



Is sensory-specific satiety for a bitter-sweet infusion modulated by context?



David Garcia-Burgos^{a,b,*}, Florencia Secchiari^c, Amalia Calviño^{c,d}

^a Department of Experimental Psychology, University of Granada, Campus Cartuja s/n, 18071 Granada, Spain

^b Department of Psychology, Clinical Psychology and Psychotherapy, University of Fribourg, 2 Rue de Faucigny, CH-1700 Fribourg, Switzerland

^c School of Pharmacy and Biochemistry, University of Buenos Aires (UBA), IQUIMEFA, UBA-CONICET, Junín 956, Ciudad de Buenos Aires, Argentina

^d Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), School of Pharmacy and Biochemistry, UBA, Argentina

HIGHLIGHTS

- Sensory-specific satiety (SSS) for infusions was proved in artificial and natural settings.
- SSS for odour and SSS for flavour showed differential sensitivity to context.
- The magnitude of olfactory SSS was lesser in the cafeteria compared to laboratory.
- Multiple SSS sessions showed a contextual control of the motivational ratings.

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ABSTRACT

The sensory-affective attributes of beverages have an important influence on a given intake and successive consumptions because of sensory-specific satiety (SSS; defined as a decrease in pleasantness ratings of a food eaten relative to uneaten foods). No studies have, however, investigated how multiple sessions of SSS for familiar drinks over a period of several days up to a week may change their pleasantness and how these hedonic-related judgments are affected by the context during SSS testing. With twenty-six participants, the present study explored the medium lasting and contextual effects of repeated SSS sessions for a bitter-sweet infusion on olfactory and flavour pleasantness over the course of three exposures in either a laboratory or a cafeteria setting. The results showed olfactory and flavour SSS for the infusion following each consumption in both the artificial and the natural setting. More interestingly, despite the failure to detect medium-term SSS (i.e., a greater decrease in pleasantness ratings of a food eaten relative to uneaten foods after repeated SSS sessions over several days as compared to the first SSS session), a contextual modulation of olfactory SSS was observed with a lesser overall magnitude in the cafeteria compared to the laboratory setting. To the best of our knowledge, the impact of eating location on the development of satiation and the differential contextual sensitivity of SSS for orthonasal odours and flavours has not been reported previously. The implications of potential environmental control of SSS are considered in this study.

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1. Introduction

Among the affective processes involved in the regulation of the quantity and the type of food ingested during and following a meal, sensory-specific satiety (SSS) appears to be an extensively studied phenomenon. The effects of the SSS procedure within an eating session have been demonstrated by decreases in food-related responses such as food intake [1,2], salivation [3], rate of consuming [4], likelihood of food choice [5] and hedonic value ratings (i.e. liking) [6–8]. Moreover,

this negative hedonic shift occurs for the food's flavour/taste [1], odour [9,10] and other sensory food attributes as texture [11] and visual appearance [12].

In addition to SSS within a single eating session, long-term SSS might influence eating over time periods of weeks or months. For instance, Rolls and de Waal [13] reported that the taste of foods that refugees in an Ethiopian refugee camp had been eating for approximately six months was less pleasant than the taste of new foods, whereas newly arrived refugees who had been eating that same diet for only two days found all foods equally pleasant. Regular consumption of high energy-dense snack foods for twelve weeks has also been found to alter SSS for these foods ([14], but not for potato chips, where differences in fat content do not seem to affect the development of SSS over

* Corresponding author at: Department of Psychology, University of Fribourg, 2 Rue de Faucigny CH-1700 Fribourg, Switzerland.

E-mail address: davidgb@ugr.es (D. Garcia-Burgos).

10-day sessions [15]). In order to demonstrate the effect of limiting snack food variety on long-term SSS and monotony in overweight adults, Raynor, Niemeier and Wing [16] compared an experimental group that ate only one chosen snack food for the entire 8-week period with a control group that ate one snack per day but with no limit on the variety of choices for that snack; over time, the experimental group showed long-term SSS (in terms of greater decrease in pleasantness of the chosen food compared to the uneaten food) and food monotony (as greater decrease in hedonic ratings of the chosen food in the experimental vs. the control group). Therefore, a large body of evidence is available on SSS in the very short term (within a meal) and, to a lesser extent, in the very long term (over several weeks to months). However, to date no research has extended the study of development of SSS in the medium term (over a few days to a week), although combining eating a food to satiety and in-home evaluation over several days seems to show a decrease in liking ratings for more than 24 h [17].

