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Chemosensory quality and intensity reflected in implicit affective responses

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A R T I C L E I N F O

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A B S T R A C T

Implicit measurements are indirect and could register emotions elicited by tasting without conscious awareness. While we know that some basic tastes such as sweetness and bitterness are innately liked or disliked, little is known about the affective responses to tactile sensations. It is also underexplored in which way the emotional responses to chemosensory stimuli are affected by the intensity of the stimulus. To address these issues an implicit method based on the Affect Misattribution Procedure using the judgment of trustworthiness to neutral faces, a proxy for valence, was developed using real tastes as primes (instead of pictures). Three different implicit measures were compared in an experiment in which 107 Italian PROP (6-n-propylthiouracil) Medium-Tasters were exposed to bitterness, astringency, and sweetness at weak/moderate and moderate/strong intensity. Samples were presented blind in aqueous solution monadically in triplicate. Participants were asked to taste a sample, then a neutral face was briefly presented on a screen, and participants were asked to indicate if they trusted the face (yes/no) and how much (on a 9-point Scale). Reaction times (RTs) for the yes/no responses were also collected. The data indicated that both taste qualities and intensity level influenced the yes/no trustworthiness judgements as well as the ratings and the reaction times. As expected, sweetness elicited the most positive affective responses and bitterness the most negative. Astringency elicited a positive response (but lower than sweetness) when it was presented at low intensity, while it elicited a more negative response when it was presented at higher intensity, and this effect was particularly evident when this was evaluated with the scale. Faster reaction times were observed for lower intensity stimuli that had been evaluated as positive but also for higher intensity stimuli that had been evaluated as negative. The results of the present study represent an advance in methodologies that tap implicit affective reactions to chemosensory qualities found in foods and beverages and that can be used to study food experience.

1. Introduction

Affective responses are often used as proxy measures of potential food choices (Mustonen et al., 2007). Such responses are predominantly based on explicit measures ("conscious" self-report ratings) (Lagast et al., 2017), which are relatively easy to apply and practical for quantitative analysis (Lawless & Heymann, 2010). However, the use of explicit affective measures has important drawbacks and limitations, both related to whether they are unambiguous reflections of stimulus valence.

It has been noted that determining our ability to express awareness of our attitudes consciously can depend strongly on the methods used to test that awareness (Field, 2000). Even if it is assumed that people can accurately access their internal feelings, there are reasons to believe that accounts of such internal states will be filtered or biased by circumstance and that access to internal feelings is subject to multiple sources of influence that may not be apparent in explicit affective judgments. In particular, explicit affective ratings are strongly context dependent in situations in which multiple stimuli are evaluated (Schifferstein, 1995; Walter & Boakes, 2009). At least part of these context effects is thought to be due to how rating scales are used. Thus, raters may spread assessments of multiple stimuli across the range of the scale, irrespective of the actual intensity range (Parducci, 1974). Therefore, a low affective judgement could reflect a relative decrease in pleasure compared to a previous stimulus within a session, or even previous exposure to similar stimuli, rather than an independent judgement.

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Most explicit measures of affective judgements, e.g., rating scales, may commonly involve a considered, relatively time-consuming response. But such conscious consideration, which may reflect an analytical process such as weighing 'pros and cons', has been found to lead to poorer outcomes, including lower satisfaction with choices (Dijksterhuis, 2004; Wilson et al., 1993) and consistency of responses across similar occasions of assessment (Nordgren & Dijksterhuis, 2009), and may therefore impair decision processes that are affectively or familiarity based (Halberstadt & Catty, 2008; Halberstadt & Hooton, 2008). Moreover, irrelevant aspects of an affective evaluation, for example, instructions to also rate sensory intensities, can influence the magnitude of the expressed affective response (Prescott et al., 2011).

Even with rapid choices, unconscious processes or motivations can bypass affective judgements of a stimulus (Chartrand, 2005; Dijksterhuis et al., 2005; Dijksterhuis & Smith, 2005). Demand characteristics may be influential, particularly in the responses that wholly or partially reflect situational or cultural appropriateness. For example, positive affective ratings of foods that are low in fat or sugar may partly reflect a desire to be seen as having a healthy diet and may thus account for findings of increases in affective ratings of products that are labelled as healthy (Cavanagh & Forestell, 2013) or organic (Lee et al., 2013). Moreover, consumers may be unaware of irrelevant aspects of the environment that exert an influence on choice irrespective of liking. For example, North et al. (1999) demonstrated that when French music was played in a wine store French wines outsold German ones, whereas the opposite effect was observed when German music was played. This may be one reason why ratings of product liking are poor predictors of choice or even later affective ratings (Köster et al., 2003; Lévy & Köster, 1999; Mustonen et al., 2007; Næs et al., 2013; Rosas-Nexticapa et al., 2005). In many cases, however, it is simply unclear why there is little correspondence between stated preferences and preferences assessed later. One possibility is that explicit measures such as ratings may gather information that is not specifically affective. For example, ratings of food liking during hunger may reflect internal states of wanting rather than the affective assessment of the food itself (Havermans, 2011).

In implicit tests, participants are not directly asked to report their feelings or attitudes, but instead these are inferred from behaviour. Furthermore, participants are not asked to express any evaluations of the object that elicit an affective response (e.g., a food product) in their performance thus reflecting automatic (i.e., unintentional) influences of the object. One promising and extensively used approach involves activating affective states directly through the use of priming stimuli that vary in valence and evaluating their impact on other affective, target stimuli. Affective priming provides an indirect measure (RTs) that is used to infer affective states. However, a more direct technique makes use of the fact that people routinely misattribute affective qualities to irrelevant aspects of the context surrounding whatever is being judged (Gawronski & Ye, 2014; Schwarz & Clore, 1983). Building on such findings, affective misattribution procedures (AMPs) ask participants for a direct and explicit affective evaluation of the target stimulus following an affective prime (Payne et al., 2005). In AMPs, there is no requirement that the targets have any intrinsic affective value. Thus, Payne & Lundberg (2014) primed affectively-neutral Chinese ideographs with briefly presented images of happy or angry faces and found corresponding increases in the liking for, or attractiveness of, the ideographs.

