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**ORIGINAL RESEARCH ARTICLE**

# Is wine an emotional object? Measurements of the subjective and automatic components of emotions in a wine-tasting situation

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## ABSTRACT

Wine is often described with emotional terms, such as surprising, disappointing, or pleasant. However, very little has been done to understand the role of emotions in wine tasting and characterise this link between emotions and wine. Many studies have looked at the extrinsic factors that can improve the emotional experience of tasters when discovering a wine, but few have been carried out on the emotional impact of the organoleptic characteristics of wines. The present study aims to determine if the automatic component of emotion has a measurable output (motor and physiological) when tasting wine. If so, does wine tasting induce a concomitant activation of the different components of emotion, such as subjective feelings or physiological and motor responses?

Sixty-five connoisseurs tasted seven different red Bordeaux wines with different sensory properties and quality levels pre-defined by wine experts. Emotions were measured using subjective (subjective feelings measurement using self-declarative questionnaires) and automatic (physiological measurements such as skin conductance and heart rate, or motor measurements through facial expressions) methods. The results showed that there was a measurable physiological and motor emotional output in wine tasting. The results also highlighted that changes in the autonomic nervous system in a wine-tasting situation are structured around the dimensions of pleasantness and arousal. Motor measurements taken through facial expressions showed a marginally significant difference between wines providing pleasant and unpleasant emotions for the activation intensity of action units. The relationships established between these components, as well as their concomitant activation, allow us to define wine as an emotional object.

**KEYWORDS:** wine tasting, emotion, sensory analysis, subjective feelings, motor measurements, physiological measurements

## INTRODUCTION

Wine tasting has been shown to elicit emotions in tasters. This raises the question of what factors influence this link between emotions and tasting. The first field of research was interested in the weight of extrinsic factors related to wine on tasters' emotions. Various studies have shown that the context of the tasting (Danner *et al.*, 2016) and the information provided to tasters, such as the level of description on the back label of wine bottles (Danner *et al.*, 2017), affect tasters' emotional responses. Interindividual differences also influence the emotional responses to wine (Prescott, 2017). For example, in their study, Mora *et al.* (2018) found an impact of age and gender on the declarative emotional response during wine tasting. Mora *et al.* (2019) also observed an association between consumer personality and the emotions induced by wines. For instance, consumers who scored higher on neuroticism generally scored higher on negative emotions, while those who scored higher on extraversion, agreeableness and conscientiousness generally scored higher on positive emotions. Danner *et al.* (2020) also found that the level of consumers' involvement with wine (defined, among other things, by their knowledge of wine) and the importance of wine in their lifestyle impacted their emotional response to wine. In this study, consumers were sorted between 'Wine Enthusiasts', 'Aspirants' and 'No Frills'. The more involved and higher-level connoisseur the consumer was, the higher the intensity positive emotions were felt. 'Wine Enthusiasts' also reported stronger positive emotions when tasting higher quality and complex wines.

Finally, there is a lot of evidence that multisensory stimuli such as food and wine can induce strong emotional responses (Danner *et al.*, 2014; Desmet and Schifferstein, 2008; van Bommel *et al.*, 2019). Moreover, various studies in neuroscience and psychophysics have shown a strong relationship between chemical senses (especially olfaction) and emotion (Yeshurun and Sobel, 2010). In the case of wines, Danner *et al.* (2016) have found a link between organoleptic quality and felt emotions. In their study, Jiang *et al.* (2017) highlighted differences in the emotional responses according to the organoleptic profile of wines. Finally, Coste *et al.* (2018) explored the emotional reactions induced by the sensory properties of red wines to see how these reactions can be used to describe and evaluate wines. In their study, conventional descriptive sensory analysis, where inexperienced consumers were asked to rate different organoleptic descriptors, could not differentiate two styles of red wines from different climates. On the contrary, the analysis using emotional attributes demonstrated that these two styles of wine could be easily distinguished. The results presented in this work demonstrate that emotional responses elicited by wine could be used to differentiate wine styles. The same results were obtained by Souza-Coutinho *et al.* (2020) in a study on white wines.

