = 60, balanced for TTS and PTS) were invited to express their liking and emotional response to 2 commercial beers of contrasting bitterness, presented at two different carbonation levels (commercial carbonation and low carbonation level) and served at two temperatures (cold and ambient). In general, when beers were served at their commercial carbonation level and at a cold temperature, they received higher liking scores and evoked more positive emotions and less negative emotions. Signficant temperature*carbonation interactions were found for liking and some emotion categories. At commercial carbonation levels, cold beer was better liked and evoked more positive emotions than beer served at ambient temperature, but no such temperature effect was observed at the low carbonation level. Although the sample size is relatively small, significant effects for liking were observed for PTS but not TTS, suggesting PTS is a more influential factor regarding liking than TTS. However, thermal tasters (TT) rated 6 out of 10 emotion categories significantly higher for beer than thermal non-tasters (TnT), indicating emotional response may be more sensitive to capture the differences across taste phenotypes than liking, and that TT show increased negative emotions to beer in general. PROP supertasters (ST) rated some emotion categories significantly higher than non-tasters (NT) and, in contrast to TTS these were the more positive emotions, such as *excited* and *content*. This is the first study to report an impact of both TTS and PTS on emotional response. Furthermore, this study observed significant relative effects of TTS and PTS on emotional response, where the effect of PTS was more pronounced in TnT. This highlights the importance of investigating the combined effects of different phenotypes on consumer response representing the reality of different consumer segments.

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1. Introduction

Since their development in the 1950s, hedonic measures (Peryam & Haynes, 1957; Peryam & Pilgrim, 1957) have been widely used to help food and beverage manufacturers predict and compare how commercially successful their products are, or are going to be (O'Sullivan, 2017). However, in today's competitive markets, hedonic measurement alone may not be enough in terms of evaluating product associated experiences (King & Meiselman, 2010; Ng, Chaya, & Hort, 2013).

The study of the emotional responses evoked by food and beverage products has grown rapidly over the last decade (Meiselman, 2015). Emotions can be elicited by the food itself, as well as other factors such as the food experience and memories that are associated with a particular food (King, 2016). A number of studies have shown that measuring product-oriented emotion can provide additional useful information beyond liking, as emotional items have been shown to be more discriminating than liking on blackcurrant beverages (Ng et al., 2013), beer (Chaya, Eaton et al., 2015), spices (King, Meiselman, & Thomas Carr, 2013) and hazelnut and cocoa spreads (Spinelli, Masi, Zoboli, Prescott, & Monteleone, 2015).

In order to quantify emotional response elicited by food and beverages, several self-reported questionnaires have been developed. These commonly comprise of a lexicon that varies in the nature of the emotion items and number (Cardello & Jaeger, 2016). The emotions that consumers experience during consumption of food can be either rated (unstructured line scale or labelled category scale) or checked (check-all-that-apply (CATA)) or ranked (best-worst-scaling). The EsSense Profile (King & Meiselman, 2010) and EsSense 25 (Nestrud, Meiselman, King, Lesher, & Cardello, 2016) were developed for a broad application to a wide variety of food and beverages. However, consumer defined emotion lexicons have been developed for specific products such as fruit salad (Manzocco, Rumignani, & Lagazio, 2013), blackcurrant beverages (Ng et al., 2013), coffee (Bhumiratana, Adhikari, & Chambers IV, 2014), beer (Chaya et al., 2015) and wine (Danner et al., 2016) to ensure the emotion terms used are relevant for the product category.

In the field of sensory and consumer science how sensory properties link to consumer emotional response has been a focus of research. Thomson, Crocker, and Marketo (2010) identified a relationship between sensory properties and consumer conceptualisations reporting that, for dark chocolate for example, cocoa flavour is associated with emotion terms *powerful* and *energetic* and bitter is associated with *confident*. Ng et al. (2013) reported that for blackcurrant beverages, positive emotions were associated with 'natural sweetness' as opposed to artificial sweetness. Within the beer category, studies have also identified sensory properties associated with emotional response elicited by beer (Beyts et al., 2017; Chaya, Pacoud, Ng, Fenton, & Hort, 2015; Dorado, Chaya, Tarrega, & Hort, 2016; Eaton, 2015). Dorado et al. (2016) found that temperature was associated with *shocked* emotion in beer, where warmer beer was rated as inducing more *shocked* emotion in a set of commercial lagers. Eaton (2015) investigated the emotional response to a range of lager beers including commercial products and spiked beer samples that varied in a broad range of sensory properties, and found that bitter beers were associated with *boring* and *underwhelming* emotions, but none of the emotion items investigated were associated with carbonation. However, Chaya et al. (2015) measured emotional response to a similar set of commercial and spiked beer samples with Spanish consumers, and found that low carbonation level decreased ratings of the emotional category *intensity (strong, powerful, intense)*. This indicates that the effect of a sensory property on emotional response, in this case carbonation, may depend on the segment of consumers.

It is well known that sensory perception varies greatly across individuals (Bachmanov et al., 2014; Hayes & Keast, 2011) and so the question arises as to whether individual variation in sensory perception also impacts emotional response. Research has shown that factors such as culture (Eaton, 2015; Silva et al., 2016) and gender (King & Meiselman, 2010) can affect emotional response and recently Kim, Prescott, & Kim (2017) revealed that sweet likers elicited stronger positive emotions when consuming sweeter products than sweet dislikers. PROP taster status (PTS) and Thermal taster status (TTS) are two other taste phenotypes known to affect sensory perception (Bajec & Pickering, 2008; Yang, Hollowood, & Hort, 2014). However, to date, no studies have investigated the effect of TTS and PTS on emotional response elicited by food and beverages.

TTS, discovered by Cruz and Green (2000), is a relatively new taste phenotype. They found that when a small area of tongue is rapidly warmed or cooled, some individuals perceive a taste sensation without any tastants present. Those who perceive a taste are named thermal tasters (TT), and those who do not perceive any tastes from temperature stimulation are named thermal non-tasters (TnT) (Green & George, 2004). Between 20% to 50% of the tested population have been reported as TT, representing a large segment of the population (Bajec & Pickering, 2008; Green & George, 2004; Yang et al., 2014). TT do not only have the ability to perceive a taste from temperature itself, but have also been shown to report heightened responsiveness to some basic tastes such as sweet, bitter, sour and salty (Bajec & Pickering, 2008; Yang et al., 2014) and temperature (both warm and cold) compared to TnT (Bajec & Pickering, 2008; Cruz & Green, 2000; Yang et al., 2014). Recently Hort, Ford, Eldeghaidy, and Francis (2016) reported that TT are more discriminating towards CO_2 levels in carbonated water than TnT. When looking at the impact of TTS on overall liking of beer, wine and a range of food items, TT had an overall increased intensity perception to oral sensations elicited by beer, wine and food items that were predominantly bitter, however this did not translate into differences in overall liking (Pickering, Bartolini, & Bajec, 2010; Pickering, Lucas, & Gaudette, 2016; Pickering, Moyes, Bajec, & Decourville, 2010). A recent study by the same group found no significant difference in intensity ratings of food categories such as raw vegetables, milk products, sweet treats, textured foods and salty snacks. However, TnT gave higher liking ratings than TT for creamy foods (a variety of milks and creams) and what the authors termed 'aversive' foods, as they are dominated by aversive sensations (bitter, sour, and/or astringent), such as broccoli and cranberry juice (Pickering & Klodnicki, 2016). Yang (2015) also found that as product-serving temperature got warmer or colder, TT liked a strawberry flavoured drink significantly less than TnT. Emotional response may give better insights into food choice behaviour than liking (Ng et al, 2013) but to date no study has investigated the impact of TTS on emotional response.