An approach that supports the distinction between short- and medium- to long-term SSS comes from habituation, a mechanism generally proposed for SSS [18,19] that presents short as well as long forms including long-term habituation to food [20,21]. Taking into account associative theories of habituation, some hypotheses for SSS have been recently confirmed including, among others, stimulus specificity [22] and dishabituation [23,24] as new food can disrupt the development of SSS if it has not been completely established [25]. For our purposes, if, for instance, medium- to long-term SSS is due to long-term hedonic habituation, one should expect repetitive food offerings to result in a decrease in hedonic response that lasts for days or weeks, i.e. more rapid rehabilitation and/or lower initial or average responses and/or less frequent responses than baseline [26]. These theories explain this by considering that long-term changes result from associations between the stimulus and the context in which the training occurs [27,28], causing anticipation of the stimulus and therefore lesser degree of processing. On this reasoning, response decrements between sessions would not be dependent solely on the parameters of test stimulus presentation, but would also include elements of the environmental situation in which it is presented [28,29]; and medium-term SSS for the infusion should be expected as a result of habituation to the infusion plus a context-infusion association. However, most of the information about long-term habituation comes from a non-food-related variety of responses in controlled human studies [18]. This associative hypothesis might not hold in the more complicated naturalistic settings in which human SSS takes place, especially since eating location seems to affect ingestive behaviour dramatically, including the cessation of eating [30–32]. In this sense, although many environmental cues influence satiety (e.g., number of people present, watching TV, or packages and dishware sizes) [33,34], the role of the physical location remains quite unexplored in short-term SSS and it is unexplored in medium- to long-term SSS, in part because the traditional view of SSS has neglected the influence of context [35].

In order to dissociate and explore the impact of contextual and between-session effects in this study, SSS was assessed using the School cafeteria as a familiar, natural eating context for the study's university participants and our laboratory as a novel context, with half of the sessions conducted in each setting. It can be argued that the acquisition of a context-infusion association should be more prominent when a novel context is used as prior exposure to a stimulus tends to reduce the readiness of that stimulus to enter into new associations [36]. Thus, based on associative theories of habituation, it was hypothesized that repetitive infusion presentations would produce smaller initial hedonic ratings with a smaller magnitude of SSS, as well as more rapid SSS, across sessions in the laboratory compared to the cafeteria setting. SSS was represented by a decrease in pleasantness according to the traditional view, although SSS is not only related to hedonic but also to motivational aspects (i.e. wanting) [37]. Given the role played by olfactory cues in the stimulation of appetite as well as satiation [8], and that SSS has been shown to occur not only for the flavour of food but also for odours

[10], both flavour SSS and olfactory SSS were included. Finally, repeated exposure to a novel food with intervals of days often increases the acceptability and intake of that food, reflecting a reduction in neophobia [38], among other phenomena. To prevent that novelty of the food affected the results and to minimize differences in the initial ratings for hedonic and motivational values, the test food was a typical and familiar food for the participants (drunk at least once a week): a yerba mate (*Ilex paraguariensis*) infusion, an herbal tea beverage widely consumed in South American countries.

2. Methods

2.1. Subjects

Prior to undertaking the study, a sample size calculation was performed with G*Power 3.1 using an α of 0.05, 80% power, and an average correlation of $\rho = .50$ between the repeated measures for 6 within subject conditions in order to detect a small effect ($\eta^2 = 0.045$). We calculated that the experiment required approximately twenty-four participants. The final number of enrollees was twenty-six healthy women, all of them students or staff of the University of Buenos Aires. Initial recruitment efforts for the second experiment did not target women exclusively but, given that study volunteers were predominantly women, the study was limited to women to improve homogeneity. Participants' (mean \pm standard deviation) age was 28.8 ± 9.5 years and body mass index was 22.2 ± 4.2 . As in the Pilot Study (see Inline Supplementary Material), participants were asked to complete the Three-Factor Eating Questionnaire (TFEQ) [39] and the Food Neophobia Scale (FNS) [40]. Their uncontrolled eating, emotional eating and cognitive restraint scores were 18.8 ± 2.8 , 9.6 ± 1.8 and 18.7 ± 2.9 , respectively. Food neophobia score was 27.7 ± 12.2 . All subjects self-reported normal smell and taste sensitivity and none of them mentioned any allergies or aversions to any of the food ingredients used in the present study. They were informed of the general procedure but not the purpose of the experiment, and all participants gave their written consent. The study was approved by the institutional ethics committee of the School of Pharmacy and Biochemistry, University of Buenos Aires.

2.2. Apparatus and solutions

As test food, a sucrose-sweetened mate (SM) infusion prepared at 1.2% w/v by placing tea-like bags containing 3 g of yerba mate with sugar (5% w/v) in 250 mL of water at 90 °C for 6 min was used. The SM infusion and the control foods (crackers, light vanilla flavoured yoghurt and unsweetened corn flakes) were used, prepared and served as described in the Pilot Study (see Inline Supplementary Material). These foods were chosen because of their different sensory characteristics compared with the bitter-sweet infusion and with each other. The laboratory and cafeteria settings that served as contexts were located at the School of Pharmacy and Biochemistry, University of Buenos Aires. According to Meiselman's [41] categorization of environmental influences, the contextual changes were related only to the situation in which the SSS tests were conducted, keeping the food and individual variables constant across sessions. Environmental influences included differences in the dimensions of the room (the ratio of tables for laboratory/cafeeteria was 1:10) and lighting (laboratory > cafeteria). Other differences between contexts were obviously the nature of the environment (a natural eating environment that already exists vs. a non-natural setting as the laboratory) and the number of people present in the room (cafeeteria > laboratory). Since the variations necessary to differentiate two contexts are not clear, the changes applied in this study were similar to those successfully used to demonstrate contextual dependence of learning and memory in human subjects [42] and were based mainly on very dissimilar physical appearance. The sensory properties of foods (taste, temperature and variety), the type of SSS test, the temporal

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