SAPIENZA UNIVERSITÀ DI ROMA
BRAINSigns

Research report on the cerebral correlates of the Sangiovese wine tasting - (Rome, August 6th , 2018)

Foreword

This BrainSigns study was supported by the Fondazione Banfi through a grant ended in June 2018. It was a pleasure to communicate that **all** the goals illustrated in the submitted research have been achieved. The research developed has been published in an international, peer-reviewed journal and in a chapter on a book edited by Springer International, by fulfilling the claim of the research grant to produce 2 publications within the end of such research **(1,2)**. As described in the proposal, the study has considered two groups of persons who drinked the Sangiovese wines in test. The first group was of "normal" wine tasters (e.g. people not trained to taste wine but just normal wine drinkers without any specific preparation) and the second group was composed by "expert" wine tasters (e.g. people who are professionally interested in the Sangiovese wine tradition and Sangiovese wine tasting). Results of the research pointed toward the existence of different ways in which our brain appreciated a good wine between "normal" and "professional" wine tasters. It emerges an interpretation in which during the drinking of a glass of wine there is a sort of swing between the emotional part, maximally present during the smell phase, and the intellectual part (including the analysis of the wine texture and flavours) during the tasting. In this part of the experience the final judgment on the wine could be "cerebrally" formed. Such results will be further enlarged in future investigations on this specific research theme.

Sincerely,

Prof. Fabio Babiloni

Publications on international journals and book for this specific grant

1) Cartocci, ...and **Babiloni**: Wine tasting: a neurophysiological measure of taste and olfaction interaction in the experience, *International Journal of Bioelectromagnetism Vol. 19, No. 1, pp. 18 -24, 2017*

2) Cherubino, ... and **Babiloni**, Wine tasting: how much is the contribution of the olfaction? *Neuroeconomic and Behavioral Aspects of Decision Making - Computational Methods in Experimental Economics (CMEE) Conference, Springer International, 2018, in press.*

Cerebral and emotional correlates of the Sangiovese wine tasting in naïve and expert testers

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1 Introduction

Agricoltural companies and wine manufacturers are operating in the environment with a high level of competition and therefore it is essential for them to retain and even improve their market position to reach high production process efficiency (Bielik and Hupkova 2011; Raz et al. 2008). This led some manufacturers and re- tailers to try creating a positive emotional connection to their brand, product, and point of sale (Malär et al. 2011). The most challenge of marketing discipline is to understand the consumer behaviour, and marketers are constantly trying to find new tactics and new methodologies to influence and to evaluate the behaviour. In this context, neuromarketing is a new discipline that allows as to view what is happening in the human brain, and which is the perception about the product or the customer experience (Horská et al. 2016).

Several scientific studies have focused on the relationship between emotion and odor. The connections between the two have been used by many authors in the classical and contemporary literature (Kohler et al. 2007). Physiologically, olfac- tory stimuli are processed according to their emotional content, even when any emotional context is lacking. Like emotions, odors may be given positive (appeti- tive), negative (aversive) or neutral valence. These close connections, which all of us encounter in everyday life, are related to cerebral substrates common to the two. In the sensory processing, the idea of the multidimensional integration has long been used to frame a range of questions about the cross-modal interactions in the physiological and behavioural responses (Stein et al. 1996; Wallace and Stein 1997; Armony and Dolan 2001; Laurienti et al. 2003).

In the last year, this phe- nomenon (cross-modality) has been receiving growing interest, it has been defined as sensory-sensory connectivity and influences of one modality over primary sen- sory cortex of another (Driver and Noesselt 2008). 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, "flavour is perhaps the most multi-modal of all our sensory experiences" (Small et al. 2012), where flavour has been defined as a perception including gustatory, oral-somatosensory, and retronasal ollfacoty sig- nals, arising from themouth 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 ol- factory wystem both through a direct olfactory stimulation (by the nose) and a ret- ro-nasal pathway (accomplished by air inhalation while weirling the wine around in the mouth). The distinction between these two olfactory stimulations modality is worthy, since evidences showed that in correspondence of congruent taste-odo pairs using the orthonasal route (implying sybject to sniff), neural suppression oc- curred in chemosensory regions. The convergence of taste and odor, firstly thought to occur only at the level of the orbitofrontal cortex, has been showed al- ready at the insula (Small et al. 2004) 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 the product perception by potential users.