PTS is a well-known taste phenotype that has been studied extensively since the 1930s (Bartoshuk, Duffy, Lucchina, Prutkin, & Fast, 1998; Bartoshuk, Duffy, & Miller, 1994; Delwiche, Buletic, & Breslin, 2001; Blakeslee & Fox, 1932; Yang et al., 2014) and classifies individuals as non-tasters (NT) if they do not perceive PROP to be bitter, medium tasters (MT) if they perceive it to be moderately bitter and supertasters (ST) if they perceive it as extremely bitter whilst holding the same concentration of 6-n-propylthiouracil (PROP) in their mouth (Herbert, Platte, Wiemer, Macht, & Blumenthal, 2014). Many studies have also reported that PROP tasters have a general heightened sensitivity to other bitter compounds (Ly & Drewnowski, 2001), as well as some other tastes such as sweet, salty and sour, compared to NT (Bajec & Pickering, 2008; Yang et al., 2014). Two previous studies have also found that ST rated the intensity of warmness and coldness from a thermode device significantly more intense than NT (Bajec & Pickering, 2008; Yang et al., 2014). Clark (2011) observed that in carbonated water MT most preferred the low carbonation sample and least preferred the high carbonation sample, whereas no clear preferences were found for ST and NT. A number of studies have also found that PTS has an impact on preference of fruits and vegetables that contain bitter elements, as well as on fatty food, sweet food and alcoholic beverages (Drewnowski, Henderson, Hann, Berg, & Ruffin, 2000; Duffy et al., 2004; Keller, Steinmann, Nurse, & Tepper, 2002; Tepper & Nurse, 1997; Ullrich, Touger-Decker, O'Sullivan-Maillet, & Tepper, 2004; Yeomans, Tepper, Rietzschel, & Prescott, 2007). However, there are also studies that failed to find a relationship between PTS and food preference (Catanzaro, Chesbro et al. 2013, Feeney, O'Brien et al. 2014, Deshaware and

Singhal 2017). Whether PTS affects emotional response to beverages is yet to be determined.

Both TTS and PTS appear to play a role in oral sensitivity and could potentially affect food preferences as well as associated emotional response. However, to date, little research has looked into how individual variation affects emotional response to food and beverages. This study aimed to i) investigate the impact of bitterness (beer type), carbonation level and serving temperature on liking and emotional response; ii) investigate the impact of taste phenotype (TTS and PTS) on liking and emotional response to beers varying in bitterness, carbonation level and serving temperature; and iii) investigate the relative effect of TTS and PTS on emotional response elicited by beer.

2. Materials and Methods

2.1. Subjects

This study was approved by the University of Nottingham Medical School Research Ethics Committee and all subjects gave informed signed consent before taking part. Beer consumers, who had previously been screened for TTS and PTS, were recruited from the consumer participant database held at the Sensory Science Centre, University of Nottingham. In total, 60 beer consumers, (average age 31 yrs., range 20-62yrs; 32F, 28M) balanced for TTS and PTS were invited to take part in this study. There were 30 consumers in each TTS category and 20 consumers in each PTS category equally distributed (10 per TTS category) across TTs and TnTs.

Recruitment criteria ensured participants were over 18 years old and drank lager more than once a month. Pregnant women or those who intended to get pregnant were excluded from the study. Participants received an inconvenience allowance for their participation.

2.2. Thermal Taster Status determination

Prior to data collection, participants were trained to use the gLMS scale by writing down their own strongest imagined or experienced sensation on the top of the scale and rating 15 remembered cross-modal sensations such as brightness of a dimly lit restaurant, hearing a nearby jet-plane take off and so on (Bartoshuk et al., 2002). A intra-oral ATS (advanced thermal stimulator) Peltier thermode (16mm x16mm square surface) (Medoc, Israel) was used to warm and cool the tip of the tongue. It was connected to a PATHWAY pain and sensory evaluation system (Medoc, Israel) and controlled using PATHWAY software (version 4, Medoc, Israel). Two temperature trials were used. For the warming trial, the thermode started at 35 ºC, was cooled to 15 ºC then re-warmed to 40 ºC and held for 1 second. For the cooling trial, the thermode started at 35 ºC, was cooled to 5 ºC and held for 10 seconds. The temperature ramp for all trials was 1 ºC/s. Warming trials were applied before cooling trials to avoid possible adaptation from the intense cold sensations (Bajec & Pickering, 2008). Two replicates of both temperature trials were conducted. A break of two minutes was given before proceeding to the next trial to allow the tongue temperature/sensation to return to normal. After each temperature stimulation, participants were instructed to rate the intensity of any sensations they perceived on a gLMS scale. TT were defined as those who perceived any taste sensation from both replicates at either warming or cooling trials, that were rated above 'weak' on the gLMS scale, whereas TnT were defined as those who did not perceive any 'taste' throughout the temperature trials (Green & George, 2004).

2.3. PROP Taster Status determination

0.32mM PROP solution (Sigma Aldrich, UK) was prepared by dissolving PROP in water on a low heat stirring plate. Each subject was instructed to roll a saturated cotton bud that had previously been dipped in the PROP solution (19 ± 2ºC) across the anterior tip of the tongue for approximately 3 seconds. Participants were then instructed to rate its taste intensity at its maximum using a gLMS scale. After a 3 min break and using water to cleanse the palate, the procedure was repeated to collect duplicate ratings. PROP taster status was defined based on mean PROP intensity ratings and the distribution of response across consumers can be observed in Figure 1. NT were defined as those rating below 'barely detectable', MT were those rating above 'barely detectable' but below 'moderate', and ST were those rating above 'moderate' on the gLMS scale following Lim, Urban, and Green (2008).

2.4. Products

Bitterness, carbonation and product serving temperature have previously been shown to associate with emotional responses elicited by beer (Chaya et al., 2015; Dorado et al., 2016; Eaton, 2015), and perception of bitterness, carbonation and temperature have also been shown to vary across TTS and PTS groups (Bajec & Pickering, 2008; Clark, 2011; Hort et al., 2016; Intranuovo & Powers, 1998; Ly & Drewnowski, 2001; Yang et al., 2014). Thus, in this study, two commercial lager beer samples (P1 and P2) of similar age but known to differ predominantly in terms of instrumental (International Bitter Unit (IBU)) and sensory bitterness (Meilgaard et al.,1982) were chosen for this study. Most beers score between 0 and 10 for bitterness on this sensory scale. P1 was a very bitter lager beer (IBU: 39, Bitter score: 7), whereas P2 was a mild lager beer low in bitterness (IBU: 7, Bitter score: 3) (Chaya et al., 2015). P1 had an ABV of 4.4, and P2 an ABV of 4.7. Bitterness was the major overriding sensory difference between the two beers but

P1 was also rated to have more body, and a higher hoppy flavour and astringent aftertaste by a commercial beer panel.

The two beers were each served at two temperatures: cold (4±2 ºC) – the recommended serving temperature for these lager beers, and ambient, representing the higher temperatures that lagers may reach (19±2ºC) in warmer climates (Dorado et al., 2016); and two carbonation levels (their commercial carbonation level (P1 = 2.5vol , P2 = 2.7vol) and a perceivably lower carbonation level). This gave a total of 8 beer samples, as illustrated in Table 1. Beers were provided by SABMiller plc (Woking, UK) and stored in the refrigerator (4 ± 2ºC) until use.

To obtain the different carbonation levels, low carbonation was achieved by preparing the lagers two and half hours before each testing session, and pouring them into a beaker with a stirrer and stirring for an hour. The commercial carbonation level samples were opened and poured into containers with a closed screw cap and served within 2 hours. Ambient beers were left in the kitchen (19±2 ºC) for at least an hour before tasting, and cold beers (4±2 ºC) were served 3 minutes after being taken from a refrigerator. All samples were 15ml, presented in clear universal tubes with a closed screw cap and labelled with random three digit codes.

