Mental workload during (un)familiar food tasting experiences

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Abstract. Food product experiences have already been studied from different phases interaction and by different measures. However, the measurement of the mental workload during the interaction with food products in a tasting experience has not been deeply investigated in literature. The aim of this study is to investigate such reactions using the Electroencephalography (EEG): brain signals have been recorded with a 6-channel system (EEG frontal theta) in order to test the interaction across two foreign food products and two local ones. Furthermore, participants were asked to evaluate familiarity with the products at first sight and after having tasted it. The EEG was processed in order to obtain a mental workload index, while the familiarity index was obtained as an average value on the declared judgments. A higher mental effort and less familiar perception was found during the tasting interaction with foreign products than with local ones. Results could deepen the knowledge on the cognitive response to food products tasting experiences characterized by their different origin in terms of familiarity.

Keywords: Mental workload, tasting experience, food, familiarity, EEG.

1 Introduction

In recent years the food and beverage sectors have been taken advantage of neuroscientific techniques for consumers' studies. Researchers and companies apply those methods to the study of products on its extrinsic features such as packaging, price, colour or shape and on its intrinsic features, such as taste and aroma. In particular, the term *neurogastronomy* has grown up in the last years [1] [2], and within it the interest in the cognitive processes related to the taste sense. The studies carried out so far in the perception of consumers towards food and beverages have determined the importance of the perception of products in their final choice and acceptance in the market[3]–[5]. The hedonic perception of taste can be modulated by diverse factors, including consumption habits or the subconscious associations of products. A factor that could influence on the perception of food is the familiarity with it. Product familiarity is defined as "*the evaluated judgment of consumers regarding their subjective knowledge about the product"* [6]. Unfamiliar foods generate less positive expectations towards the product [7] and their absence of previous taste experiences are linked to low hedonic consumer perception[8]. So, the familiarity with a product is important for cross-cultural researches as products that are consumed in one culture could not be accepted or easily to perceive for different cultures consumptions[9]. Generally traditional likings' ratings are used to measure how acceptable is a product in cross-cultural researches. However, as described above, rational responses may not represent consumer preferences totally. Thanks to neuroscientific studies these aspects can be deeply understood. Particularly, the gustatory system and its human brain processing information has been deeply examined using techniques like functional Magnetic Resonance Imaging (fMRI) and magnetoencephalography (MEG)[10]. The initial sensory processing of taste is associated with the insula [11], which is considered the primary taste area. Instead, the secondary taste area is associate with the orbitofrontal cortex and pre-frontal cortex, as they are related to the taste hedonics' recognition [12]. Several studies employing the Electroencephalography(EEG) focused on the Pre-Frontal brain areas confirmed the relationship between prefrontal brain activity and the taste processing information [13], [14]. The possibility of the application of a non-invasive technique like EEG allows to investigate brain processes not only in laboratories, but also during daily activities in life. Particularly in the food and beverage sector, several studies imply EEG technique to analyse the extrinsic products features [5][15] and also intrinsic ones[16], [17]. Most of these researches are focused on understanding brain processes when an experience is pleasant or unpleasant by the imputation of an Approach-Withdrawal Index[5], [18], calculated by means