There is no doubt that wine marketing is an area where not only the economic but also the non-economic factors, such as emotions and hidden reactions of a cus- tomer, play a decisive role. Even in the current era when it seems that the econom- ic indicators are of a great importance and affect both the business and consumer decisions (Bielik et al. 2014), there are also hedonistic values that can affect choosing a bottle of wine for special occasions or demonstrating some specific, non-economic values, e.g. the environmental ones (Olsen et al. 2012). The affect that the consumers experience also cannot be adequately measured by the self- reported verbal indicators due its complexity (Zajonc 1980; Panksepp 1998; Da- vidson 2004). Therefore, the neuro-marketing methods are proposed to measure the hidden consumer reactions at the process of buying but also consuming certain products. They can also help with identifying proper retail solutions and specific in-store parameters (Nagyová et al. 2014). In the present research project, several objectives have been determined:

1) to investigate the cerebral and emotional reaction to the two specific Sangiovese wines gustation with and without the direct olfactory contribution in a group of „normal" wine drinkers;

2) to investigate the cerebral and emotional reaction to the same Sangiovese wines in a group of expert wine tasters.

Those objectives will be achieved by using an electroencephalographic index, as- sumed 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 Wa-tanuki 2003; Henkin and Lect 2001). Concerning the emotional index, a list of 16 emotional words has been defined by a behavioral categorization study using the model of circumplex affect (Russell and Barrett 1999); the words were in fact classified based on pleasantness/unpleasantness and aoursal (high/low) describing the wine tasing (Ferrarini et al. 2010). The Emotional index has been already ap- plied to neuromarketing studies on advertising (Cherubino et al. 2016 a,b) and an- tismoking public service announcement (Cartocci et al. 2017), supporting the suit- ability of its use to product testing.

2 Methodology and Sample

2.1 Experimental procedures

The tests measured the brain activity and the emotional engagement of individuals during a degustagion of the two types of the Italian wines (BelNero e Rosso di Montalcino, both same producer) and they have been conducted in two different locations, on two separate groups of persons characterized by very different experience in wine tasting, e.g. professionals and not professionals.

Figure 1. *The type of red wine employed in the tests across the two experimental groups.*

The experiments have been conducted in the Industrial Neuroscience Laboratory of Sapienza, at the University in Rome and in Montalcino. Participants were 15 naïve wine-tester subjects, balanced for gender, with an average age of 37.5 ±

15.52. as well as 15 professional persons in the field of Sangiovese wine tasting, with a similar average age as the naïve ones.

2.1.1 Normal wine testers

The two type of wines, Rosso di Montalcino and Belnero were served in a randomized order across all the participants to this test. Three conditions were experienced by the participants of this experiment: 1) the smelling of the glass of wine; 2) the Closed Nose procedure and the 3) Open Nose procedure. The Closed Nose condition was performed with the participants wearing a nose clip. Wines were randomly assigned to participants and served at room temperature to avoid undesidered temperature-related effects (Craig et al. 2000). After smelling the wine for 10 seconds, participants were asked to drink from the glass and to keep the wine into the mouth for 10 seconds before swallowing. The quantity was 20 ml for each wine trial, and before each trial participants were instructed to drink a glass of water.

Figure 2. *A participant in the "normal" wine testers during the drink of the Rosso di Montalcino at the laboratory of the Industrial Neuroscience at the University Sapienza of Rome. Of interest the equipment of eyetracker glasses as well as the set of active electrodes*

disposed on the forehead. In addition, on the right hand it could be appreciated the sensors for the capture of the heart rate and the Galvanic Skin Response.