In order to avoid first order effects (Dorado, Pérez-Hugalde, Picard, & Chaya, 2016; Macfie, Bratchell, Greenhoff, & Vallis, 1989), a dummy sample was served at the beginning of each session. Dummy samples were cold commercial carbonation level samples served 10 minutes after being taken from the refrigerator to provide a mid-range sample. The dummy sample for a particular session (either P1 or P2) was aligned to the type of beer served in that session i.e. if P1 samples were being evaluated then P1 was served as the dummy sample.

2.5. Emotional lexicon

A beer specific emotion lexicon for English consumers, developed by Eaton (2015) following the procedure described in Chaya et al. (2015), was used to measure emotional response. The 10 emotional categories and associated terms used are shown in Table 2. For each emotional category, participants were presented with the list of associated terms. Participants were instructed to read all the associated terms and to rate the overall intensity of each emotional category on a continuous line scale anchored from 'very low' to 'very high' at 10% and 90% of the scale respectively (Figure 2).

2.6. Procedure

Participants were invited to take part in two sensory sessions conducted in individual sensory booths in the sensory lab at the University of Nottingham lasting approximately 30 minutes each. Participants were instructed to refrain from eating and drinking any strong flavoured food for one hour prior to the session. Participants evaluated either P1 or P2 in a session. In the first session, half of the participants evaluated P1, and half evaluated P2. Beer samples were served monadically and followed a randomised balanced design. The dummy sample was always evaluated first (Dorado et al., 2016).

For each sample, participants were instructed to drink half of the sample first and rate how much they liked the beer sample using a Labelled Affective Magnitude (LAM) scale (Schutz & Cardello, 2001). Following the liking ratings, participants were instructed to drink the remaining sample and rate how intensely they felt for each of the emotion categories (Dorado et al., 2016; Eaton, 2015). The presentation order of the emotion categories was randomised across participants but the same order was kept for each consumer (Dorado et al., 2016; King & Meiselman, 2010).

Data were collected using Compusense Cloud (Compusense, Canada). Mineral water (Evian, Danone, France) and unsalted crackers (Rakusen's, UK) were provided for palate cleansing before each sample.

2.7. Data Analysis

Dummy sample data were removed before performing any further data analysis. Ratings on the LAM scale were converted to scores between 0 and 100, whereas ratings for emotion response were converted to scores between 0 and 10. An outlier analysis with boxplots was performed for each emotion category and liking, and no outliers were identified.

In order to examine the impact of bitterness (beer type), carbonation level, and serving temperature, as well as the effect of taste phenotypes (TTS and PTS), analysis of variance (ANOVA) was performed for liking and each emotion category data. Two-way interactions were included in the ANOVA to determine if interactions occurred across the five factors. Where significant effects were observed, Tukey's HSD multiple comparison tests were applied to identify the differences. All statistical analyses were performed using XLSTAT version 2016.07 (Addinsoft, Paris, France) at an α–risk of 0.05.

3. Results

3.1. The impact of temperature, carbonation level and beer type on liking and emotional response

As shown in Table 3, significant effects of temperature and carbonation were found on liking ($p \leq 0.0001$). Cold beer was significantly preferred (mean liking of 52.5) over ambient beer (mean liking of 46.7), and low carbonation was significantly less preferred (mean liking of 39.8) to commercial carbonation level (mean liking of 59.4). No significant effect of beer type on liking was observed ($p=0.54$). In addition, no significant interactions were found for beer type with temperature ($p=0.62$) or carbonation ($p=0.22$), but an interaction approaching significance ($p=0.07$) was observed for temperature and carbonation. As indicated in Figure 3, at the commercial carbonation level, cold beer was significantly more preferred than ambient beer, whereas at the low carbonation level, no significant difference was found. In fact both low carbonation beers (cold and ambient) were significantly less liked than the beers at the commercial level of carbonation (cold and ambient).

Overall no significant differences between the two types of beer were observed in any of the emotion categories ($p>0.05$) (Table 3). A significant temperature effect was found for four of the emotion categories and approached significance for a further four emotion categories ($p \leq 0.1$). As shown in Figure 4a, cold temperature evoked significantly higher *content* and *excited*, and less *disconfirmed* and *disgusted* emotions than ambient temperature. Approaching significance($p<0.1$), ambient temperature evoked more *underwhelmed*, *shocked*, *bored*, and less *tame/safe* than cold temperature.

There was a significant effect of carbonation on all the emotion categories ($p \leq 0.05$). The commercial carbonation level evoked significantly higher ratings for *content*, *excited, tame/safe, nostalgic and curious* and lower ratings for *underwhelmed, shocked, bored, disconfirmed* and *disgusted* emotions than low carbonation level (Figure 4b).

Significant temperature and carbonation interactions were observed for *content, excited, shocked* and *disconfirmed* ($p \leq 0.05$) (Figure 5). Tukey post hoc tests revealed that at low carbonation level, no significant differences between ambient and cold temperatures were observed, whereas at commercial carbonation level, cold temperature evoked significantly more *excited* and *content* and significantly less *shocked* and *disconfirmed* feelings than ambient temperature.

3.2. The impact of TTS and PTS on liking and emotional response

No significant difference across TTS (p=0.23) was observed for liking. For PTS, a significant effect was observed (p=0.001) (Table 4), where liking was significantly greater for ST (mean liking of 52.3) and MT (mean liking of 50.9), than for NT (mean liking of 45.6) (Figure 6). There was no significant interaction between TTS*PTS for liking (p=0.48).

When looking at the impact of TTS on emotional response, there was a significant TTS effect for six out of ten emotional categories (p≤0.05) (Table 4). As illustrated in Figure 7a, TT felt significantly more *tame/safe, curious, underwhelmed, shocked, bored* and *disgusted* than TnT.

For PTS, a significant effect was observed for *content*, *excited* and *bored* (p≤0.05) and the effect approached significance for *tame/safe*, *curious* and *disgusted* (p≤0.1) (Table 4). Tukey's post hoc tests showed that NT felt significantly less *content* and *excited* than ST and MT, and more *bored* than ST (Figure 7b), but no significant differences were observed between ST and MT.

Significant interactions between TTS and PTS were observed for four out of ten emotion categories (*content, tame/safe, curious* and *underwhelmed*) (p≤0.05) and interactions approached significance for two additional emotion categories (*excited* and *nostalgic*) (p≤0.1).

As shown in Figure 8, within TnTs, ST felt significantly more *content*, *tame/safe* and *curious* than NT. Moreover, ST felt significantly more *tame/safe* than MT. Within the TnT group, there were no significant differences between MT and NT for any of the emotional categories. In addition, MT did not rate *content*, *curious* and *underwhelmed* significantly different from ST and NT. Interestingly, no significant PTS effect was observed for any of the four emotional categories for the TT group.

4. Discussion

4.1. Impact of carbonation/temperature on liking and emotional response

Significant temperature and carbonation effects were observed for liking and emotional response which is not surprising given the experimental treatments moved the products away from how they are traditionally served, but does confirm that these attributes are important in terms of consumer acceptability. Studies have suggested that experience and familiarity could greatly influence food intake and preference (Aldridge, Dovey, &

Halford, 2009; Cardello & Maller, 1982). Cardello and Maller (1982) suggested that foods are most accepted at the condition that the food is normally served. Lager beers are commonly served carbonated and at a cold temperature, thus it was not surprising to find that the cold and commercial carbonated beers were preferred over the other two beers served at ambient and low carbonated levels. Despite large differences in the bitterness of the two products this does not appear to have affected consumer response to a significant degree and it could be that consumers are willing to accept a broader range of bitterness when it is optimised for the product. It is acknowledged that changing the traditional way in which the products are normally served via the experimental conditions may have affected the samples in other ways (Bartoshuk, Rennert et al. 1982) and, as the sensory characteristics of the beer products were not monitored in this study, this presents a limitation.