of motivational processes in terms of alpha band (8-12 Hz), towards the stimuli based on which an increasing left hemisphere activity is associated with approach attitude to the stimulus, while an increasing right hemisphere activity is associated with withdrawal attitude[19]. On the other hand, changes in the EEG spectral power over the frontal scalp areas in theta frequency band (4-7Hz) have been connected to higher levels of task difficulty[20], its increase has been observed when the required mental workload increases [21]. Particularly the term "*mental workload"* can be defined as the proportion of information processing capability used to perform a task[22][23] and it involves neurophysiologic, perceptual and cognitive processes[24]. A high level of mental workload reflects not only task specificities, but also performer features[25]. It is applied in different research fields: neuro-aesthetics[26], for the detection of the effort employed during avionic and car driving tasks [27][28], during different challenging listening conditions [29], during human–computer interaction studies[30]. It is considered a very relevant mental concept in cognitive neuroscience applied to those fields where human decision-making is crucial, such as neuroeconomics and neuromarketing because of its close relationship between human performance[31]. Despite this evidence, the mental workload has not yet been studied in taste research. Therefore, the aim of this paper is to investigate the cognitive reactions of a group of local (Italian) people to the cross-sensory interaction with an intrinsic feature(taste) of products belonging to different countries (foreign and local). We estimated such cognitive reactions by using the mental workload index mentioned above. We investigated the influence of the familiarity with the products on these brain processes in order to predict if the external factors such as the origin of the products can influence on its decoding information processes during its tasting experience. Results will shed light on business applications for food companies/marketers and in academic researches on the brain circuits during a taste experience. Based on the aforementioned literature, the following research hypothesis was posed:

H1: Foreign products which are unfamiliar for consumers before and after the taste experience have higher mental workload values than local products during the tasting experience.

2 Materials and methods

2.1 Experimental protocol

Eight healthy volunteers (four female) all of Italian nationality have been involved in the study. None of them consumed Chinese food in their daily routine. Informed consent was obtained from each participant after the explanation of the study, which conformed to the revised Declaration of Helsinki and was approved by the local institutional ethics committee. The experiment consisted in the comparison of two different typologies of food products: a foreign group with Chinese products and the local one with Italian products. The foreign group consists of four different products, where the two most unfamiliar ones were chosen for the study; and the local group of two different products. Products were randomized and the same portion of food was given to all participants. During the study, participants interacted with the products during three different phases:

1. Observation of an empty plate as baseline (30 s)
2. Product observation (30 s)
3. Product tasting of variable duration.

Participants were asked to evaluate their level of familiarity with the products on a scale from 0 to 10 before and after the taste of each one. The question was: "How familiar are you with the (aspect/taste) of this product?". Thanks to the interview it was possible to choose the two foreign products that were less familiar to consumers in order to be compared with the two local products, both in terms of aspect (*before taste* question) and taste (*after taste* question). Figure 1 shows the four products tested.

Local Product 1

Local Product 2

Foreign Product 1

Foreign Product 2

Figure 1. Foreign and local products tested.

2.2 Signal processing

The frontal brain activity has been recorded by means of 6 dry electrodes (Fpz, AF3, AF4, AFz, F3, F4) using the LiveAmp system (BrainProducts) with a sampling frequency of 250 Hz. All the electrodes were referred to both earlobes and their impedances were kept below 10 kΩ. The EEG signals were firstly band-pass filtered with a fifth-order Butterworth filter between 1 and 30 Hz and then segmented into epochs of 1 s. The Fpz signal has been used to correct eyes-blink artifacts from the EEG data by means of the Reblinca algorithm[32]. Each EEG epoch with amplitude higher than ±80 μV or the slope trend higher than 3 was removed in order to have an artifact-free EEG dataset.

2.3 Mental workload Computation

From the artifact-free EEG dataset, the Power Spectral Density (PSD) was calculated for each EEG epoch using a Hanning window of 2 seconds with a buffer of 125 ms. Then, the EEG frequency bands were defined accordingly with the Individual Alpha Frequency (IAF) value estimated for each subject. The alpha peak has been obtained before starting with the experiment asking to the subject to keep his eyes closed for one minute, because the alpha peak is maximum during this condition. In particular, the theta (IAF-6 ÷ IAF-2) band has been defined. The Mental workload has been computed as the average of the PSD in theta band over the frontal electrodes. The difference respect to the baseline has been considered.

2.4 Performed Analysis

Wilcoxon signed-rank test [33] has been performed to assess the difference between the total average of the familiarity of both Foreign and Local products, and to compare the experienced mental workload during the tasting of both Foreign and Local products.
Two different Pearson correlation analysis[34] has been performed between the average mental workload during the taste experience and the declared average familiarity towards the products before (during the products' observation) and after the tasting.