2.1.2 Experienced wine testers

The two type of wines, Rosso di Montalcino and Belnero were presented to the subjects through a series of predefined phases as described in the following: 1) *Observation* of the label of the bottle, lasting 30s; 2) *Observation* of the wine inside the glass, lasting 30 s; 3) *Smelling* of the glass of wine, 15s; 4) *Degustation* of the wine. Note as the two types of wines tested were randomized and served to the participants in the order to avoid any sort of bias for the presentation effect.

Figure 3. *A professional wine taster with the equipment for the measuring the cerebral and the emotional reactions to the different phases of the wines tasting. Note as the devices are the same of those employed for the measuring of the cerebral and emotional reactions in the standard wine tasters. It could be recognized the set of cerebral sensors (on the fore- head), the eyetracker glasses and the sensors fo the measuring the heart rate and the GSR as in Figure 3.*

2.2 EEG Recording 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, ground and reference), following the 10-20 International System, and the impedance were kept below 10 kΩ. Each EEG trace was then converted into the EEGlab format to perform signal preprocessing such as artefacts detection filtering, and segmentation.

The EEG signals have been pass filtered at 2-30 Hz and depurated of ocular artefacts by using the independent component analysis (ICA). Individual alpha frequency (IAF) has been calculated for each subject 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. 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 waveform related to the increase or decrease of the global power in the analysed 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:

$$AW = GFP\alpha\_right - GFP\ \alpha\_left$$

Where the GFPα_right and GFP α_left stand for theGFP 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 talking into account the frontal EEG asymmetry's theory by Davidson and coworkers (1990).

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 (Roth 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 the LEDAlab software (Benedek and Kaernbach 2010), the tonic component of the skin conductance (Skin Conductance Level, SCL) was estimated.

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 viceversa.

3 Results

3.1 Normal wine tasters

In this section it will be presented the results obtained in the first group of the ex- perimental wine testers, across the different phases designed. Since the group was composed by normal wine tasters, there was observed no differences between the perception of the two red wines presented (e.g Rosso di Montalcino and Belnero). For this reason, in the following the average across the type of wines will be pre- sented for the cerebral and emotional data estimated.

3.1.1 Approach Withdrawal Index

The population values estimated for the Approach/Withdrawal index (AWI) across the three phases suggested the existence of a positive trend of cerebral appreciation during the experience, from the smell of the wine to its degustation with the open nose. The AWI reports an Approach (positive) tendency when the persons test the wine in the Open Nose condition, while the Closed Nose condition did not elicit any effect (e.g. close to the zero level) and the Smell phase produced a Withdrawal effect (e.g. negative cerebral appreciation) condition.

The Figure 4 presents such information in a graph in which on the x-axes there are the three phases of the experiment, while on the z-axes there is the values for the AW index estimated. Positive values of the AW index are associated with positive cerebral appreciation and viceversa.

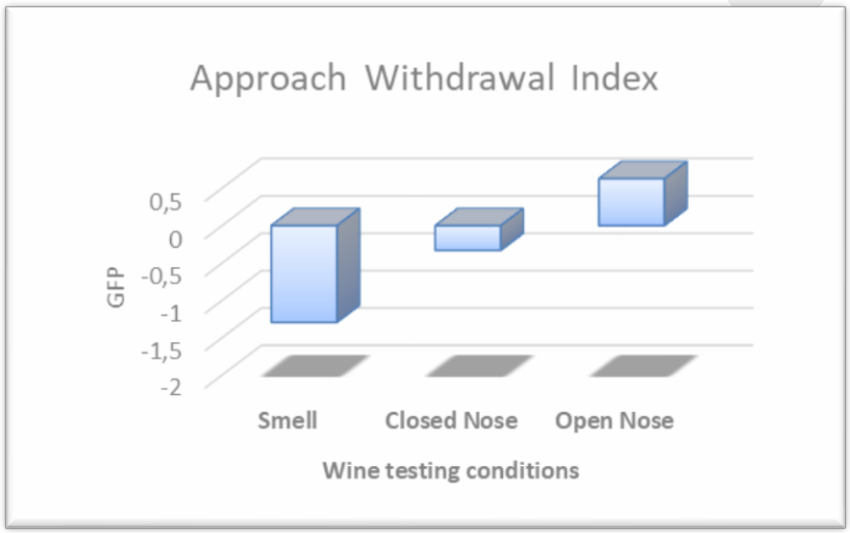

Figure 4. *The graph showes the average AW values reported by the experimental group in the three wine tasting conditions (Smell, Closed and Open Nose). Note as the Open Nose condition was the most cerebral appreciated conditions across all the investigated phases.*