Furthermore, emotional response was aligned with hedonic ratings; when a greater liking score was given, increased positive emotions and decreased negative emotions were generally observed. For example, both cold beer and commercial carbonation level samples were more preferred, and evoked more positive emotions and less negative emotions than ambient and low carbonation beer samples respectively. It should be noted that in a previous study King et al. (2013) found that the position of the liking question altered the emotional response in that if liking was asked before, emotional response increased, and if liking asked after, the emotional response was often lower. Although any order effect will have affected all products in a similar way, it is acknowledged that in general the emotional responses may be higher than if the liking question had been asked last.

Interestingly, significant temperature and carbonation interactions on both liking and emotional response were observed in this study. The impact of temperature was bigger at commercial carbonation than at low carbonation, which suggested that serving beer at ambient temperature has a detrimental effect at commercial carbonation level, perhaps because consumers may be more excited about the carbonated product in the first place, whereas serving low carbonated beer does not excite consumers and therefore did not impact how they feel about the products any further. To date, there is limited literature looking into the relationship between serving temperature and carbonation on liking/emotional response. Green (1992) has investigated the impact of carbonation and temperature on perceived intensity of irritation. They found a significant temperature effect at high carbonation levels, but not at low carbonation levels (Green, 1992). Previous studies showed that both carbonation level and serving temperature altered the sensory properties of beverages (Bartoshuk, Rennert, Rodin, & Stevens, 1982; Green & Frankmann, 1987; Kappes, Schmidt, & Lee, 2007; Lederer, Bodyfelt, & McDaniel, 1991).

Although the sensory profile of the beers was not collected in this study, the sensory properties that were altered by these two factors (carbonation and temperature) are very likely to affect emotional response as previously reported (Chaya et al., 2015; Dorado et al., 2016; Eaton, 2015). The data here suggests that when lager is served at a cold temperature, which it is traditionally served at, it is particularly important for beer manufactures to ensure consistent optimal carbonation levels to elicit positive emotions during drinking experience.

4.2. Impact of TTS on liking and emotional response

There is only a limited literature looking into TTS and food preferences, and to date there is no data regarding emotional response. Bajec & Pickering (2010) investigated the association between TTS and self-reported liking for a large range of food items. They found TnT reported greater liking of cooked fruits and vegetables compared to TT and speculated that differences in texture perception between the phenotypes might account for the findings. More recently Pickering and Klodnicki (2016), reported that no difference was found across TTS for intensity ratings of foods, but that TnT gave higher liking ratings for creamy foods and also tended to like food with "aversive" orosensations (sour, bitter, astringency) more than TT. Previous studies have reported that TT are also more sensitive to temperature (Bajec & Pickering, 2008; Yang et al., 2014) and more discriminating of carbonation (Hort et al., 2016) than TnT, which may impact liking. However, in this study no significant differences were observed in liking between TT and TnT which is in agreement with a previous study with beer (Pickering, Bartolini, et al., 2010). Several studies have suggested that variation in taste sensitivity does not always translate into liking (Pickering, Bartolini, et al., 2010; Pickering et al., 2016).

What is particularly interesting in this research is that unlike the liking data, a significant TTS effect was found for six out of ten emotion categories, where TT felt more *tame/safe*, *curious, underwhelmed, shocked, bored, disconfirmed* and *disgusted* than TnT when drinking beer and, interestingly, it seems the impact of TTS is larger on the negative emotions. No significant interactions were found between TTS and carbonation/temperature which suggests this is an overall TTS effect on emotional response to beer regardless of beer conditions.

This finding adds further weight to previous findings (Chaya et al., 2015; Eaton, 2015; King et al., 2013; Ng et al., 2013; Spinelli et al., 2015) that emotional response provides additional insights beyond traditional hedonic liking where consumer response is concerned. This is the first study that looked into the effect of TTS on emotional response, and suggests that emotional response may be a more sensitive approach to capture the differences across the TTS taste phenotype than liking.

4.3. PTS on liking and emotional response

Although sample size is quite small, this study found that ST and MT significantly liked the beers more than NT. The liking data was supported by the emotional response data where NT rated *content* and *excited* emotions significantly lower, and *bored* significantly higher than ST. A number of studies have reported that PROP tasters are not only more sensitive to bitterness from PROP/PTC, but also to various oral stimuli, including other bitter compounds (Bartoshuk, 1979; Hall, Bartoshuk, Cain, & Stevens, 1975) and bitter-tasting foods such as dark chocolate, black coffee and brassica vegetables (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006; Gayathri Devi, Henderson, & Drewnowski, 1997; Shen, Kennedy, & Methven, 2016). Other studies showed that those individuals who perceive PROP as extremely bitter typically show a lower preference of Brassica vegetables and also avoid strong-tasting foods such as fatty foods and alcoholic beverages (Dinehart et al., 2006; Duffy et al., 2004; Shen et al., 2016; Tepper, 2008). This study did not find ST to have a lower preference for alcoholic beverages, instead an opposite trend was found. This could be due to the fact that food adventurousness also plays a role in ST. Ullrich, Touger-Decker et al. (2004) reported that PROP tasters who are food adventurous liked a wide range of products. However, as no food adventurousness information was collected in the current study this could not be examined.

PTS is partially associated with the bitter receptor gene TAS2R38 (Kim et al., 2003). Since PTS is observed to have an impact on a range of taste and trigeminal perception (Bartoshuk, 1979; Tepper & Nurse, 1998; Yang et al., 2014), other factors such as fungiform papillae density (Bartoshuk et al., 1994; Hayes, Bartoshuk, Kidd, & Duffy, 2008), and other genes such as gustin (Calo et al., 2011) are also hypothesised to contribute to the heightened taste sensitivity of PROP tasters. An fMRI study also observed differences in cortical response to a fat stimulus across PTS groups (Eldeghaidy et al., 2011). This study is the first study to explore the impact of PTS on emotional response.

4.4. Interactions between taste phenotypes

Individuals are not just one taste phenotype and the effect of interactions between different phenotypes is likely to be important for understanding differences in perception. Yang et al. (2014) found relative effects of these different phenotypes on taste perception intensities. Here, significant interactions between TTS and PTS were observed for the emotion categories of *content, tame/safe, curious* and *underwhelmed* where within the TnT group, ST rated *content*, *tame/safe* and *curious* significantly higher than NT, but no significant PTS effect was found within the TT group. Although TTS and PTS are shown to be independent taste phenotypes (Bajec & Pickering, 2008; Yang et al., 2014), this is the first study that reports relative effects for certain phenotypic combinations on emotional response.

There is limited research investigating the effect of individual variation in taste perception on emotional response to food. Kim et al. (2017) reported that sweet likers rated positive emotions greater when consuming highly sweet products, compared to sweet dislikers. Macht & Mueller (2007) found that ST were more associated with increased negative emotional responses after viewing an anger-inducing film clip and Herz (2011) found that ST associate more with increased visceral disgust (such as strange food, contamination) than moral disgust. Interestingly, this study also observed that the nature of the discriminating emotions are different across TTS and PTS, where the effect of TTS appeared to be more focussed on negative emotions such as *underwhelmed, shocked, bored and disgusted*, and the effect of PTS appeared on positive emotions such as *content and excited*, as well as the liking score.

However, why PTS may be more associated with positive emotions, and TTS with negative emotions is currently unclear. It could be hypothesised that TT only have a clear idea of what they do not like, hence, they are more likely to express their negative emotions. For PTS, perhaps ST have a clearer idea of what they like, and hence are more likely to express their positive emotions when tasting products they like. However, this is merely a hypothesis and needs further investigation.