However, these different studies are based on self-report. Only the subjective part of emotions is captured. For Scherer (2001), emotion is defined as "a set of episodic

variations in several components of the organism in response to events evaluated as important for the organism" (pp. 92–120). Appraisal theories postulate that emotions are elicited by the evaluation of a stimulus by the organism. Different characteristics of the stimulus are assessed, such as novelty, pleasantness, predictability, importance for goals, cause of the stimulus, manageability of the consequences of the event and compatibility with social or personal norms (Ellsworth and Scherer, 2003; Coppin and Sander, 2016). Scherer (2001) identifies five components of the emotion: cognitive evaluation of stimuli, physiological, motor expression, motivational (action tendencies) and finally, a subjective feeling component, which reflects the emotional experience, and which would be the reflection of the changes occurring in all the components. Scherer (2001) emphasises dynamic interrelationships between the five components of emotion. Appraisal theories of emotion seem to provide the best framework for studies on wine tasting. Indeed, in their study, Coppin *et al.* (2021) found that many relevant factors, such as self-reported expertise, tasting conditions and sensitivity to key information about wine, impact the subjective emotional response to wines. These results correspond with the theoretical context of appraisal, according to which emotions provoked by a stimulus arise after evaluating certain criteria of interest. In the study of sensory stimuli other than wines, such as odours (Delplanque *et al.*, 2009), the appraisal theories of emotions have proven to be effective. Danner *et al.* (2017) also show that consistency with expectations about a wine influences the intensity of the emotions felt during tasting. Once again, these results are consistent with appraisal theories where the predictability of a stimulus is one of the parameters assessed to trigger the emotion.

Thus, according to appraisal theories, to complete the characterisation of the emotions felt during tasting, it is necessary to carry out complementary measurements to the simple self-report of the consumer's subjective emotions. Two kinds of emotional responses can be distinguished and measured. As in the studies cited above, the first one is a subjective, explicit and evaluative response, the subjective feelings. It can be through verbal expression (through emotional lexicon) and through the auto-declarative evaluation of valence (pleasure/displeasure) and arousal (weak/strong). Ferrarini *et al.* (2010) developed a list of 16 emotional terms appropriate to Italian culture to describe emotions elicited by wine consumption, divided into two categories: high/low arousal and high/low pleasantness. In this study, most of the terms selected to describe emotions in wine tasting were emotional terms associated with pleasure. Silva *et al.* (2016) also showed an association between wine and positive low-arousal emotional responses, with emotional terms such as calm and loving in a population of Dutch and Portuguese consumers. Monseau and Deneulin (2014) developed a lexicon of 34 emotional terms relevant to wine tasting in Swiss culture. This study also showed that wine is more associated with positive than negative emotions and that emotions are strongly linked to the quality of wine. In their study, Danner *et al.* (2016),

by adapting an emotional lexicon for Australian wine consumers, also showed that high-quality wines elicited more intense positive emotions compared to wines of lower quality.

The second kind of emotional response is an automatic, implicit and uncontrolled response. This response has a motor component that passes through facial expressions or changes in the Autonomic Nervous System (ANS). Bensafi *et al.* (2002) showed that ANS activity, such as heart rate and skin conductance, presented variations among dimensions of pleasantness and arousal. A strong correlation exists between the pleasantness factor of emotional responses and heart rate variation. In fact, an increase in heart rate variation is observed in a rejection context, for example, in response to unpleasant odours (Bensafi, 2002; Bensafi *et al.*, 2002). Electrodermal activity has long been used to indicate arousal in psychophysiological studies. Bensafi *et al.* (2002) observed a positive correlation between arousal and skin conductance level (SCL) variation for odours. For more complex stimuli such as juices, Danner *et al.* (2014) showed that tasting different juices elicited different ANS responses for skin conductance level and pulse volume amplitude and that there is a differentiation between liked and disliked samples for the intensity of different facial expressions such as “disgusted” or “neutral”. They also suggest that ANS and facial expression provide different information than that of self-reported appreciation of the product. For food products, physiological measurements and motor measurements could provide information on food preferences that may not be provided by other more explicit tests (De Wijk *et al.*, 2012; De Wijk and Noldus, 2021; Spinelli and Jaeger, 2019). To our knowledge, this automatic response has never been studied in the wine field and seems a relevant perspective to characterise the specificity of emotions elicited by wine organoleptic properties (Niimi *et al.*, 2019).

This study aimed to determine whether the automatic component of emotion has a measurable output (motor and physiological) during wine tasting. The first approach was to assess the degree of discrimination of wines using these measures. The second was the verification of correlates recognised in the literature between subjective feelings and motor or physiological components in a wine-tasting situation.

**TABLE 1.** Characteristics of the different Bordeaux wines chosen for the study, classified by quality score. Organoleptic characteristics are obtained by a consensus profile (ISO 13299, 2016).