An intriguing aspect of AMPs is that in changing the affective value of a neutral target by a priming stimulus, the task becomes a projective technique since the valuation of the valence of target automatically reflects that of the prime (Payne et al., 2005; Payne & Lundberg, 2014). In other words, the valence of the prime can be inferred from the measured valence of the formerly neutral target.

One form of AMP involves estimating the trustworthiness of emotionally-neutral, novel facial images, judgements that can be made with high reliability (Brownlow, 1992) on the basis of very brief (<100 msec) exposures (Todorov et al., 2009; Willis & Todorov, 2006). Judgements of facial trustworthiness appear to be essentially affective in that they are positively correlated with judgements of emotionally positive qualities such as happiness in emotionally neutral faces and negatively with anger and aggressiveness (Oosterhof & Todorov, 2008; Todorov & Duchaine, 2008; Winston et al., 2002). It is argued (Oosterhof & Todorov, 2008) that degree of (un)trustworthiness is a proxy for potential threat, that is, of possible harmful intentions.

Consistent with this notion faces judged to be untrustworthy are remembered better, which may be an adaptive survival strategy (Mattarozzi et al., 2015; Rule et al., 2009). Trustworthiness judgements are also reflected in amygdala activity – itself reflecting threat (Amaral, 2002) - which increases as trustworthiness judgments of emotionally neutral facial expressions decrease (Engell et al., 2007; Todorov et al., 2008; Winston et al., 2002). It has been argued that evaluations of trust are attempts to infer intentions by attributing emotional content to neutral faces (Todorov et al., 2008). As such, as with the projective nature of other AMPs, these evaluations become proxy measures of valence.

The bulk of studies on affective priming has used visual stimuli as both primes and targets (Fazio et al., 1986). More recently, affective priming has been demonstrated using positive and negative food pictures, but also flavours and odours as the priming stimuli, and words as targets. For example, primes in the form of pictures of liked and disliked foods increase or decrease the speed of responding to, respectively, congruent positive and negative target words (Hermans et al., 2005; Lamote et al., 2004) or pictures (Hermans, Baeyens, & Eelen, 1998; Verhulst et al., 2006), thus showing that affective priming functions cross-modally (i.e., primes and targets refer to different modalities). Positive and negative flavours were found to influence responses to affectively congruent/incongruent non-food words (Veldhuizen et al., 2010) and yogurts differing in flavours or fat content were found to affect the evaluation of photographs of people with positive and negative personality traits in a projective task (Mojet et al., 2015). This supports the notion that priming activates a general affective state that is then influential when target stimuli are assessed, even when non-visual stimuli are used as a prime. However, the literature using as primes flavours, odours or foods and not pictures is very limited, and much is unknown of the implications of this experimental setting and of the practical constraints to be considered. In fact, differently from visual stimuli, flavours and odours require longer time to switch from one to another (e.g., carry over effects, need of cleaning the palate between evaluation, air saturation after odour release) so that in the case of the yogurt evaluation, for example, the study was performed in different days for each product (Mojet et al., 2015).

Here we examined the impact of primes that consisted of unambiguously valenced tastes (sweetness, bitterness), innately liked and disliked, respectively (Prescott, 2013), as well as one tactile oral sensation (astringency). Bitterness is always affectively negative when experienced out of the context of foods/beverages, and it is also associated with negative emotional states such as hostility and threat (Chen & Chang, 2012; Sagioglou & Greitemeyer, 2014) as well as increased emotional reactivity (Macht & Mueller, 2007). There is also evidence that exposure to bitterness can increase negative mood (Dubovski et al., 2017). Sweetness, on the other hand, is universally positive (Prescott & Rozin, 2015), although the extent of its affective value varies from person to person (Iatridi et al., 2019; Kim et al., 2014). Astringency is often perceived as a negative attribute, such as in soy (Carrão-Panizzi et al., 1999) and dairy products (Lemieux & Simard, 1994), nuts (Crowe & White, 2003), and juices (Tang et al., 2001), fruits and vegetables (Drewnowski & Gomez-Carneros, 2000) representing a barrier for acceptability. On the other hand, it is a desirable quality in many beverages (coffee, tea, wine) and not necessarily the main reason of disliking for astringent foods (Childs & Drake, 2010). For example, astringent sensations are described using descriptors reflective of high-quality (lots of character, long lasting after taste) by wine consumers (Lesschaeve & Noble, 2005).

The affective values of tastes vary as a function of taste intensity, although the direction and magnitude of this changes from taste to taste and as a function of individual differences (Samant et al., 2017; Samant & Seo, 2019). This is particularly true in the case of astringency, where the negative effect on liking for foods and beverages can depends more on intensity (and concentration) than on the quality of the sensation (de Beer et al., 2012; Yousaf & Tepper, 2022).

While there are data suggesting that priming does not reflect the *magnitude* of affective state, e.g., how much pleasant/unpleasant (Lamote et al., 2004; Verhulst et al., 2006), there are other data indicating that affective priming may distinguish between stimulus properties other than valence, e.g. between different emotions of the same valence (Rohr et al., 2012, 2015).

In this study, we aimed at testing a potentially useful implicit method to investigate affective reactions to chemosensory sensations differing in valence and intensity using an affective priming task involving face trustworthiness. Therefore, the objectives of this study are threefold: (1) to test the use of two unambiguously valenced basic tastes (sweetness and bitterness) and a tactile sensation (astringency) as primes together with a facial trustworthiness task to measure valence; (2) to evaluate if the intensity of these chemosensory qualities reflected in the implicit response; (3) to evaluate the effectiveness of three different implicit measurements in capturing participants implicit affective responses using a modified Affect Misattribution Procedure: reaction times, trustworthiness ratings (towards neutral faces) using a binary response (yes/no), trustworthiness ratings (towards neutral faces) on a 9-point scale (not at all/very much).