3.1.2 Emotional Index

The population estimated value for the Emotional Index results showed an inter- esting modulation across the different testing phases as suggested by the Analysis of Variance performed (F=9.678; p=0.005). It can be observed as the Closed Nose condition was the condition perceived by the evaluated population as the more un- pleasant, while the Smell phase was perceived as the more rewarding from the point of view of the experience. Such information could be retrieved in Figure 5, where the same conventions of Figure 4 hold. The statistical differences between the estimated emotions across the phases of the experience is quite interesting. It could be appreciated as the maximum values of the perceived emotion in this ex- periment was obtained during the smell phase of the wine glass. Emotions associ- ated with the Close and Open Nose conditions are less intense than those evoked by the smell phase in this group.

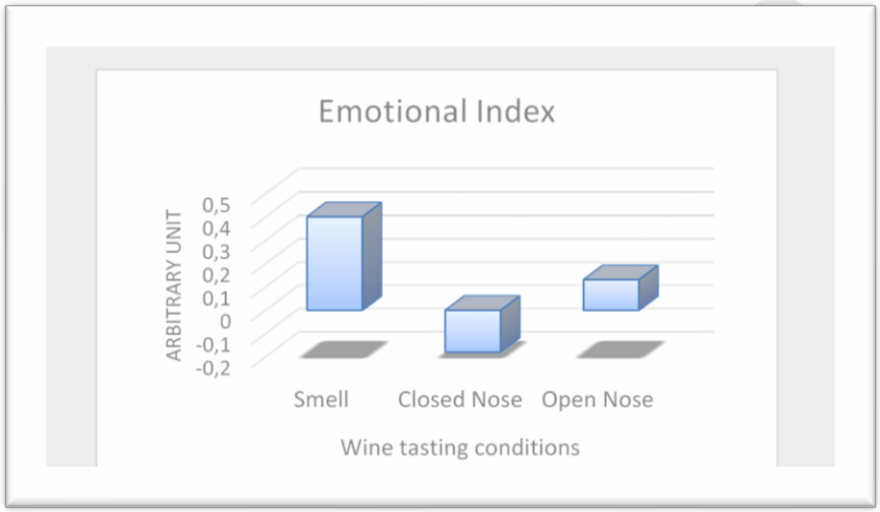

Fig. 5 *The graph shows the average EI values reported by the experimental group in the three wine tasting conditions (Smell, Closed Nose, Open Nose). It is of interest the low val- ues of the Emotional index on the Closed Nose condition as opposed to the Smell condition.*

3.2 Professional wine tasters

In this section, it will be presented the results obtained along the several phases of the experiment in which professional wine testers have been involved. In this case the differences between the perception of the two wines are relevant and they will be specifically reported in the following.

3.2.1 Approach Withdrawal Index

As it is possible to observe from the Figure 6, the population values estimated for the AW index are clearly modulated by the different phases of the experiment. In addition, along the experiment the appreciation increased for the experts, irrespec- tive of the wine tasted. The maximum of the AW index for the experiment was observed in the final phase of the experiment, the part in which the wines were tasted. In such phase the wine that presented higher values of AW index was the Belnero. The Figure 6 presents the experimental results obtained in this group, where the different experimental conditions are presented and illustrated in the x- axes. Two different bottles are represented above each bar of the estimated AW index.

The left bottle was always relative to the Rosso di Montalcino and indicated the AW values estimated for the part of the experiment involving that specific wine. The right bottle on the top of each bar is the figure of the Belnero wine, suggesting that the values of AW index estimated are relative to the observation, smelling and tasting of such wine.

