Appetite 63 (2013) 112–118

Contents lists available at SciVerse ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Research report

Sensory-specific satiety for a food is unaffected by the *ad libitum* intake of other foods during a meal. Is SSS subject to dishabituation? ☆

S. Meillon [a,b,c,f,*], A. Thomas [a,b,c], R. Havermans [d], L. Pénicaud [a,b,c], L. Brondel [a,b,c,e]

[a] CNRS, UMR 6265, Centre des Sciences du Goût et de l'Alimentation, F-21000 Dijon, France
[b] INRA, UMR 1324, Centre des Sciences du Goût et de l'Alimentation, F-21000 Dijon, France
[c] Université de Bourgogne, UMR, Centre des Sciences du Goût et de l'Alimentation, F-21000 Dijon, France
[d] Department of Clinical Psychological Science, Faculty of Psychology & Neuroscience, Maastricht University, P.O. Box 616, 6200 MD Maastricht, The Netherlands
[e] Service d'Hépato-Gastroentérologie, CHU Dijon, Dijon, France
[f] CSGA, 9 E bd Jeanne d'Arc, 21000 Dijon, France

ARTICLE INFO

Article history:
Received 27 September 2012
Received in revised form 3 December 2012
Accepted 5 December 2012
Available online 21 December 2012

Keywords:
Sensory-specific satiety
Dishabituation
Pleasantness
Food intake
Meal

ABSTRACT

Sensory-specific satiety (SSS) is defined as a decrease in the pleasantness of a specific food that has just been eaten to satiation, while other non-eaten foods remain pleasant. The objectives of this study were the following: (1) to investigate whether SSS for a food is affected by the *ad libitum* intake of other foods presented sequentially during a meal, (2) to compare the development of SSS when foods are presented simultaneously or sequentially during a meal, and (3) to examine whether SSS is modified when foods are presented in an unusual order within a meal. Twelve participants participated in three tasting sessions. In session A, SSS for protein-, fat- and carbohydrate-rich sandwiches was measured after the *ad libitum* consumption of single type of each of these foods. In session B, SSS was measured for the same three foods consumed *ad libitum* but presented simultaneously. Session C was identical to session A, except that the presentation order of the three foods was reversed. The results indicate that once SSS for a given food is reached, the *ad libitum* consumption of other foods with different sensory characteristics does not decrease SSS, regardless of the order in which the foods are presented. Once reached, SSS is thus not subject to dishabituation during a meal.

Introduction

Sensory-specific satiety (SSS) is defined as a decrease in the pleasantness of a specific food that has just been eaten to satiation, while other non-eaten foods with different sensory characteristics remain pleasant. SSS is a form of negative alliesthesia (the affective part of a sensation) in which the pleasure induced by a stimulus decreases until that stimulus becomes neutral or even unpleasant (Cabanac, 1971). SSS plays an important role in food intake and food choice by promoting the end of an eating bout and the search for food variety (Hetherington & Rolls, 1996).

The mechanisms involved in the development of SSS are not completely understood. SSS is assumed to be a primarily sensory-based phenomenon because it is not related to post-ingestive and post-absorptive effects of food ingestion. Indeed, SSS is reached quickly after food ingestion (Rolls, Rolls, Rowe, & Sweeney, 1981), and sensory stimulation without ingestion (sham feeding) leads to partial SSS (Rolls & Rolls, 1997; Smeets & Westerterp-Plantenga, 2006). The sensory properties of a food that contribute to the development of SSS include its smell (Rolls & Rolls, 1997), taste (Brondel, Lauraine, Van Wymelbeke, Romer, & Schaal, 2009; Rolls & Rolls, 1997), texture (Guinard & Brun, 1998), and visual appearance (colour and shape) (Rolls, Rowe, & Rolls, 1982). SSS is not the result of a decrease in taste sensitivity because the decrease in the pleasantness of a food eaten *ad libitum* is not related to one's capacity to detect a decrease in taste intensity (Rolls, Rolls, & Rowe, 1983). A study conducted in nonhuman primates confirmed that the responsiveness of gustatory neurons in the nucleus tractus solitarius (NTS) is not decreased after repeated presentations of sweet foods (Yaxley, Rolls, Sienkiewicz, & Scott, 1985).

SSS is thought to result from a habituation mechanism (Epstein, Temple, Roemmich, & Bouton, 2009). Habituation is defined as a decrease in responsiveness to a stimulus when that stimulus is presented repeatedly or for a prolonged time (Groves & Thompson, 1970). This decrease appears to be a central neural process because it is specific to one stimulus; the responses to other stimuli recover (Thompson & Spencer, 1966). Habituation is considered to be a

☆ *Acknowledgements:* We gratefully acknowledge Philip Bastable of the "Research Pole" of Dijon University Hospital for revising the English. We also gratefully acknowledge Michael A. Romer for reviewing the manuscript and for his useful advice.

* Corresponding author.
E-mail address: sophie.meillon@dijon.inra.fr (S. Meillon).

0195-6663/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.appet.2012.12.004

form of learning that allows "animals/humans to filter out irrelevant stimuli and focus selectively on important stimuli" (Rankin et al., 2009). In the case of SSS, habituation induces reductions in both physiological and behavioural responses to eating, i.e., food-specific decreases in salivation (Epstein, Rodefer, Wisniewski, & Caggiula, 1992), pleasure (Rolls et al., 1983) or wanting for the food (Havermans, Janssen, Giesen, Roefs, & Jansen, 2009). Neurobiological studies in nonhuman primates (Rolls, Critchley, Browning, Hernadi, & Lenard, 1999; Rolls, Sienkiewicz, & Yaxley, 1989) and humans (O'Doherty et al., 2000) have confirmed the existence of a food-specific habituation mechanism by demonstrating both a decrease in the response of neurons in the orbitofrontal cortex to a food eaten to satiety and a recovery in the response to other foods not eaten to satiety.