Specifically, we hypothesise that intensity is associated to a decrease of positive valence; that sweet and bitter solutions elicit, respectively, positive and a negative response both if presented at a moderate intensity or a strong intensity; and finally, that in the case of astringency the response would be negative at a higher intensity, but positive at a lower intensity.

2. Materials and methods

2.1. Screening and selection of participants

One hundred and seven Italian participants ranging from 18 to 40 years of age (women: 60%; mean age: 27.6 years old) were recruited from the Florence area. Participants were selected among participants to previous studies conducted at the SensoryLab – University of Florence. Only individuals that were classified as "PROP medium taster", thus responding to a 3.2 mM propylthiouracil solution between 17 and 53 (respectively "moderate" and "very strong") on a general Labelled magnitude Scale (Bartoshuk et al., 2004) were selected to minimise differences in the response to basic tastes and tactile sensations related to taste phenotype (Gent & Bartoshuk, 1983; Pickering & Robert, 2006; Prescott et al., 2001). PROP non tasters and supertasters, pregnant or breastfeeding women and subjects who were taking drugs for ADHD, insomnia, anxiety, high blood pressure, rheumatoid arthritis, epilepsy, allergic dermatitis (autonomic nervous system interference) were not eligible to participate in the test. All recruited participants reported normal or corrected-to-normal vision. The study was conducted according to the principles established in the Declaration of Helsinki for medical research involving humans and was subject to ethical standards that promoted and ensured respect for all human subjects and protected their health and rights. In line with national regulations given that the research was not medical, the research protocol was not submitted for approval to an ethical committee. The researchers involved in the study followed the code of Ethics & Standards for Sensory Project Managers developed by the Italian Sensory Science Society. Written informed consent was obtained from all participants according to the GDPR (General Data Protection Regulation) 2016/679.

Participants were compensated with a shopping coupon of € 20 for their participation in the study.

2.2. Tasting samples

Sweet, bitter and astringent tasting samples were presented at two different concentration levels (low and high) each, together with plain water. The concentration of the tastants was decided based on published psychophysical data (Feeney & Hayes, 2014; Masi et al., 2015; Monteleone et al., 2017; Yeomans et al., 2007) and preliminary tests conducted with 100 subjects to select solutions with weak/moderate (from 6 to 17 on a gLMS; Low) or moderate/strong (from 17 to 35 on a gLMS; High) rated intensity. The sample set was then composed of seven different solutions as reported in Table 1. All the solutions were prepared with water low in sodium, with the exception of astringency that was prepared using potable distilled water.

2.3. Face images selection

Face images consisted of 21 coloured pictures of neutral faces selected from a freely available face database (https://tlab.uchicago.edu/databases/). Developed by Oosterhof & Todorov, (2008), these consisted of un-manipulated computer-generated face images that have been rated for how much they were perceived as attractive, competent, dominant, mean, frightening, extroverted, threatening, likeable and trustworthy on a 9-point scale, ranging from 1 (not at all) to 9 (extremely). Only faces that showed a mean score close to the neutral point of the scale for each evaluated trait dimension were selected for being employed in the study. Artificially generated faces were used instead of actual faces because social features of neutral faces such as trustworthiness might be difficult to control in real images (Dotsch & Todorov, 2012). Selected faces were balanced for gender, had a neutral expression, were bald, Caucasian, and were represented with a direct gaze toward the observer (Fig. 1).

2.4. Experimental sessions

The study took place in the Sensory Laboratory of Florence University, Italy. The experimental procedure included two different laboratory sessions. In the first session, participants performed an implicit priming task (based on a revised Affect Misattribution Procedure, Payne et al., 2005) that investigated the unconscious influence of the different taste samples in modulating the evaluation of trustworthiness for the neutral faces. Skin conductance was also measured but these data will not be presented here. For a schematic representation of the study design, see Fig. 2. In the second session, participants rated the intensity of the same samples. In both sessions, respondents were not informed about the sensory quality of samples that they were tasting.

At the beginning of the first session, participants were instructed on the experimental procedure in which they were asked to evaluate the trustworthiness of different neutral faces after tasting different samples. The instructions emphasized that the facial images would be presented very briefly and that the experimenters were primarily interested in their first impression or 'gut' reaction. Participants were kept unaware of the purpose of the experiment and of the possible effect of tasted samples in influencing their responses to faces. Prior to the data collection, participants were trained to the procedure. Water samples were provided, and participants were asked to perform the task several

Table 1
Concentration of the tastants in each sample at low and high intensity.

Sample	Intensity	Concentration (g/Kg)
Bitter	Low	Caffeine: 1.5
	High	Caffeine: 3
Sweet	Low	Sucrose: 71.88
	High	Sucrose: 200
Astringency	Low	Aluminum sulfate: 0.8
	High	Aluminum sulfate: 1.6