3 Results and discussion

3.1 Declared results

In figure 2 the results on the declared judgments of participants before the taste experience-during the observation- showed a significant less familiarity for foreign products than local ones (p=0,0156) in the sight perception.

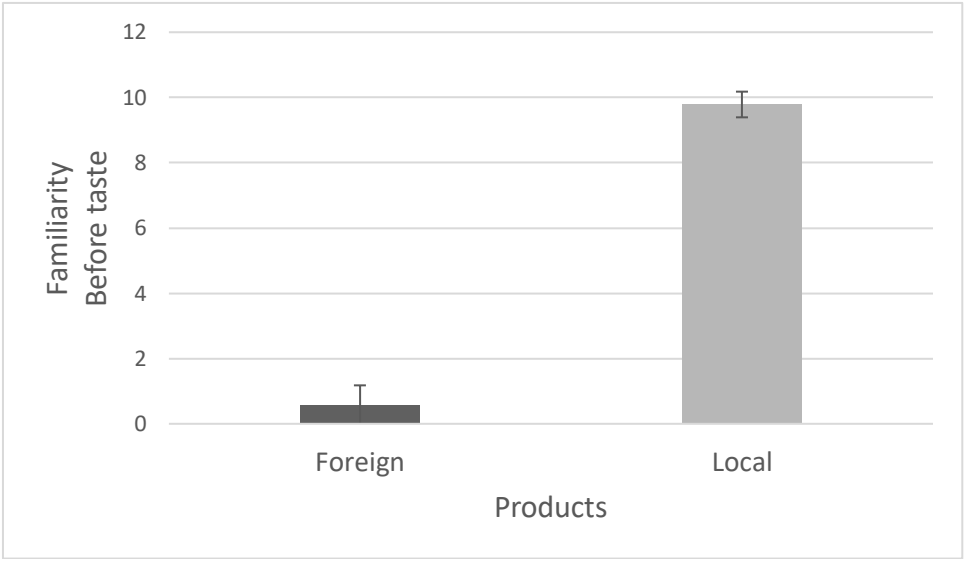

Figure 2. The graph shows the average declared familiarity values reported participants before the taste of the products. Error bars represent standard error.

Results on the declared judgments of participants after the taste experience in figure 3 showed a significant less familiarity for foreign products than local ones (p=0,0156) in the taste perception.

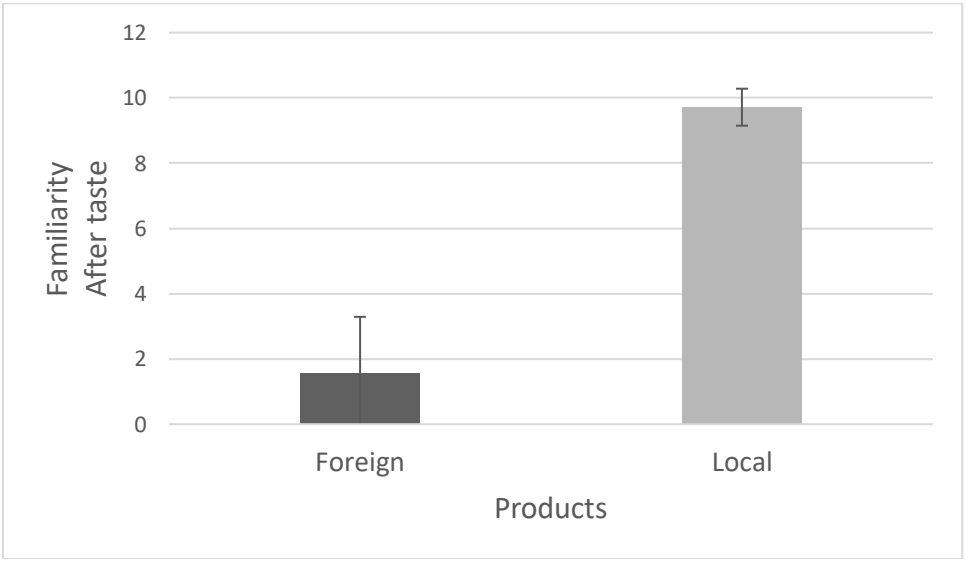

Figure 3. The graph shows the average declared familiarity values reported by the participants after the taste of the products. Error bars represent standard error.