	Wine 1	Wine 2	Wine 3	Wine 4	Wine 5	Wine 6	Wine 7
Vintage	2018	2019	2018	2015	2018	2016	2016
Price	Less than 10 €	Less than 10 €	Less than 10 €	15 €	Less than 10 €	25 €	41 €
Quality score	3.08 <sup>a</sup> (+/- 1.06)	4.75 <sup>ab</sup> (+/- 0.91)	5.21 <sup>ab</sup> (+/- 1.28)	5.25 <sup>ab</sup> (+/- 1.21)	5.29 <sup>ab</sup> (+/- 0.92)	6.25 <sup>b</sup> (+/- 0.94)	6.33 <sup>b</sup> (+/- 0.91)
Organoleptic characteristics	Strong odour intensity, phenols, marked bitterness	Jammy fruit and woody vanilla, sweetness and acidity	Moderate odour intensity, slightly woody, and vegetal, astringency	Woody vanilla, bitterness and acidity	Fresh fruits, sweetness and bitterness	Jammy fruit and woody vanilla, astringency	Woody vanilla, sweetness

\* Average quality score (out of 10) given by the panel of experts (confident interval  $\alpha = 5\%$ ). Values marked with different letters differ significantly ( $p$ -value < 0.05, Friedman test, post hoc Nemenyi test).

## MATERIALS AND METHODS

### 1. Participants

Participants living in the Bordeaux region were recruited by phone by a company specialising in consumer studies. Several selection criteria were used to select participants, including:

- ▶ consumption of Bordeaux red wine at least twice a month;
- ▶ wine professionals were excluded from the study;
- ▶ the participants were chosen as being halfway between novices and experts in tasting, in other words, connoisseurs. For this study, participants were considered novices if they had low wine consumption habits and a low level of wine knowledge. Professionals in the wine sector involved in wine tasting were considered experts. The level of knowledge was defined using a questionnaire adapted from Koenig *et al.* (2020) and Mueller and Francis (2008) (Supplementary data). This questionnaire was administered during recruitment by phone, and a minimum score of 5 out of 8 was required for the consumer to be selected;
- ▶ as differences in emotional response to wine according to gender and age were found in a previous study (Mora *et al.*, 2018), an equal distribution was sought, recruiting consumers from three age groups (18–34 years, 35–54 years and 55 years or more) and approximately the same number of men and women consumers.

In total, 65 subjects took part in the study: 34 men and 31 women. The average age was 44 years  $\pm$  15 (minimum: 18 years, maximum: 70 years).

### 2. Wines selection

The study focused on red wines from the Bordeaux region and different PDOs (Protected Designation of Origin). Seven red wines were selected on a varied price range and a quality score (technical assessment) defined by a panel of experts (Table 1). Prior to the study, 12 tasting experts, according to the criteria defined by Parr *et al.* (2002), evaluated each of the wines and assigned them a quality score out of 10 and associated tasting notes. A Friedman statistical test verified that these wines were representative of a quality continuum (Friedman test,  $F = 19.52$ ,  $df = 6$ ,  $p$ -value < 0.01).

The volatile profiles of the wines were determined using Gas Chromatography-Mass Spectrometry analysis coupled with stir-bar extraction to detect olfactory faults (Franc *et al.*, 2009). For each wine, these analyses were repeated in triplicate. The concentrations of the different key compounds (2-isobutyl-3-methoxypyrazine, chloroanisoles, bromoanisoles, geosmin and ethylphenols) were below the analytical detection limits for all wines except Wine 1. The average concentrations of 4-ethylphenol and 4-ethylguaiacol in this wine were 2477 µg/L (+/- 71) and 177 µg/L (+/- 43), respectively, confirming the previous trend (quality score and tasting notes) during tastings by experts.

### 3. Measurements of emotional components

#### 3.1. Physiological ANS measures

Physiological data were collected with the Smartcenter acquisition system (Biopac), a portable small-form data acquisition system. The data were recorded and analysed with Acqknowledge® 5.0.5 software (Biopac) with separate settings for the electrocardiogram and the electrodermal activity:

- ▶ Electrodermal activity (EDA) - Skin conductance response (SCR) and skin conductance level (SCL) measured in µSiemens with pre-gelled disposable Ag/AgCl electrodes placed on middle phalanges of the index and middle finger of the non-dominant hand of the participant. The acquisition sample rate was fixed at 2000 samples/sec. After data acquisition, the waveform was resampled at 31.250 samples/sec, and a low pass fixed at 1 Hz was applied. A phasic signal was generated by Acqknowledge® from the recorded tonic signal after data acquisition.