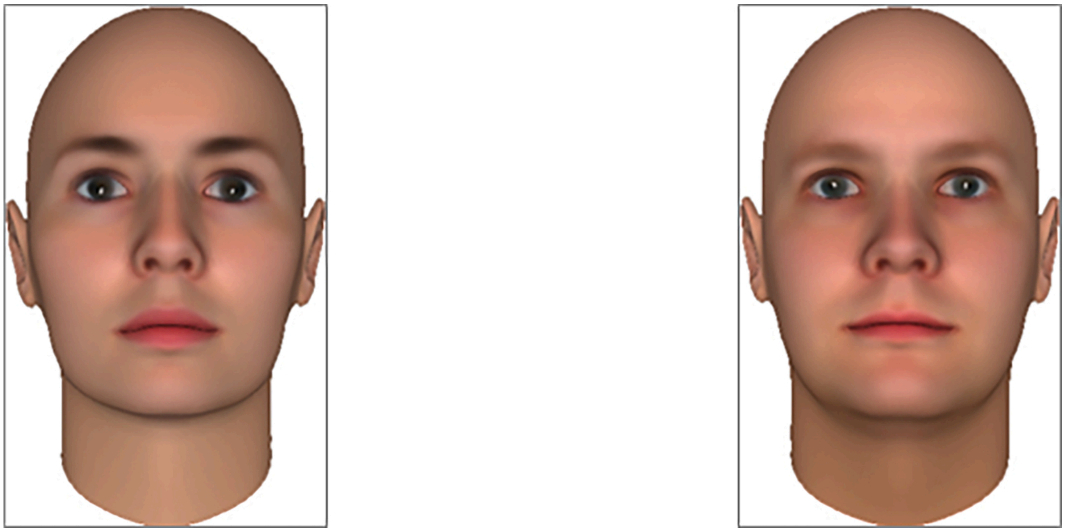

Fig. 1. Example of female and male neutral faces employed in the experimental procedure. Retrived from the face database developed by Oosterhof & Todorov, (2008).

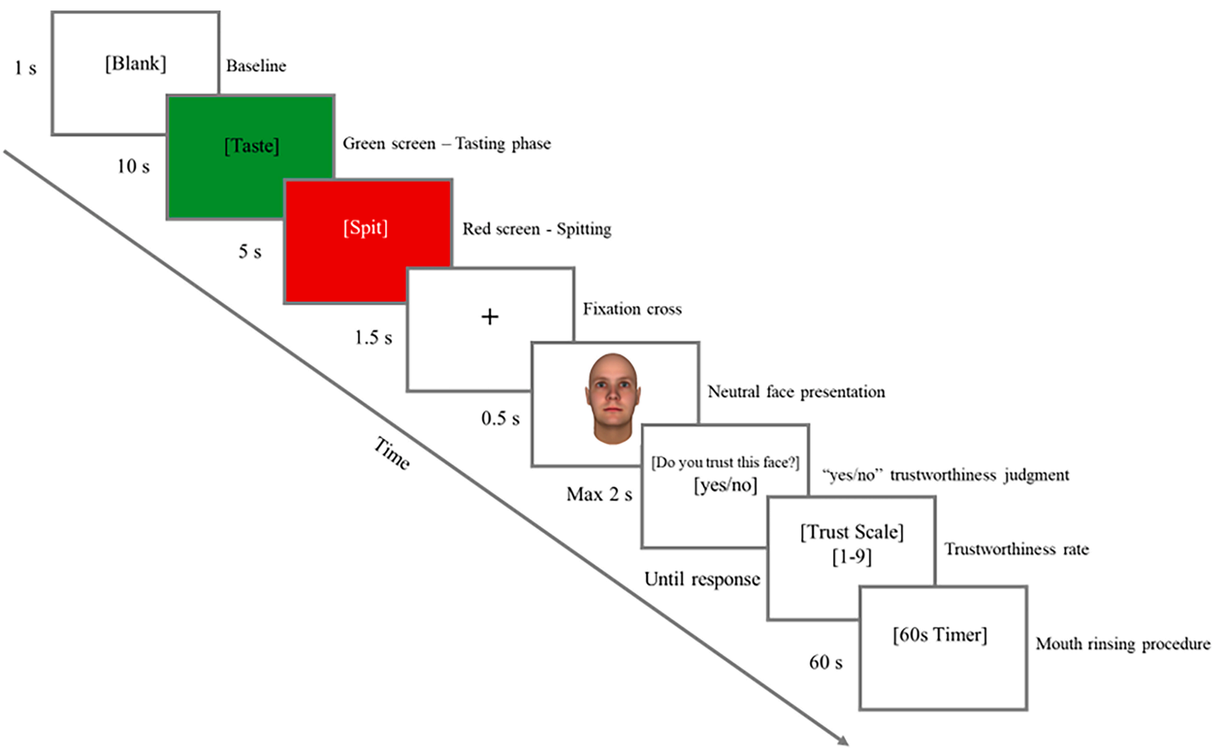

Fig. 2. Illustration of the test structure based on the Affective Misattribution Procedure. The image corresponds to one trial. The procedure shown was repeated for the seven tasting samples in three replicates. Between trials, a mouth-rinsing procedure of 60 s was carried out.

times until they felt comfortable with the procedure.

The experimental procedure was set using E-prime software (Psychological Software Tools, Pittsburgh, PA), which recorded participants' responses. Participants were seated in front of a computer at a viewing distance of about 60 cm. Then, they were presented with a taste sample (10 ml) in an 80 ml plastic cup identified with a random three-digit code. The presentation order of the seven samples, each presented in triplicate, was randomized and balanced within each series. First, participants viewed a blank screen for a 1 s duration, then a green screen appeared indicating the beginning of the tasting phase, when participants held the sample in their mouth for 10 s. Next, a red screen appeared indicating that participants should spit the sample within the next 5 s. After the 5 s countdown, a fixation cross was displayed in the centre of the screen for 1.5 s to orientate participants' gaze to the position in which a randomly selected neutral face was then presented for 0.5 s. Face presentation time was selected to tap automatic implicit responses to the stimulus (Bar et al., 2006; Todorov et al., 2009; Willis & Todorov, 2006). After the face presentation, participants were asked to evaluate face trustworthiness by the means of a "yes/no" trustworthiness judgment that consisted in pressing one of two buttons on the keyboard labelled "yes" or "no" (Todorov et al., 2009). Participants were asked to respond as quickly as they could. In this phase both responses and RTs were recorded.

In the following screen, participants were then asked to rate how much they trusted the previously presented face. This evaluation was made on a 9-point scale, ranging from 1 (not at all) to 9 (very much) (Treinen et al., 2012). Participants responded by using the number keys at the top of the keyboard. For this evaluation, there was no time constraint. At the end of each trial, participants rinsed their mouth for 60 s.