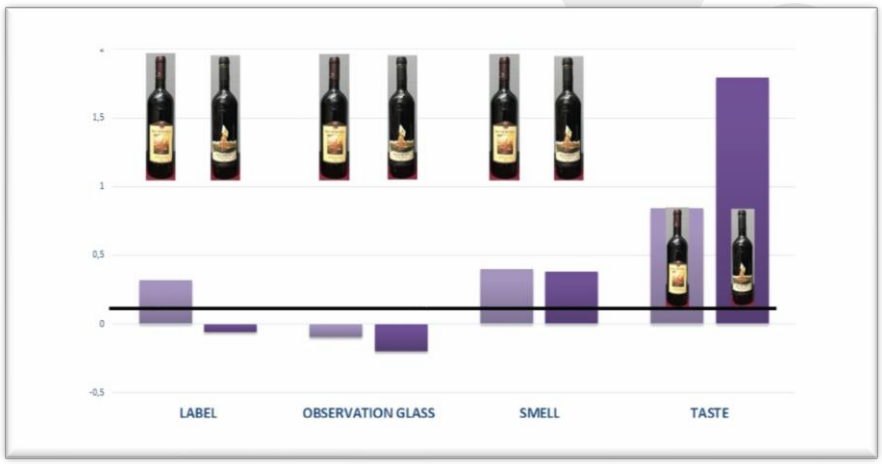

Figure 6. *Values of the AW index presented as the population average across the different phases of the experimental setup. Each value was estimated for the couple of wine across the phases, namely the Rosso of Montalcino (left bottle) and of the Belnero (right bottle). It could be appreciated the increase of the AW index during the taste phase of the entire expe- rience.*

3.2.2 Emotional Index

As the Figure 7 clearly describes, the population values of the emotional index es- timated were different for the two wines analyzed. It remains quite remarkable the modulation of the emotion in the population investigated across the different phases of the interaction with the wines. The maximum positive values of the emotion were observed during the smell phase while the minimum values are ob- served during the taste. In this smell condition the differences between the two wines are minimal and less than the difference in emotions during the tasting phases. The Figure 7 present the modulation of the emotion between the two kind of wines across the different phases of the experimental design employed. Also, in this case the same convention of the Figure 6 applies with the image of the bottle above the left bar of each phase is relative to the Rosso di Montalcino and the Belnero viceversa.

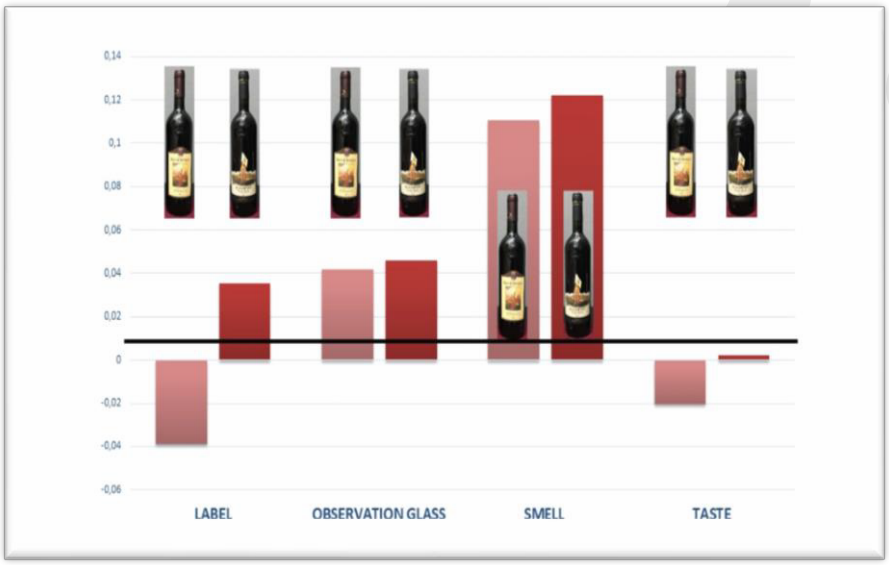

Figure 7. *Values of the Emotional index presented as the population average across the different phases of the experimental setup. Each value was estimated for the couple of wine across the phases, namely the Rosso of Montalcino (left bot- tle) and of the Belnero (right bottle). It could be appreciated the increase of the Emotional index during the smell phase of the entire experience.*