- ▶ Heart rate measured in beats per minute with three pre-gelled disposable electrodes placed on the clavicles and the breastbone of the participant. The acquisition sample rate was fixed at 2000 samples/sec. Electrocardiographic R waves were detected offline, and intervals between consecutive R-waves on the ECG were converted into heart rate, expressed in beats per minute (BPM). A band pass filter between 1 and 35 HZ was applied to the ECG waves prior to the conversion to heart rate.

The ECG Transmitter and the EDA transmitter (BioNomadix from Biopac) are attached to the participant with a Velcro strap, and the data is wirelessly streamed to the SmartCenter unit.

#### 3.2. Motor measures

Facial expression measurement was performed using FaceReader 8.1.15 and the Action Units module. Participants were filmed with a Logitech BRIO 4K pro webcam. To ensure optimal brightness, participants were illuminated with a Hama LED ring light, “Spot Light FoldUp 102”. The Action Units (AUs) module provides the activation intensity of each of the face’s AUs of the Facial Action Coding System (FACS) (Ekman and Friesen, 1978), frame by frame. Action Units (AUs) are the smallest visible units of muscular activity in the face (contraction or relaxation), which results in a movement of part of the face and produce changes in facial

appearance. The FACS produces a purely descriptive account of facial expressions and does not provide any interpretation of them.

Due to technical problems related to video recording, 15 participants had to be excluded from the study, and the results were processed on 50 participants.

#### 3.3. Subjective feelings

##### 3.3.1. Valence and arousal

According to the model of Russell (1980), valence and arousal represent the implicit cognitive structure that people unconsciously use to conceptualise affect. Valence describes the extent to which an emotion is perceived as pleasant or unpleasant; arousal refers to its intensity (Bradley and Lang, 2000). Valence was assessed using the SAM (Self-Assessment-Manikin) 9-point scale (Bradley and Lang, 1994). The SAM is a non-verbal approach with pictorial anchors (pleasant to unpleasant). The instruction provided to the participant was “Indicate the intensity of pleasure or displeasure that the evaluated product brings to you”.

The arousal is the activation, or physiological excitement, triggered by an emotion on a continuum ranging from calm to excited (Mehrabian and Russell, 1974). Arousal was assessed using the SAM 9-point scale (Bradley and Lang, 1994). The SAM is a non-verbal approach with pictorial anchors (high arousal to low arousal). The instruction provided to the participant was “Indicate the level of arousal or excitement that the evaluated product brings to you”.

##### 3.3.2. Type of emotion: Emotional lexicon specific to wine

Participants were also asked to characterise the type of emotion experienced by selecting three emotions from an emotional inventory of 25 words specifically adapted to wine tasting. Participants were instructed: “From the following list of emotions, indicate the three that most closely match your emotional state”.

A preliminary study and validation of an emotional lexicon specific to wine was carried out. Van Zyl and Meiselman (2016) indicated that each emotional lexicon is cultural and product-dependent. Previous studies proposed different emotional lexicons specific to wine, but none are specific to French consumers and tasters, i.e., an Italian lexicon (Ferrarini *et al.*, 2010), a Swiss lexicon (Monseau and Deneulin, 2014), a Dutch and Portuguese lexicon (Silva *et al.*, 2016) specific to wine, beer and soft drinks, and an Australian lexicon (Danner *et al.*, 2016). Based on these different lexicons, a selection was made to propose an adapted lexicon independent of the culture and linguistically adapted to the French language. Each term appearing in at least two of the lexicons was selected. The four lexicons were translated into French following a back-translation procedure. Several online translators were used for this purpose to ensure the accuracy of the translation into French. Then, the list was translated back into the original languages (English, Italian, Portuguese, or Dutch). The experimenter then checked the

correspondence between the initial and back-translated words. New translations were made when necessary.

#### 4. Procedure

The experiment took place during individual one-time sessions in the morning (10 AM) for a duration of 2 hours. At the rate of one session per day, the 65 sessions took place over 15 weeks. The room in which the experiment took place was equipped with a non-tinted mirror overlooking another room in which the experimenter was present so that the presence of the experimenter would not disturb the participants' concentration and emotional response.

After an explanation of the experiment and the signature of the participant's consent form, the participant was equipped with the devices necessary for the acquisition of physiological measurements. The participant was then placed in front of a screen, on which the various instructions relating to the experiment were displayed, including a voice recording broadcast via an audio speaker. All instructions were carried out using the PsychoPy v2021.2.3 software.

A phase of familiarisation with the equipment and procedure was carried out using spring water. The participants were informed that they would taste different red Bordeaux wines. During the evaluation, the samples were evaluated in monadic sequential. On average, twenty-five millilitres of each wine were presented in a transparent glass (ISO 3591, 1977). The samples were presented anonymously (random three-digit coding) and served randomly for each participant, following an optimal randomised plan to avoid possible alcohol-related biases.