The second session took place on average 8.4 days apart from the previous one; this delay was considered a sufficient time delay to avoid an influence of the implicit task on the subsequent intensity evaluations. During the second session, participants were invited to come back to the laboratory to evaluate the intensity of the seven samples. Participants were introduced to the use of the gLMS (Bartoshuk et al., 2004) following the procedure described in Dinnella et al. (2018). Samples were identified with a random three-digit code. The order of the sample presentation was randomized among participants using a balanced Latin square design and presented in three replicates. Participants were instructed to taste each sample, keep it in mouth 3 s before spitting it, wait further 5 s, and rate the perceived intensity using the gLMS scale (0–100). After tasting a sample, water and plain crackers were served as palate cleansers (90 s). Data were collected with the software Fizz (ver.2.51B, Biosystèmes).

2.5. Data analysis

To detect significant differences between samples in intensity and elicited trustworthiness ratings, two Three-Way Mixed ANOVA models with samples (seven levels: the three chemosensory stimuli at two concentration plus water) and replicates as fixed factors and subjects as random factor was carried out (Næs et al., 2010). Mean centering by subject by subtracting the mean from each value before analysis was used to minimise the effect of the use of the scale.

The association between the tasting samples and the trustworthiness judgment (“yes” or “no”) for neutral faces was studied using first the one proportion test for each sample (Wald confidence interval) and then with a Chi-square test with the two samples of each sensory quality (Low and High) as rows and “yes” or “no” trustworthiness judgment as columns ($\alpha = 0.05$), followed by a Fisher exact test per cell.

The RTs were studied as a function of taste quality, concentration and trustworthiness using two Three-Way Mixed ANOVA models with two level interaction (quality*concentration). The first model was performed on RTs collected when participants evaluated a face as trustworthy (“yes” response), while the second model was performed on RTs collected when participants evaluated a face as non-trustworthy (“no” response). Water sample was excluded from these analyses since no difference in the proportion of “yes” and “no” trustworthiness responses was found ($p = 0.169$). In both models taste quality (sweetness, bitterness, astringency) and concentration (low and high) were set as fixed factors and subjects as random factor. Consistently with previous studies on RTs to facial trustworthiness, responses faster than 250 ms and slower than 1500 ms were excluded from the data analysis (Hoogeveen et al., 2016). RTs data were log-transformed before analysis to reduce distribution skewness (Ratcliff, 1993).

When ANOVA models were performed, Tukey’s Honestly Significant Difference (HSD) post hoc tests ($\alpha = 0.05$) were used to identify significant differences between the samples.

To assess the linear correlation between RTs, rated intensity, and trustworthiness scores, Pearson’s correlation coefficients were calculated separately for the trusted and not trusted faces. Significance criteria was set at $\alpha = 0.05$.

Statistical analyses were performed using XLSTAT software version 2020 1 (Addinsoft, Long Island, NY, USA).

3. Results

3.1. Samples perceived intensity

As expected, samples with lower concentration of the tastants were rated within the weak/moderate range of the gLMS (from 6 to 17), whereas samples with the higher concentration of the tastants were rated as moderate/strong (from 17 to 35). Significant differences between samples were found for intensity ($F_{(6,2242)} = 335.454$, $p < 0.0001$). Post-hoc tests showed that water was the least intense sample, followed by astringent, bitter, and sweet samples at low concentration and astringent and sweet samples at high concentration. The bitter sample at high concentration was perceived as the most intense. This also allowed to check if samples reproduced the hypothesized intensity levels (see Fig. 3). A significant difference was found between replicates ($F_{(2,2242)} = 10.101$, $p < 0.0001$), with the third replicate that was perceived as less intense as compared to the previous two as an effect of habituation.

3.2. Effect of taste intensity and quality on “yes/no” trustworthiness judgment and RTs

Table 2 reports the results of the one proportion test per sample and of the Chi-square test per sensation (with the two levels of intensity). A significant difference in the proportion of the “yes” and “no” was found for all samples except water. The proportion of “yes” was higher in all the samples, with the exception of bitter at a higher intensity. This indicate that all the sensations were associated with a positive affective response for the majority of the respondents, with the higher proportion for sweetness, except bitterness at a strong intensity that was associated for 59.04% of the respondents with a negative response. Only for bitterness ($p < 0.0001$) and astringency ($p = 0.0002$) there was an association between intensity and the proportion of “yes” and “no” in the trustworthiness judgements. In the case of bitterness this supports the result of the one proportion test, indicating that weak bitterness and strong bitterness were associated with more positive or more negative trustworthiness judgments, respectively. In the case of astringency this indicate that even if both levels of intensity induced a higher proportion of “yes” (positive trustworthiness judgements) the proportions are different and in particular were lower than expected in the case of strong astringency.

When participants tasted bitter and astringency at high concentration, there were lower rates of positive, as well as a higher rates of negative, trustworthiness judgments, while the opposite was found at their low concentrations. For sweetness, a higher rate of positive, as well as a lower rate of negative, trustworthiness judgments were found at both concentrations (see Table 2).

The mixed ANOVA model on RTs collected when participants evaluated a face as trustworthy (“yes” response) highlighted a significant effect of taste quality ($F_{(2,850)} = 4.238$, $p = 0.0015$) and concentration ($F_{(1,850)} = 15.822$, $p < 0.0001$) with no significant interaction ($p = 0.666$). When participants trusted a face, RTs were significantly slower for the bitter samples as compared to the astringent ones while no difference was found between the sweet samples and the other sensations (Fig. 4a). RTs were significantly slower for stronger tastes as compared to weaker ones (Fig. 4b). The mixed ANOVA model on reaction times collected when participants evaluated a face as non-trustworthy (“no” response) highlighted a significant effect of concentration ($F_{(1,549)} = 6.940$, $p < 0.011$) with no significant effect of taste quality ($p = 0.734$) and of their interaction ($p = 0.783$). For non-trusted face RTs were significantly faster when participants tasted stronger samples as compared to weaker ones (see Fig. 4c).