3.2 Mental workload results

Results on the mental workload of participants during the taste of foreign products reported a significant higher mental workload than for the local ones (p=0,0156) (Fig. 4).

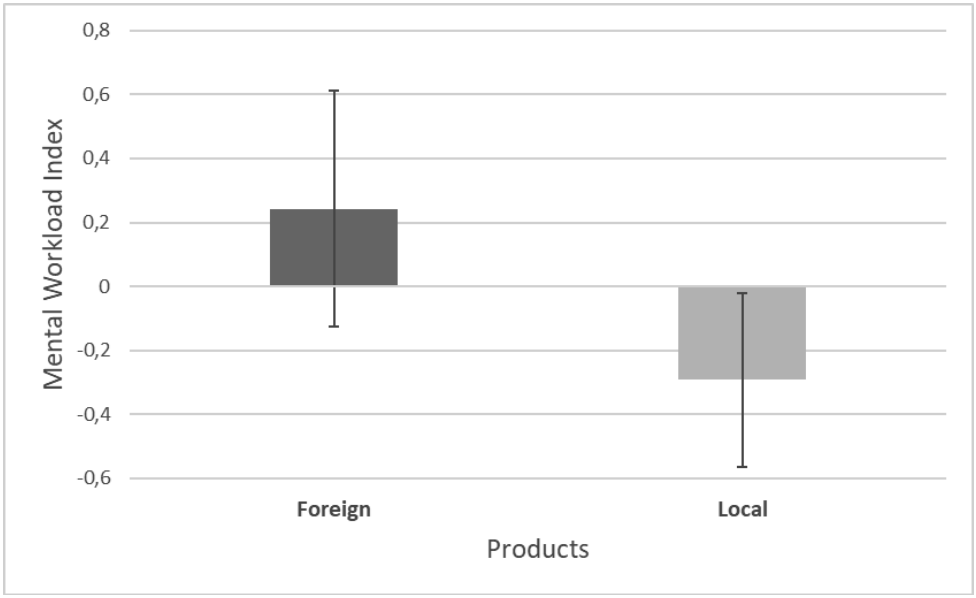

Figure 4. The graph shows the average mental workload during the taste of the products. Error bars represent standard error.

3.3 Mental workload and declared correlation results

The results showed a considerable negative correlation of the mental workload during the taste of products and their familiarity consumer perception before and after the taste. Figure 5 shows the significant negative correlation between the familiarity with the product before the taste (sight) and the mental workload during the taste (R= -0.6408; p= 0.0135). Figure 6 shows the significant negative correlation between the familiarity with the product after the taste (taste) and the mental workload during the taste (R= -0.5502; p=0.0415).