5. Conclusion:

This study has confirmed that both carbonation level and serving temperature impact liking and emotional response to beer, although the impact of temperature was only evident at the commercial carbonation level.

PTS was shown to have more impact on liking than TTS as significant effects were only found for the former. However, differences in emotional response to beer according to TTS were observed in this study, where TT rated beer significantly higher for eliciting *tame/safe, curious, underwhelmed, shocked, bored*, and *disgusted* emotions than TnT. This indicates that emotional response measurement might be a more sensitive way to gain insights into the impact of taste phenotypes on beverage acceptability. This was also observed for PTS where ST rated beer higher for *content, excited*, and lower for *bored* than NT. This is the first study to show that PTS and TTS effect emotional responses evoked by beer. In addition, this study also highlighted significant relative effects of PTS and TTS on emotional response, where the effect of PTS is more apparent in TnT, and warrants further investigation. This study clearly shows that both TTS and

PTS impact emotional response to beer, which may explain some of the individual variation observed in consumer beverage choice behaviour.

6. References

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Figure

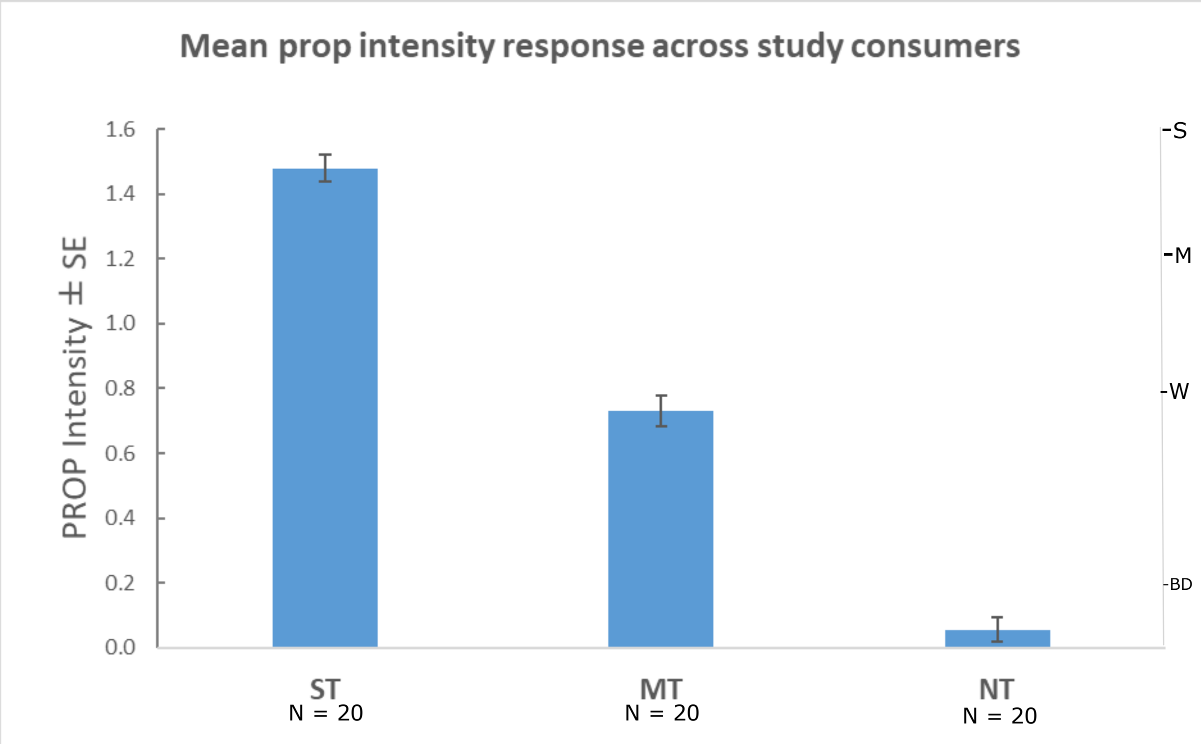


Figure 1: Mean PROP taste intensity response by PTS group. ST-supertasters, MT-Medium tasters, NT-nontasters; BD – Barely detectable, W-Weak, M-moderate, S–strong on gLMS scale.

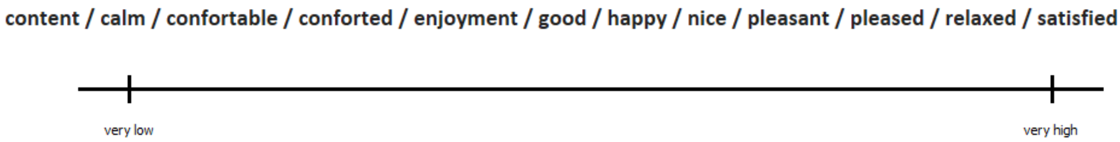


Figure 2. Example of emotion category (Content) presented to participants.

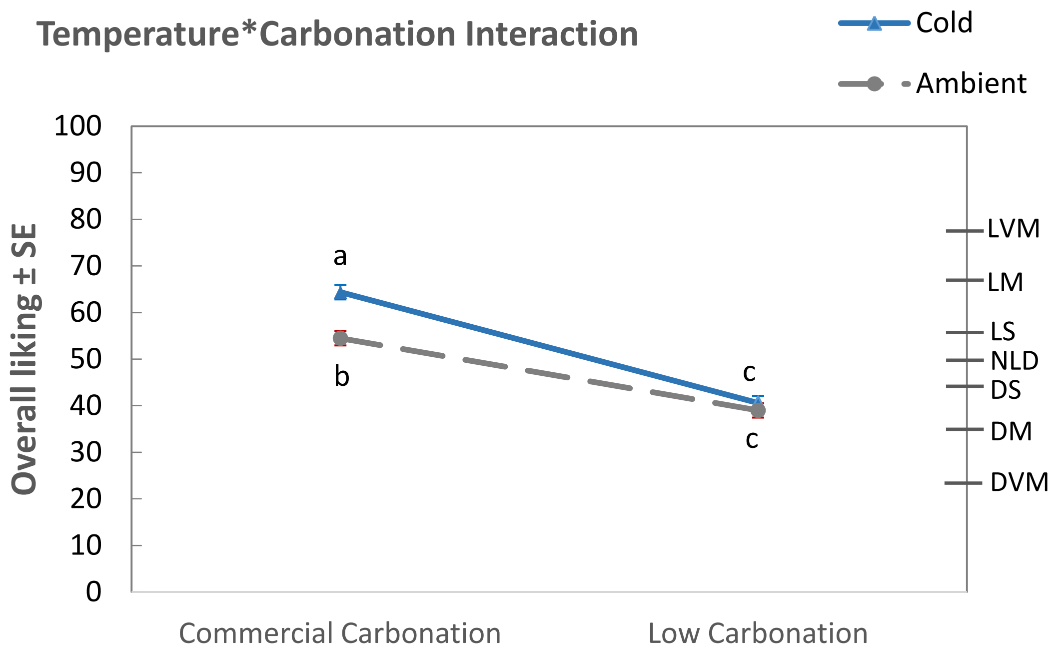


Figure 3: Effect of temperature and carbonation on overall liking (Mean score ± SE). [abc]Different letters indicate significant difference ($p \leq 0.05$). *LVM – Like very much, LM – Like moderately, LS – Like slightly, NLD – Neither like or dislike, DLS – Dislike slightly, DLM – Dislike moderately, DVM – Dislike very much.*