A weak, but significant, negative correlation was found between RTs and degree of trustworthiness when participants judged a neutral face as trustworthy ($r = -0.17$, $p < 0.0001$) and between sample intensity and degree of trustworthiness when participants judged a neutral face as

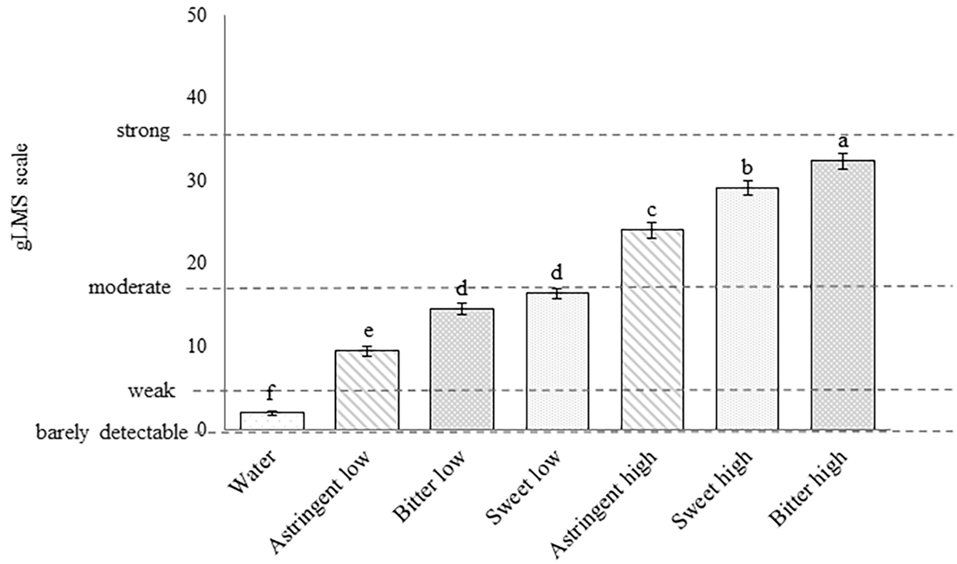

Fig. 3. Mean intensity scores of different tasting samples at low and high concentration and water on the general Labeled Magnitude Scale (gLMS) ($p < 0.0001$). Different letters indicate a significant difference between samples according to Tuckey Honestly Significant Difference (HSD) post hoc tests ($\alpha = 0.05$).

Table 2
Percentages of "yes/no" trustworthiness judgment of neutral faces after each sample evaluation and p-values from One proportion and Chi-square tests (in brackets). Percentages **in bold** are significantly higher per row after one proportion test. < and > indicate that the observed value is significantly lower or higher than the expected theoretical value after Chi-square test per sensory quality at two level of intensity (Chi-square per cell significant for $\alpha = 0.05$; Fisher Exact Probability Test).

Sample	Intensity	Trust/ Yes(%)	Trust/ No (%)	One proportion test (p-value)	Chi-square (p-value)
Water	–	46.59	53.41	0.169	–
Bitter	Low	**59.71**>	40.29<	0.001	19.31
	High	40.96<	**59.04**>	0.002	(<0.0001)
Sweet	Low	**70.5**	29.5	<0.0001	3.36
	High	**63.04**	36.96	<0.0001	(0.067)
Astringency	Low	**73.52**>	26.48<	<0.0001	13.97
	High	**58.74**<	41.26>	0.002	(0.0002)

untrustworthy ($r = -0.13$, $p = 0.007$). No significant correlation was found between sample intensity and degree of trustworthiness when participants judged a neutral face as trustworthy and between RTs and degree of trustworthiness when participants judged a neutral face as untrustworthy ($p > 0.489$).

3.3. *Effect of samples on trustworthiness ratings*

Main effect of sample ($F_{(6,2245)} = 51.271$, $p < 0.0001$) was found for trustworthiness ratings. Post-hoc tests revealed that the highest trustworthiness scores were observed when the neutral faces were preceded by sweetness and astringency at low concentration, followed by sweet at high concentration. On the contrary lower trustworthiness ratings were found when faces were preceded by astringency at high concentration, bitter at low concentration and water, while the bitter sample at high concentration elicited the lowest trustworthiness ratings (see Fig. 5). However, while sweetness at both levels of intensity was found to elicit a trustworthiness judgment above the mean (sweet low intensity = 6.4; and sweet high intensity = 5.74), and bitterness at both intensity levels below the mean (bitter high intensity = 4.55; bitter low intensity = 5.18) as well as water (4.82), judgements following astringency were below the mean at the high intensity (5.12) and above the mean at the low intensity (6.04). A significant difference was found between replicates ($F_{(2,2245)} = 51.274$, $p < 0.0001$). Post-hoc tests showed that during the third replicate faces were perceived as more trustworthy as compared to the previous two. This may reflect the slightly lower perceived intensity in the third replicate (see §3.1).

