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Wine tasting: a neurophysiological measure of taste and olfaction interaction in the experience

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Abstract. In the last years have been provided evidences of sensory–sensory connectivity and influences of one modality over primary sensory cortex of another, a phenomena called crossmodality. Typically, for the wine tasting, sommeliers in addition to the use of the gustation, by the introduction of the wine into the mouth, employ the stimulation of the olfactory system both through a direct olfactory stimulation (by the nose) and a retro-nasal pathway (inhaling air while swirling the wine around in the mouth). Aim of the present study was to investigate the reaction to the wine gustation with and without the direct olfactory contribution, through an electroencephalographic index of approach or withdrawal (AW) motivation, and an autonomic index (Emotional Index – EI), deriving from the matching of heart rate and galvanic skin response activity and considered an indicator of emotional involvement. Results showed a statistically significant increase of the EI values in correspondence of wine tasting with the olfactory component ($p<0.01$) in comparison to the tasting without the direct olfactory contribution, and a trend of greater approach attitude was reported for the same condition. Data suggest an interaction of the two sensory modalities influencing the emotional and the cognitive aspects of wine tasting experience in a non-expert sample.

Keywords: List 5-8 keywords (e.g. Cardiac Tissue; Membrane; Cell Function)

1. Introduction

In the last years, the phenomena called cross-modality has been receiving growing interest, it has been defined as sensory–sensory connectivity and influences of one modality over primary sensory cortex of another [Driver and Noesselt 2008]. This interaction between sensory modalities have been investigated both at a cellular and a functional level [Poirier et al 2007; Ibrahim et al 2016], also in relation to stimuli memorization [Chiang et al 2016], since considering, beyond cross-modality, the study of synesthesia (i.e. the experience of feeling one sensation in response to a different sensory stimulus) [Saenz and Koch 2008; Pearce 2007]. The importance of studying the interaction among sensory modalities becomes of immediate clarity when applied to the study of a daily experience for humans: food and wine perception. In fact, in the case of food, cross–modal interactions occur between aroma, taste and texture [Poinot et al 2013]. Furthermore, “flavor is perhaps the most multi-modal of all of our sensory experiences” [Small et al 2012], where flavor has been defined as a perception including gustatory, oral-somatosensory, and retronasal olfactory signals, arising from the mouth during foods and beverages consumption. Moreover, typically, for the wine tasting, sommeliers in addition to the use of the gustation, by the introduction of the wine into the mouth, employ the stimulation of the olfactory system both through a direct olfactory stimulation (by the nose) and a retro-nasal pathway (accomplished by air inhalation while swirling the wine around in the mouth).

The distinction between these two olfactory stimulation modalities is worthy, since evidences showed that in correspondence of congruent taste–odor pairs using the orthonasal route (implying subjects to sniff), neural suppression occurred in chemosensory regions [Small et al 2004]. The convergence of taste and odor, firstly thought to occur only at the level of the orbitofrontal cortex, has been showed already at the insula [Small et al 2012] and piriform cortex [Maier et al 2012; Small et al

2013] levels. Therefore, analysis of the contribution of olfaction to the process of wine tasting is fundamental in order to study flavor perception.

Aim of the present study was to investigate the reaction to the wine gustation with and without the direct olfactory contribution, through an electroencephalographic index, assumed as an indicator of approach or withdrawal (AW) motivation [Davidson et al 1990], and an autonomic index (Emotional Index – EI), based on the circumplex model of affect [Russell and Barrett 1999], and deriving from the matching of heart rate and galvanic skin response activity, considered an indicator of emotional involvement [Vecchiato et al 2014].

The AW index has been already applied to food taste [Di Flumeri et al 2017] and odor [Di Flumeri et al 2016; Kim and Watanuki 2003; Henkin and Levy 2001]. Concerning the emotional index, a list of 16 emotional words has been defined by a behavioral categorization study through the use of the model of circumplex affect [Russell and Barrett 1999]; the words were in fact classified on the basis of pleasantness/unpleasantness and arousal (high/low) describing the wine tasting [Ferrarini et al 2010]. The EI has been already applied to neuromarketing studies on advertising [Cherubino et al 2016a,b] and antismoking public service announcements [Cartocci et al 2017], supporting the suitability of its use to product testing.

2. Material and Methods

2.1 Sample and Protocol

Participants were naïve wine-taster subjects, balanced for gender, with an average age of 37.5±15.52. The experimental procedure consisted in the tasting of two Italian wines (Sangiovese and Morellino di Scansano) once in the Open Nose and after that in a Closed Nose condition, resulting in a total of four wine tastings. The Closed Nose condition was performed with the participants wearing a nose clip. Wines were randomly assigned to participants and served at room temperature in order to avoid undesired temperature-related effects [Craig et al 2000]. Participants were asked to drink from the glass and to keep the wine into the mouth for 10 seconds before swallowing (Fig. 1). The quantity was 20 ml for each wine trial, and before each trial participants were instructed to drink a glass of water.