4 Discussion: perception, action and emotion

Many studies suggest a close relationship between olfactory and affective infor- mation processing. Odors can modulate mood, cognition, and behavior (Soudry et al. 2011). The physiology involved in the wine tasting suggests as the wine vola- tile 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 sen- stion. However, it is a common experience that the wine tasting experience will be poor if the subject has a cold. 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. Present data numerically support such old heuristic obser- vation for experts and for naïve wine tasters.

4.1 The case of wine tasting in naïve testers

In the case of naïve users, the collected data suggests a clear interaction between the two sensory modalities of taste and olfaction, since it was observed an in- creased emotional and cognitive appreciation of wine tasting experience with the Open Nose when compared to the Closed 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 stucy (Castriota-Scanderbeg et al. 2005). Taken together, these results suggest as the modulation of Smell and the Open Nose condition are important in the wine degustation when compared to the Closed Nose (or cold) condition. For all concern the fact that the cognitive (AW) increased appreciation for the Open Nose condition was not significantly different from change although it demostranted anincrease in the average value, we hypothesize that this could be due to the high variance estimated for the AW index. However, it is not possibile to disentangle such result from also the fact that the result was not obtained in professional wine taster, e.g. sommelier. In fact, it was found in previous research (Castriota- Shanderbeg et al. 2005) that sommerli- er showed a bilateral activation in the prefrontal cortex during wine tasting. This coud suggest that the lack of statistical significance found in the AW index (that is based on the unbalance of the prefrontal cortices activity) in the present study could be influenced by the expertise of the participants. Finally, as showed in the Pazart et al. study (2014) a difference exists in brain activity in wine experts com- pared to novices' testers. This could also be at the basis of the avoidance tendency (suggested by a greater frontal right activity) showed by our testers in the Smell condition. Also, probably caused by the fact that they were not used to approach wine by Smell, therefore possibly adversing the action itself. On the other hand, it is interesting to note that indeed the Smell condition produced in the participants the higher emotional involvement (EI), so suggesting a parallel intense emotional reaction to such condition.

4.2 The case of wine tasting in expert's testers

The results obtained for the experienced wine testers suggested some similarities and more striking differences with the group of naïve wine testers. It was observed as, like the naïve users, the major part of the emotional responses is linked to the smell of the wine glass. In fact, it is possible to compare the Figure 5 and the Fig- ure 7 to understand how the emotions linked to the wine experience are related to the smell perception. It is interesting to underline that such result is similar, irre- spective of the different cultural level for the wine appreciation that are present in the two groups. Among such emotional cross-cultural similarities, also the differ- entiation of the different wines (Figure 7) for the Smell condition appears not rel- evant. Thus, the present research underlines the universal value of smell for elicit positive emotions connected to the wine (e.g. across cultural levels in wine appre- ciation).

Instead, emotions could vary across the different phases for experienced users along the tasting of the different wines. However, in this experiment it was experienced an almost null value of the emotional index along the wine tasting per se. It is of extreme interest, in our opinion, the fact that in this wine tasting phase we observed the maximum values for the AW index, e.g the cerebral appreciation of the wine in the expert experimental group investigated. This fact, observed in Figure 6, could be interpreted as a sign of "intellectual" effort in decoding the dif- ferent signatures of the different wines. In fact, the differences between wines are also remarkably larger than the differences in emotions for the same phases. It emerges an interpretation in which during the drinking of a glass of wine there is a sort of swing between the emotional part, maximally present during the smell phase, and the intellectual part (including the analysis of the wine texture and fla- vours) during the tasting. In this part of the experience the final judgment on the wine could be "cerebrally" formed. How such kind of differentiation of the per- ception could be capitalized by the wine producers is a subject of future research.

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