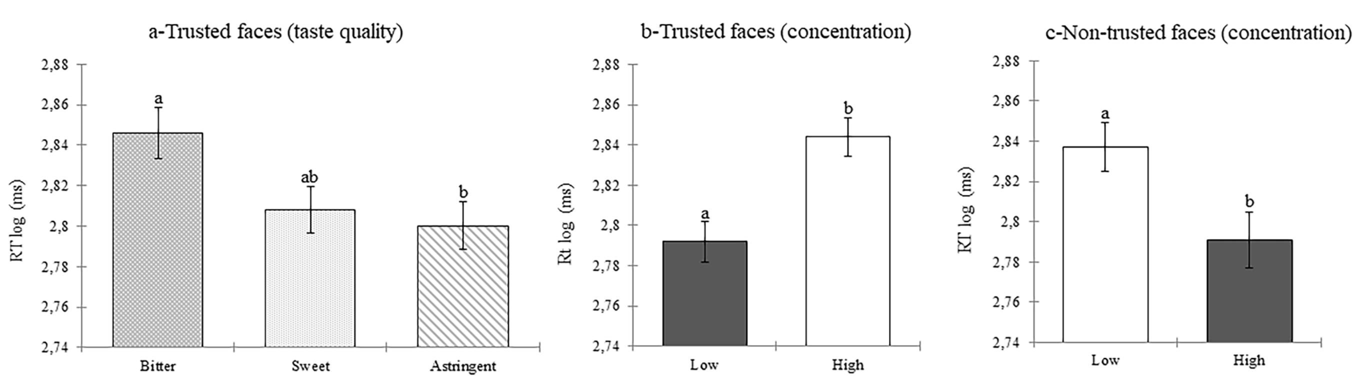

Fig. 4. Mean reaction times logtransformed (RTs) for trustworthiness judgements of neutral faces after tasting samples. Effect of taste quality (a) and concentration (b) on trusted faces and taste quality on non-trusted faces (c). Different letters indicate a significant difference according to Tuckey's Honestly Significant Difference (HSD) post hoc tests ($\alpha = 0.05$).

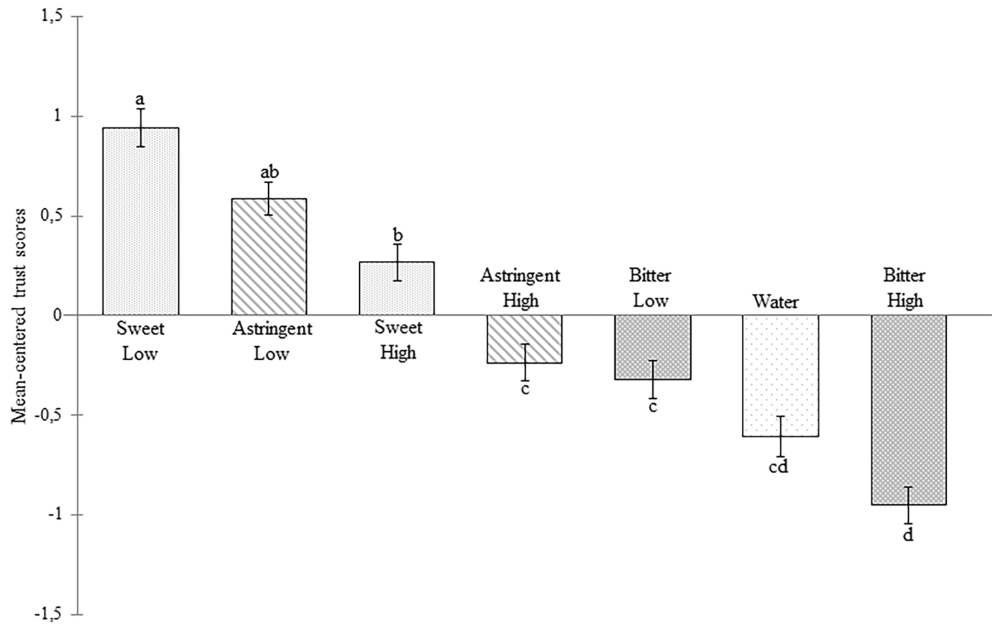

Fig. 5. Mean-centred trustworthiness ratings for neutral faces as a function of tasting samples. Different letters indicate a significant difference according to Tuckey's Honestly Significant Difference (HSD) post hoc tests (α = 0.05).

4. Discussion

The present research aimed at evaluating a potentially useful implicit method to investigate affective reactions to chemosensory sensations differing in valence and intensity using an affective priming task involving face trustworthiness. When the three different implicit measurement methods (yes/no trustworthiness judgements, reaction times, and trustworthiness ratings) were compared, all measures were effective in uncovering the implicit affective influence of the tasted samples on the subsequent evaluation of face trustworthiness, albeit with some differences. Both the yes/no trustworthiness judgements and the trustworthiness ratings highlighted the effect of chemosensory quality and intensity in modulating the trustworthiness responses. RTs were mostly useful in discriminating among different intensities, consistently with the typical findings for RTs to stimulus intensity (Delwiche et al., 1999; Yamamoto & Kawamura, 1981).

As expected, when bitterness was used as an affective prime stimulus it elicited a negative response that affected the trustworthiness of faces, while the opposite effect was found for sweetness. These results are coherent with previous studies that highlighted the effect of basic tastes in eliciting positive (sweetness) or negative (bitterness) affective reactions (Chen & Chang, 2012; Swan et al., 2013; Sagioglou & Greitemeyer, 2014). These results are also compatible with evidence from functional magnetic resonance imaging studies that have provided evidence of stimuli-induced emotional responses to taste in which the consumption of sweet tasting solutions resulted in pronounced neural activations in the amygdala, a part of the brain associated extensively with both emotional processing (O'Doherty et al., 2001) and with perceptions of trustworthiness (Adolphs et al., 1998; Winston et al., 2002). As hypothesised the higher intensities elicited a more negative response than did the lower intensities. This is consistent with numerous studies that have shown relationships between taste intensity and degree of liking in basic taste solutions, foods, and beverages (Mojet et al., 2005; Pangborn, 1970; Samant et al., 2017, Dubovski 2017).

Interestingly, the reaction times were faster when the stimuli were characterised by low intensity and evaluated as positive, but also when the stimuli were characterised by stronger intensity and evaluated as negative. This suggests that lower intensities *per se* are automatically perceived as more positive than stronger intensities, and when there is an incongruency between the intensity and expected valence of the stimulus, the reaction times are longer. These observations are consistent with previous studies reporting significantly longer reaction times in incongruent conditions compared with congruent ones (Fan et al., 2003).