Figure 1. *The picture represents one of the participants equipped with the EEG band on the forehead and the autonomic sensors on the fingers during one of the wine tasting trial.*

2.2 EEG Recordings and Signal Processing

The EEG signal was recorded Hz by the BrainVision LiveAmp amplifier (Brain Products GmbH), with a sampling frequency of 250 by 8 EEG electrodes [Fp1, Fpz, Fp2, AF3, AFz, AF4], following the 10-20 International System, and the impedances were kept below 10 kΩ. Each EEG trace was then converted into the EEGlab format in order to perform signal preprocessing such as artefacts detection, filtering, and segmentation. The EEG signals have been band pass filtered at 2–30 Hz and depurated of ocular artefacts by using the independent component analysis (ICA). The EEG data have been rereferenced by computing the common average reference (CAR). Individual alpha frequency (IAF) has been calculated for each subject in order to define four bands of interest according to the method suggested in the literature [Klimesch, 1999]. Such bands were reported in the following as IAF+, where IAF is the individual alpha frequency, in Hertz, and is an integer displacement in the frequency domain which is employed to define the band ranges. In particular, we focused the present analysis on the alpha bands (IAF-4, IAF+2).

To summarize the activity from all these electrodes, the Global Field Power (GFP) was computed. This is a measurement introduced by Lehmann and Skrandies [1980] to summarize the overall activity over the scalp surface. GFP is computed from the entire set of electrodes by performing the sum of the squared values of the EEG potential at each electrode, resulting in a time-varying weveforms related to the increase or decrease of the global power in the analyzed EEG.

The cerebral appreciation has been monitored in the target population by using the Approach Withdrawal index, according to the theory related to the EEG frontal asymmetry theory [Davidson, 2004]. The AW index is correlated to the unbalance of the right and left prefrontal activity. The formula used is the following:

$$AW = GFP_{\alpha\_right} - GFP_{\alpha\_left} \quad (1)$$

Where the GFP_{α_right} and GFP_{α_left} stand for the GFP calculated among right (Fp2, AF4) and left (Fp1, AF3) electrodes, in the alpha band, respectively. The waveform of AW cerebral index has been estimated for each second and then averaged for all the duration of the stimuli. The AW index was then standardized according to the baseline EEG activity acquired at the beginning of the experiment. Positive AW values mean an approach motivation toward the stimulus expressed by the subject, while negative AW values a withdrawal tendency. The AW index was in fact normalized returning a z-score values across all the experiment for each subject. In fact, such index has been defined by taking into account the frontal EEG asymmetry’s theory by Davidson and coworkers.

2.3 The Autonomic data recordings and signal processing

The Blood Volume Pulse (BVP) and Galvanic Skin Response (GSR) have been recorded with the Shimmer System (Shimmer Sensing, Ireland) with a sampling rate of 52 Hz. For the recording of these signals, three were placed to the palmar side of the middle phalanges of the second and third fingers, on the non-dominant hand of the participant, according to published procedures [Boucsein et al 2012]. In order to obtain the Heart Rate signal from the BVP, it has been used the Pan-Tompkins algorithm [Pan and Tompkins 1985]. The constant voltage method (0.5 V) was employed for the acquisition of the skin conductance and by using of the LEDAlab software [Benedek and Kaernbach 2010], the tonic component of the skin conductance (Skin Conductance Level, SCL) was estimated.

In order to match GSR and HR signals producing a monodimensional variable which returns the emotional state of subjects, the Emotional Index has been defined by taking into account the GSR and HR signals [Vecchiato et al 2014]. We refer to effects plane [Russell and Barrett 1999; Posner et al. 2005] where the coordinates of a point in this space are defined by the HR (horizontal axis) and the GSR (vertical axis). Several studies have highlighted that these two autonomic parameters correlate with valence and arousal, respectively (see [Mauss and Robinson 2009] for a review). The interpretation of the EI implies that the higher the value the more positive the emotion experienced by the subject and vice versa.

3. Results

3.1. Approach Withdrawal Index

Despite not reaching the statistical significance due to the relative high variance of the estimates, Approach Withdrawal Index results provided evidence of a trend characterized by Approach tendency in the condition with the nose via accessible, while a tendency of Withdrawal in the condition without the olfactory contribution to the wine tasting (t=-0.681 p=0.521) (Fig. 2).