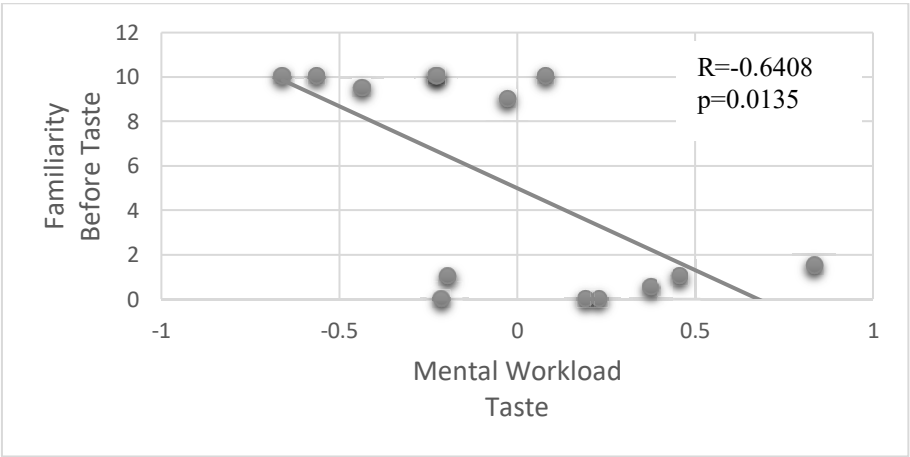

Figure 5. Correlation between Mental Workload and Familiarity before the taste.

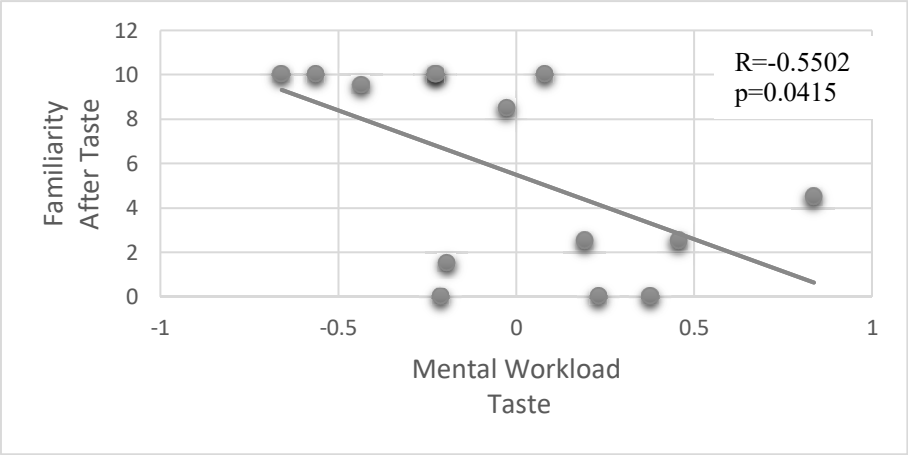

Figure 6. Correlation between Mental Workload and Familiarity after the taste.

3.4 Discussion

The selected foreign products of the study had very different extrinsic features, such as color and shape, from the traditional Italy food. It enables consumers to recognize on a first contact with products their unfamiliarity, as the visual aspects were not recognized by previous models. This first impression could be considered as an expectative to the flavor. In fact, after the tasting experience, the difference between the declared familiarity of both groups of products (foreign and local) was also significative. This fact confirms that not only the sight but also the taste was not recognized. In the measurement of the brain activity during the taste interaction with the products, participants knew that after the taste they would be asked some questions. Therefore, during the taste experience they tried to recognize the flavor that they were tasting. On the one hand, the results of the declared familiarity after the taste show the unfamiliarity with foreign products. On the other hand, the results of the mental workload index show that this process requires higher frontal brain activity. These results confirm what previous literature says about the relationship of an unfamiliarity product with the consumer mental workload[5] and about the perception of the aesthetic experience (in this case considered as the observation before the taste): it is significantly modulated by the previous specific knowledge experienced by the participants[26]. The added value of this study lies in the innovation of the application of this cognitive index during a taste experience. Moreover, the correlation of the mental workload index and the familiarity shed light for food practitioners and different fields researchers. The insertion of products in new markets requires a high investment for companies, therefore a correct understanding of the consumers' brain processes against unfamiliar products could shed light on how to design the products based on the market where companies want to enter. Also, when chefs create new products, they should be aware that unfamiliar foods will elicit different brain responses in consumers. In the academic field, these results can be applied to different topics, such as the multisensory(sight-taste) interaction with products; the mental workload index application on a taste experience and the (un)familiar relation with mental workload. Finally, further research should be done with a group of participants that usually consume foreign products (considered as *experts*), in order to test if the workload index is still modulated as in this study with "non experts".

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