In a review, Thompson and Spencer (1966) showed that there are nine general characteristics of the habituation response. The description of one of these characteristics was revised and refined by Rankin et al. (2009), who determined that when habituation occurs, the "presentation of a different stimulus results in an increase in the decremented response to the original stimulus. This phenomenon is termed "dishabituation". Is this characteristic applicable to the SSS response, and is SSS subject to dishabituation?

In other words, if SSS is a habituation mechanism, the pleasantness of a food eaten *ad libitum* should be restored, at least in part, when a new food is introduced (dishabituation). In accordance with this hypothesis, several studies have shown that the presence of dishabituating stimuli, such as food variety or a distraction (e.g., TV, music or video games), during ingestion promotes food intake and delays the development of SSS (Brondel, Romer, Van Wymelbeke, Pineau, Jiang, et al., 2009; Epstein et al., 1992; Hetherington, Foster, Newman, Anderson, & Norton, 2006). However, to our knowledge, only one study has examined whether the introduction of a new food can restore the pleasantness of a food that was recently eaten *ad libitum*. Indeed, Havermans (Havermans, 2012) observed that once SSS for a test food was established, neither the consumption of a new food nor distraction by a computer game dishabituated the SSS for the test food. Therefore, these findings suggested that SSS is not subject to dishabituation.

To our knowledge and in agreement with the findings of Havermans (Havermans, 2012), the process of SSS for foods eaten during a multicourse meal has never been studied. In Western countries, meals generally consist of three consecutive courses. One might wonder how SSS for a course eaten *ad libitum* might evolve after other courses had been eaten *ad libitum*. Is SSS for a course subject to dishabituation when other courses are eaten *ad libitum* afterwards?

The main objective of our study was to investigate whether SSS for a food is affected by the *ad libitum* intake of other foods presented sequentially during a meal. The secondary objectives of our study were to compare the development of SSS during a meal in which foods are presented sequentially with that during a meal in which foods are presented simultaneously and to examine whether SSS is affected when foods are presented in an unusual order during a meal.

Methods

Participants

Twelve participants (six men and six women) were recruited from the undergraduate student population of the University of Dijon, France. To be included, participants had to be between 20 and 35 year of age and in good health. The exclusion criteria were the following: pregnancy; pathologies such as diabetes, impaired renal function and acute and chronic infection; smoking (more than five cigarettes/day); aversion for any of the foods consumed during the study. All the participants provided written consent to participate in the experiment, which was approved by the Regional Ethics Committee of Burgundy (France).

General procedure

The participants participated in three 30-min sessions (A, B and C) in the Centre for Taste and Feeding Behaviour in Dijon. Sessions A and B were separated by a 7-day interval, and the order of the sessions was randomised. Session C, which had not been planned prior to the commencement of the experiment, was conducted 3 weeks after the second session in order to complete the study. Each session began at 10 a.m. and occurred in isolated sensory booths that were maintained at a standardised temperature (20 ± 1 °C). The participants were instructed to not eat, drink or smoke during the morning of a test and to fast between the test and the evening meal on the preceding night.

Before and after a snack (see below), the participants indicated their level of hunger using a 100-mm visual analogue scale that was anchored at its ends by the statements "not at all hungry" (0) and "very hungry" (+100). The participants also indicated the intensity of their desire to eat at that moment using a 100-mm visual analogue scale that was anchored by the statements "not at all" (0) and "very much" (+100).

Food stimuli and snack intake

In each session, a snack was offered. This snack consisted of six different types of open sandwich served on a plate. The choices comprised one slice of white sandwich bread (Harry's Moelleux, Barilla and Fratelli Corp., Parma, Italy; 17 g, 194.7 kJ) with 15 g of either turkey ham, duck breast, cheese, butter, jam or honey and cut into nine equal, square pieces measuring 30 mm × 30 mm. Therefore, the sandwiches were rich in either protein, fat, or carbohydrate. The protein-rich sandwiches were the turkey ham (Blanc de Dinde, Carrefour, France; proteins: 91 p.100 w/w total nutrients) and duck breast sandwiches (Magret de canard du Sud-Ouest fume, Delpeyrat, France; proteins: 67 p.100 w/w total nutrients). The butter (Beurre tendre, Elle & Vire, France; lipids: 98 p.100 w/w total nutrients) and cheese spread sandwiches (Fromage à la crème, Elle & Vire, France; lipids: 73 p.100 w/w total nutrients) were fat-rich. The carbohydrate-rich sandwiches were the strawberry jam (Confiture de fraises, Carrefour, France; carbohydrates: 99 p.100 w/w total nutrients) and honey (Miel Mille Fleurs, Lune de miel, France; carbohydrates: 99 p.100 w/w total nutrients) sandwiches. The energy contents of the turkey ham, duck breast, butter, cheese, jam and honey sandwiches were 36.8, 41.9, 83.7, 48.1, 49.8 and 51.1 kJ, respectively.

The meal presented in this study was simplified for practical reasons, and sandwiches were chosen to standardise the volume of the foods ingested in each course. The sandwich ingredients were chosen because they strongly evoked the sensory properties (smell, taste, texture and appearance) associated with proteins, fats or sweets, rather than for their macronutrient content. Specifically, turkey ham and duck breast were associated with a strong "protein image", butter and fat cheese were associated with a strong "fat image", and honey and strawberry jam were associated with a strong "sweet image".

Procedure for sessions A, B and C

During the first session, the participants tasted and rated their liking of the six different sandwiches. After this first rating, the experimenter selected the more highly rated of each type of sandwich (protein-, fat- and carbohydrate-rich) to serve as the snack.