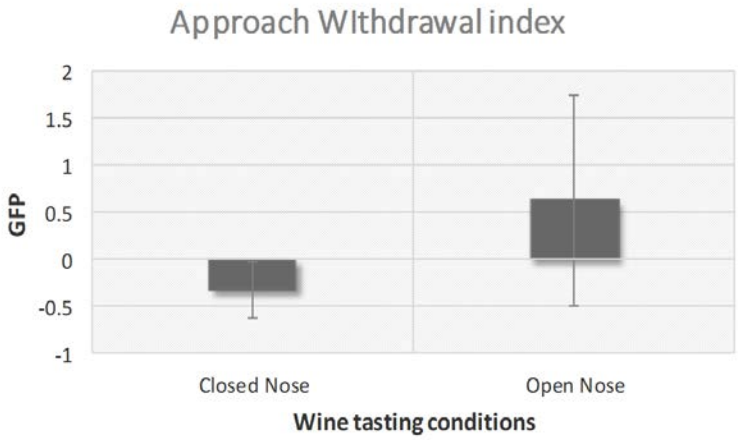

Figure 2. *The graph showes the average AW values reported by the experimental group in the two wine tasting conditions (Closed and Open Nose). Error bars represent standard error.*

3.2. Emotional Index

Emotional Index results showed a statistically significant increase in correspondence of the Open Nose condition, in comparison to the Closed Nose condition (t=-5.032 p=0.004) (Fig. 3). We remind that the higher the value of the Emotional Index, the higher the positive emotion perceived by the subjects and viceversa. In this respect, Fig.3 clearly show a positive emotional increase with respect to the baseline of the condition with the Open Nose than in the Closed Nose situation.

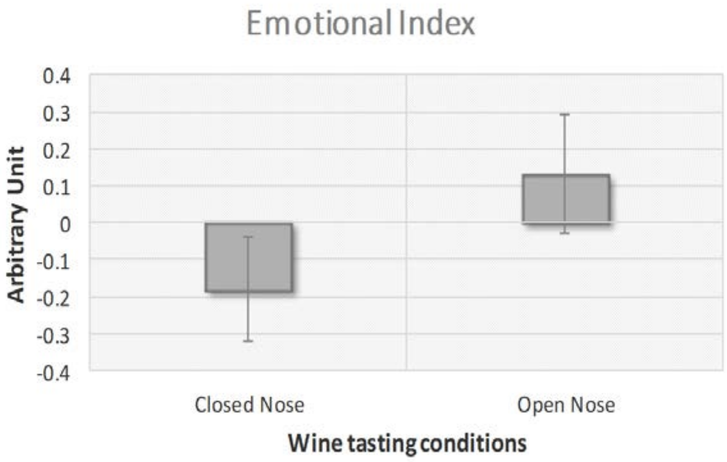

Figure 3. *The graph showes the average EI values reported by the experimental group in the two wine tasting conditions (Closed and Open Nose). Error bars represent standard error.*

4. Discussion

The physiology involved in the wine tasting suggest as the wine volatile substances warmed by the hand in the glass before the degustation could target immediately the olfactory areas, by contributing to the formation of the taste sensation. However, it is a common experience that the wine tasting experience will be poor if the subject has a cold. In particular, it is generally suggested do not drink costly wine in such condition, since the absence of olfaction modality could decrease greatly the pleasure to drink wine. The present data support numerically such old heuristic observation between experts. In fact, data suggest a clear interaction between the two sensory modalities oftaste and olfaction, since it was observed an increased emotional and l cognitive appreciation of wine tasting experience with the Open Nose when compared to the Close Nose condition.

Thus, both emotional and cognitive appreciation were increased on average by allowing to the volatile substances of the wine to proper target the olfactory areas. The increased emotional appreciation was obtained in naïve subjects also by using functional Magnetic Resonance Imaging in previous study [Castriota-Scanderbeg et al 2005]. Taken together, these results suggest as the modulation of the Open Nose condition was important in the wine degustation when compared to the Close Nose (or cold) condition. For all concern the fact that the cognitive increased appreciation for the Open Nose condition was not significantly different from chance although it demonstrated a clear increase in the average value, we hypothesize that this could be due to the high variance estimated for the AW index. However, it is not possible to disentangle such result from also the fact that the result was not obtained in professional wine taster, e.g. sommeliers. In fact, it was found in previous research [Castriota-Scanderbeg et al 2005] that sommeliers showed a bilateral activation in the prefrontal cortex during wine tasting. This could suggest that the lack of statistical significance found in the AW index (that it is based on the unbalance of the prefrontal cortices activitity) in the present study could be influenced by the expertise of the participants.

5. Conclusions

It has been shown that the "experienced pleasantness" for the wine tasting results from intrinsic properties (such as the molecular composition of a drink) and the state of the individual (such as being thirsty) [Allison and Uhl 1964], together with extrinsic properties (such as price) of products [Plassmann et al 2008]. Plassman and colleagues provided evidence that varying the price of wine affects the BOLD activity in the medial orbitofrontal cortex, an area associated to experienced pleasantness, but not in areas associated to primary taste. Therefore, it would be interesting to further investigate also extrinsic properties of the wine by such neurophysiological indicators. Finally, due to the possible influence of the expertise of participants it would be worthy to investigate also this contribution to the neurophysiological response.

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