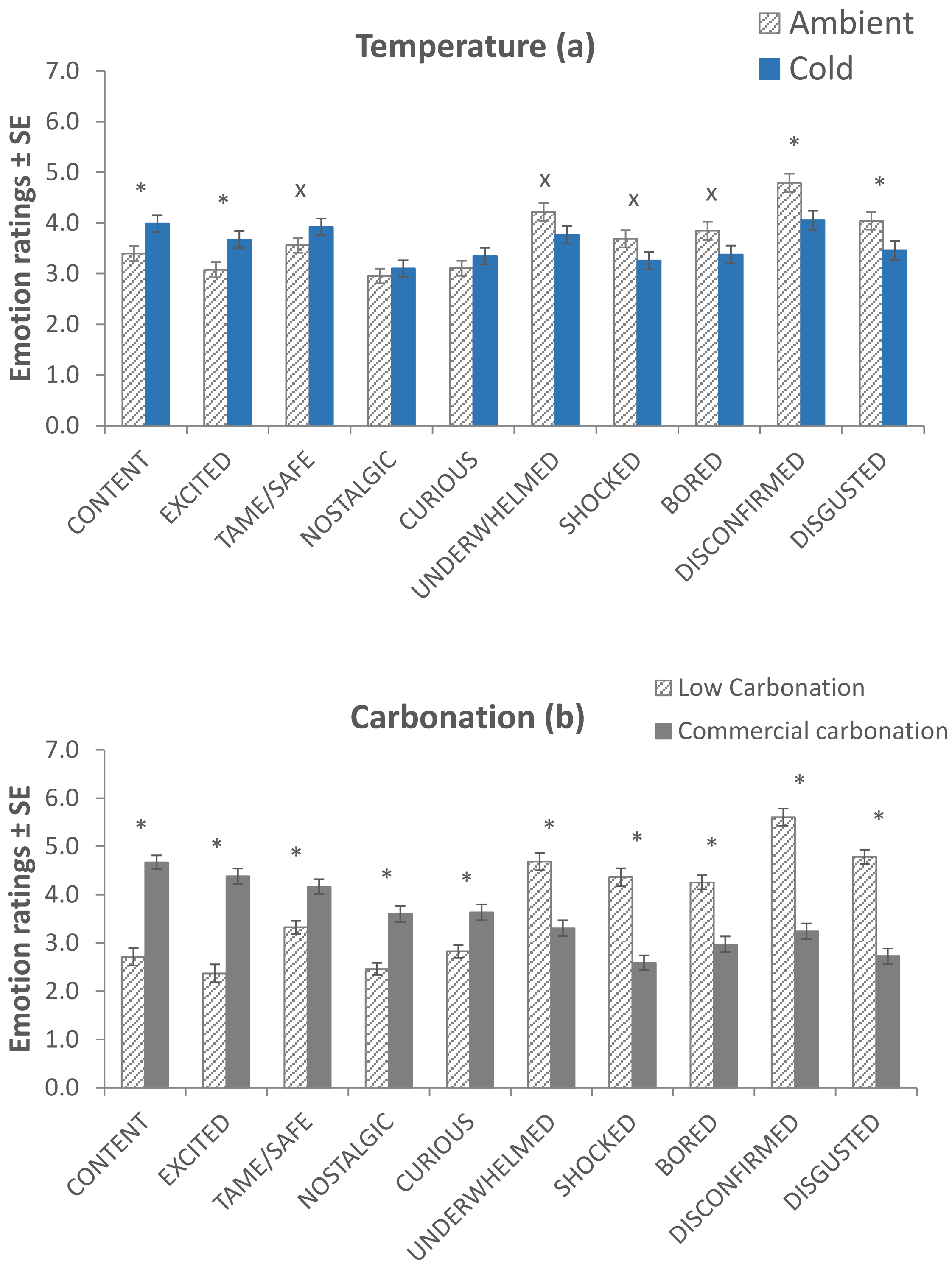


*Figure 4: Effect of temperature (Graph a) and carbonation (Graph b) on emotional response (Mean scores ± SE). *indicates significant difference ($p \leq 0.05$), ^{x} indicates approaching significant difference ($p \leq 0.1$).*

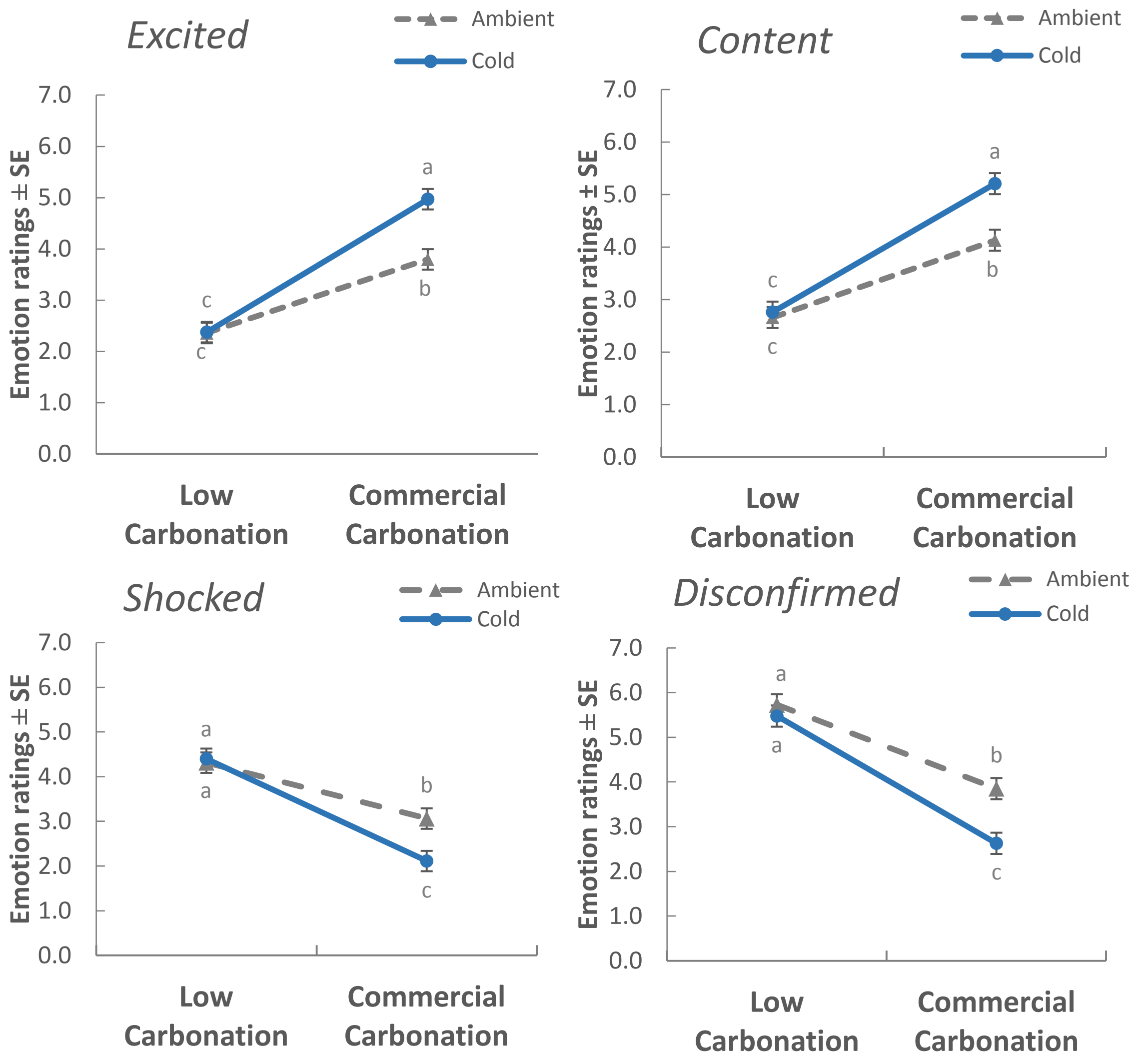


Figure 5: Temperature and Carbonation interaction plots for excited, content, shocked and disconfirmed emotions *(Mean scores ± SE).* [abc]*Different letters indicate significant differences (p≤0.05) from Tukey's post hoc test.*