When astringency was used as prime stimulus it elicited an implicit affective positive reaction although the magnitude of the effect was smaller as compared to sweetness. Furthermore, as hypothesised, astringency elicited a positive response when it was presented at low intensity, while it elicited a more negative response when it was presented at higher intensity, in particular when this was evaluated with the scale. This outcome is not surprising given reports that astringency is often rated as affectively negative (De Toffoli et al., 2019; Endrizzi et al., 2021; Jaeger et al., 2009; Laureati et al., 2018; Lesschaeve & Noble, 2005) but also as a driver of liking in some foods and beverages (e.g. wine) when perceived at lower intensity (Bajec & Pickering, 2008).

Other factors may also have contributed to these results. The first is the significantly lower intensity of astringency as compared to bitterness and sweetness both at low and high concentrations, which could have reduced any aversive characteristics that might have been evident at higher concentrations. Secondly, it has been pointed out that the different chemical substances commonly used to elicit astringency may be characterised also by multiple sensory sub-qualities (Lee & Lawless, 1991). In particular, bitter, sour, and sweet were reported as aluminium sulfate descriptors (Fleming et al., 2015), and may have contribute to the sensation perceived by the individuals in the implicit task and the intensity test in this study. It should be also noted that participants were not aware of the name of each sensation they were asked to evaluate ("astringency", "bitterness" and "sweetness" were never mentioned in the instructions). Furthermore, the perception of astringency builds slowly in intensity after tasting; the perceived intensity of astringency increases linearly to a maximum at 13–15 s post-ingestion, regardless of the concentration of the astringent compound (Bajec & Pickering, 2008; Guinard et al., 1986; Ishikawa & Noble, 1995). In this study the faces were evaluated after at least 7 sec (and by 9 sec) with the yes/no question, while ad libitum time was given for the evaluation of trustworthiness on the scale. In the second session, instead, intensity was evaluated after 8 s. We may expect therefore that the peak intensity was not reached at the time of the evaluation, and this may also explain the lower perceived intensity of astringency. The slightly more negative performance of astringency at its higher concentration when evaluated with the scale, as compared to when evaluated with the "yes"/"no" trustworthiness judgments, could be explained by the longer time of exposure to the sensation in this second evaluation.

The effects involving astringency could perhaps have been clarified by asking participants to provide an explicit measure of liking of astringency. We chose not to do this in order to maintain the study as an implicit method only procedure, particularly since there was no need to have explicit affective measures of sweetness and bitterness. Interestingly, in the absence of an explicit measure of astringency liking, these data indicate the usefulness of this implicit procedure. Our prediction was the astringency outside the context of foods or beverages could, like bitterness, be affectively negative especially at high concentrations. The data suggest that this is the case, thereby acting as a "test case" for the utility of the measures tested here. The consistency of the results for sweetness and bitterness with expected outcomes suggests that confidence regarding the meaning of the astringency implicit results is warranted.

When water was used as prime stimulus no significant difference was found between the trustworthiness judgement for faces ("yes","no"), while tasting water negatively affected the trust ratings. This result is not surprising since water could be connoted with tastes and odours that could influence its affective response negatively (for a review see Haese et al., 2014). Furthermore, in the context of the present experiment water could be considered as an ambiguous stimulus since participants were blind about aqueous solution quality, thus leading or reinforcing negative affective reactions (Tae et al., 2020).

Our interpretation of the results is that the experimental procedures induced specific affective reactions that were reflected accurately in participants' responses on the implicit affective assessment task. Because participants were not directly asked about their liking for the samples and were unaware of the purpose of the experiment, the affective misattributions of taste and intensity valence over neutral faces seem unintentional. The implicit task thus successfully differentiated among distinct chemosensory qualities but also among the same chemosensory quality as a function of intensity. The results of this experiment suggest that a task in which participants taste samples with different chemosensory quality and intensity and then are asked to evaluate the trustworthiness of neutral faces holds value as an implicit measure of affective response.

The present findings provide a further advance in exploring alternative methodologies to assess affective reactions to foods that may help overcome the major limitations and problems of explicit methods such as cognitive biases (Danner et al., 2014; de Wijk et al., 2012), social desirability and self-representation biases (Schwarz, 2001), and lack of introspective capacity of participants (Köster, 2003; Nisbett & Wilson, 1977). Furthermore, these findings have implications for our understanding of how people are affectively activated by chemosensory perception and by basic tastes or tactile sensation per se (not in the context of a food), considering that affective associations are known to be a key proximal driver of behavioural outcomes (Kiviniemi & Bevins, 2008; Kiviniemi & Duangdao, 2009). Although the present results were derived through variations in tastes in the absence of a food context, it is likely that this methodology would be as effective in a product context since a limited amount of previous research suggests that food primes are possible (Mojet et al., 2015).

5. Conclusions

The priming results presented here are consistent with the affective misattribution effect demonstrated by Payne et al., (2005) using emotional pictures. The results of the present study represent an advance in the study of methodologies to tap implicit affective reactions to chemosensory qualities that are found in foods and beverages. Future research should more systematically explore different features of the implicit affective assessment task to extend its use to different basic sensations (e.g. sourness, saltiness) and more complex food-related stimuli, as well as to study the emotions elicited by food products. We argue that combining explicit with implicit measures will enable exploration of conscious and unconscious reactions to foods to better understand the determinants of consumer choices.

Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript.

CRediT authorship contribution statement

L. Pierguidi: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **J. Prescott:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **S. Spinelli:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition. **C. Dinnella:** Methodology, Writing – review & editing. **A. De Toffoli:** Conceptualization, Investigation, Data curation. **T.L. White:** Writing – review & editing. **E. Monteleone:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Authors JP and EM, respectively editor and associate editor of this journal, were not involved in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another editor, as per the journal guidelines.

Data availability

Data will be made available on request.

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