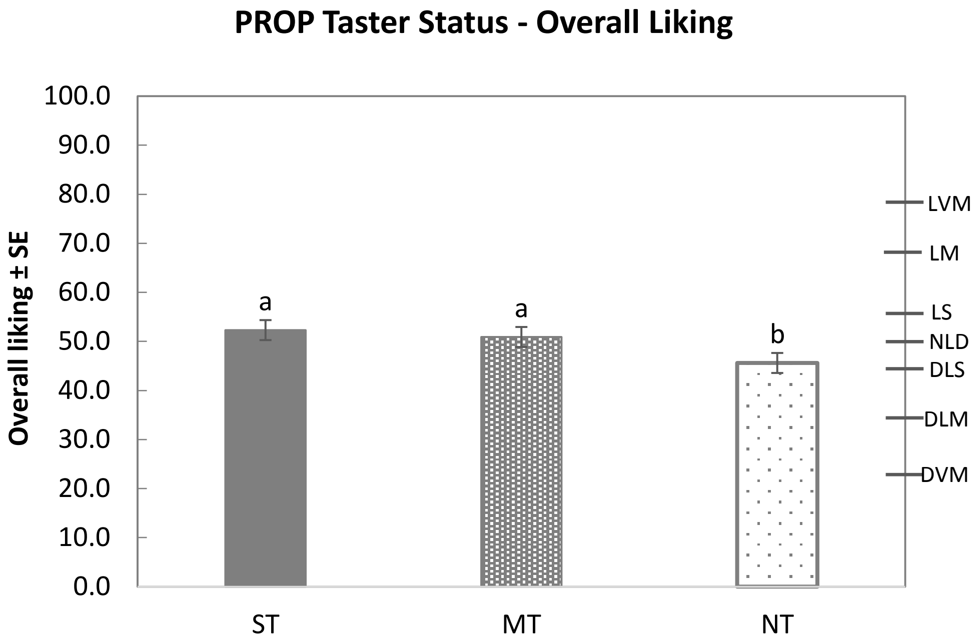
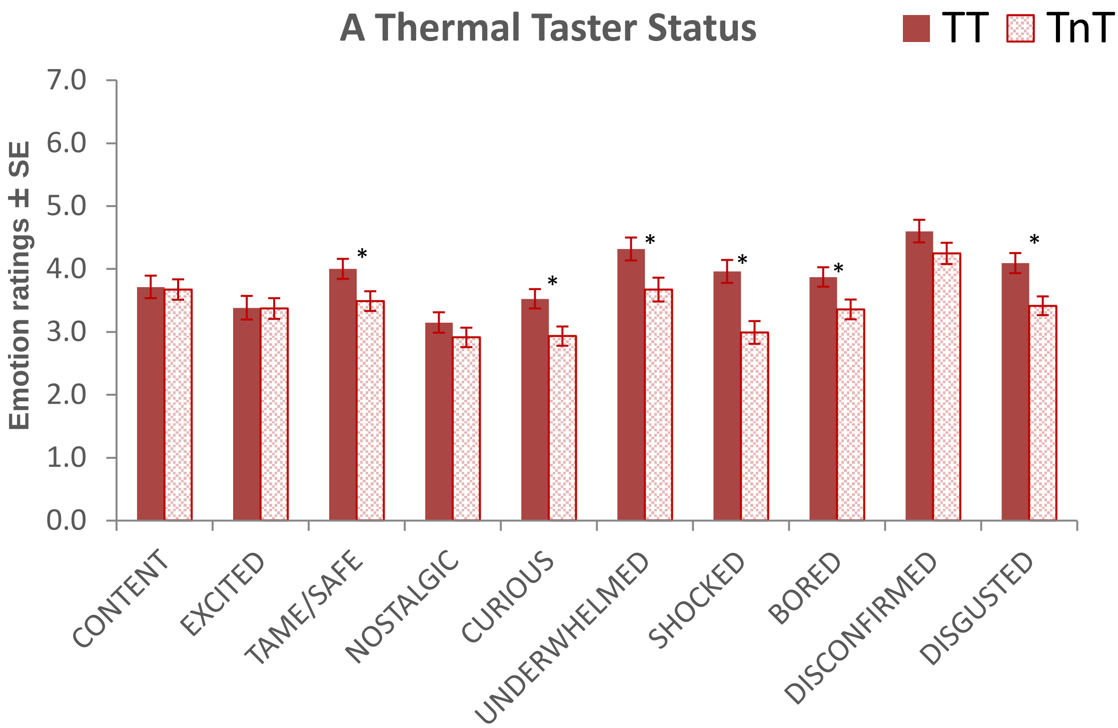


Figure 6: Effect of PROP Taster Status on overall liking (Mean scores ± SE). [ab]*Different letters indicate significant differences (p≤ 0.05). LVM – Like very much, LM – Like moderately, LS – Like slightly, NLD – Neither like or dislike, DLS – Dislike slightly, DLM – Dislike moderately, DVM – Dislike very much.*



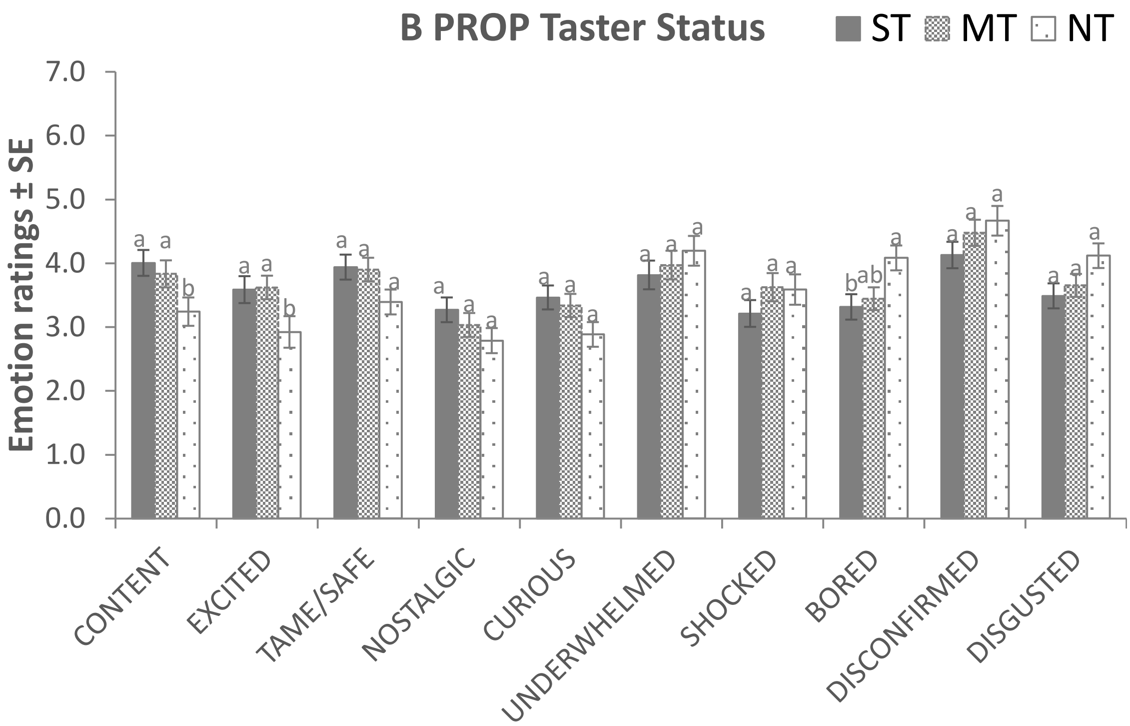


Figure 7: Effect of Thermal taster status (A) and PROP Taster Status (B) on emotional response (Mean scores ± SE). [ab]Different letters indicate significant differences ($p \leq 0.05$).

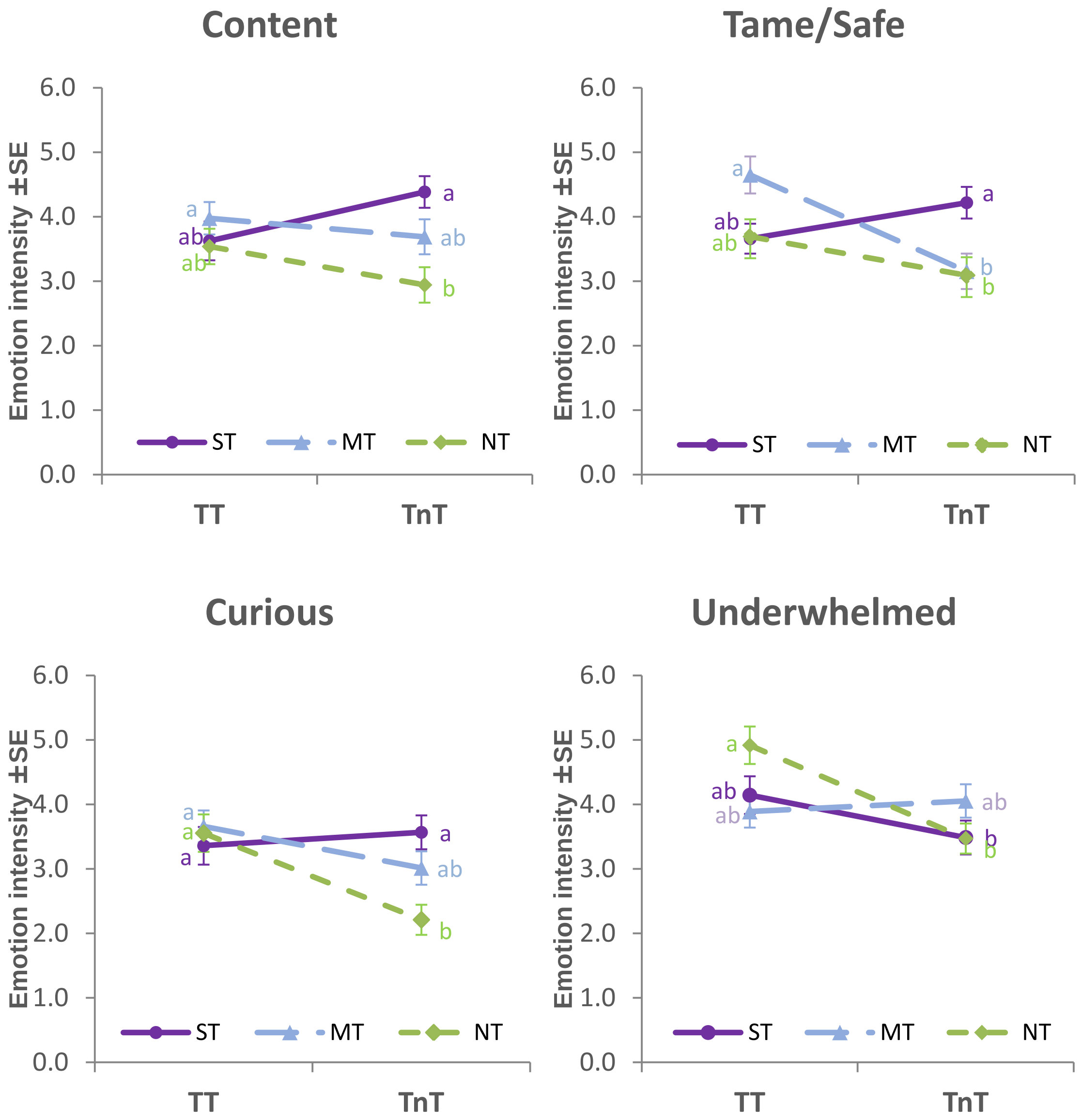


Figure 8: TTS and PTS interaction plots for content, tame/safe, curious and underwhelmed emotions. [ab]Different letters indicates significant difference at p≤0.05 from Tukey's post hoc test.

Table

Table 1. Beer samples and experimental treatments

Product	Carbonation	Temperature
P1	Commercial carbonation	Cold
P1	Low carbonation	Cold
P1	Commercial carbonation	Ambient
P1	Low carbonation	Ambient
P2	Commercial carbonation	Cold
P2	Low carbonation	Cold
P2	Commercial carbonation	Ambient
P2	Low carbonation	Ambient

Table 2: Emotion categories and associated terms

SHOCKED	Shocked, alarmed, cheated, confused, overwhelmed, strange, weird
TAME/SAFE	Tame, safe
CONTENT	Content, calm, comfortable, comforted, enjoyment, good, happy, nice, pleasant, pleased, relaxed, satisfied
EXCITED	Excited, enthusiastic, fulfilled, fun, impressed, interested, optimistic, pleasantly surprised, want, warm
DISCONFIRMED	Disappointed, dissatisfied, unpleasantly surprised
DISGUSTED	Disgusted, horrible, repulsed/repelled, unpleasant
NOSTALGIC	Nostalgic, desirous, relieved
BORED	Bored
UNDERWHELMED	Underwhelmed
CURIOUS	Curious

Table 3: Summary p-values table of ANOVA main effects and double interactions for temperature, carbonation and beer type on liking and emotion categories

	Temperature	Carbonation	Beer Type	Temp.* Carbonation	Temp.*Beer Type	Carbonation *Beer Type
LIKING	**0.0001**	**< 0.0001**	0.541	0.07	0.623	0.218
CONTENT	**0.003**	**< 0.0001**	0.666	**0.015**	0.365	0.553
EXCITED	**0.003**	**< 0.0001**	0.489	**0.004**	0.441	0.125
TAME/SAFE	0.092	**< 0.0001**	0.306	0.148	0.692	0.509
NOSTALGIC	0.487	**< 0.0001**	0.994	0.112	0.201	0.414
CURIOUS	0.258	**< 0.0001**	0.406	0.704	0.408	0.899
UNDERWHELMED	0.057	**< 0.0001**	0.959	0.595	0.926	0.325
SHOCKED	0.059	**< 0.0001**	0.864	**0.024**	0.985	0.870
BORED	0.054	**< 0.0001**	0.710	0.371	0.524	0.986
DISCONFIRMED	**0.002**	**< 0.0001**	0.735	**0.041**	0.379	0.740
DISGUSTED	**0.015**	**< 0.0001**	0.515	0.084	0.823	0.883

Emboldened numbers indicate significant effects at $p \leq 0.05$.

Table 4: Summary p values table of ANOVA main effects and interactions for TTS and PTS on liking and emotion categories

	TTS	***PTS***	***TTS*PTS***
LIKING	0.226	**0.001**	0.476
CONTENT	0.835	**0.005**	**0.016**
EXCITED	0.945	**0.006**	0.062
TAME/SAFE	**0.017**	0.068	**0.001**
NOSTALGIC	0.263	0.175	0.069
CURIOUS	**0.006**	0.067	**0.013**
UNDERWHELMED	**0.007**	0.425	**0.022**
SHOCKED	**< 0.0001**	0.266	0.789
BORED	**0.033**	**0.022**	0.603
DISCONFIRMED	0.135	0.173	0.169
DISGUSTED	**0.005**	0.082	0.130

Emboldened numbers indicate significant effects at $p \leq 0.05$.