For each sample, the following instruction was given to the participant (in French):

“At the sound signal, take glass number XXX and evaluate its visual, olfactory and gustatory properties. When you have the wine in your mouth, stay a few moments in front of the screen. Spit, then stand facing the screen again for a few moments before raising your hand.” (Instruction 1, see Figure 1).

For each participant, the first sensory contact with the wine sample (whether visual, olfactory or gustatory) represented the beginning of the overall tasting and the beginning of the measurements. The end corresponded to the time when

the wine was spat out. The tasting time was left open and therefore depended on each participant.

When the participant raised their hand after the tasting, the following instructions were given: “Fill in the evaluation sheet and raise your hand when you have finished” (Instruction 2, see Figure 1).

The time to complete the declarative part was open. When the participant raised their hand after filling it in, they moved on to the next sample of wine.

#### 5. Data analysis

##### 5.1. Valence and arousal scores

To facilitate the representation and comprehension of the results, the scores on the SAM scales have been inverted. A score of “1” represents negative valence or low arousal, and a score of “9” represents positive valence or high arousal.

##### 5.2. Heart rate variation

To measure the heart rate variation following the tasting of a glass of wine, each participant's average heart rate from 10 to 5 seconds before the start of the tasting was subtracted from the average heart rate from 5 to 10 seconds after the tasting. These time windows of interest were set up after preliminary work on 10 participants at the laboratory, which aimed to determine the optimal time and duration for these windows.

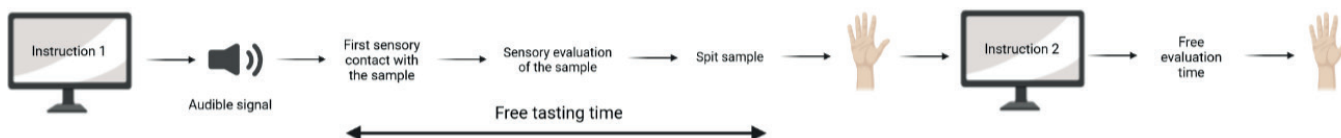
Prior to the analyses, heart rate variation was converted to heart rate variation ratio to prevent individual variations in heart rate related to weight, physical activity, etc.

A baseline of heart rate variation ratio was determined using the data obtained during the familiarisation phase with the glass of water.

##### 5.3. Electrodermal activity

Three types of measurements were made for electrodermal activity:

► The number of sensory event-related skin conductance responses (SCR) elicited by one wine sample according to four specific moments of tasting. For each sample, it was observed if each of the following events induced or not a SCR: visual evaluation (first look), ortho-nasal evaluation (first sniffing), gustatory evaluation (in the mouth), retro-nasal evaluation (after spitting).



**FIGURE 1.** Extract of the experimental procedure for the evaluation of one wine.

The instructions (displayed on the screen and broadcast in French through a speaker) were as follows: Instruction 1: At the sound signal, take glass number XXX and evaluate its visual, olfactory, and gustatory properties. When you have the wine in your mouth, stay a few moments in front of the screen. Spit, then stand facing the screen again for a few moments before raising your hand. Instruction 2: Fill in the evaluation sheet and raise your hand when you have finished.

Therefore, for one sample, each participant could have from zero to four sensory-event-related SCRs. The minimum separation between stimulus events and SCR was fixed at 0.9 seconds and the maximum at 4.1 seconds. The SCR threshold level was fixed at 0.1  $\mu$ S.

► The highest amplitude of the four electrodermal responses that could have been measured for each wine and each participant was selected as a measure of the maximum amplitude of the sensory event-related SCR elicited in that participant by that wine. If a participant had no sensory-event-related SCR for a wine, the value for this measure was equal to zero. To remove extreme values and overcome interindividual variations, for each wine, the minimum and maximum 5 % of non-zero values were discarded. As few participants passed the visual and/or olfactory stage and one participant did not evaluate one of the wines, the number of electrodermal responses was weighted by the times of tasting carried out for each participant and by the total number of participants having tasted the sample. The amplitude measurements of the skin conductance responses were normalised using the formula:  $\log(\text{measurement} + 1)$  (Venables and Christie, 1980).

► The variation in the amplitude of the skin conductance level (SCL) = (skin conductance level from 0 to 10 seconds after spitting) - (skin conductance level from 10 to 0 seconds before the beginning of the sensory evaluation). To remove extreme values and overcome interindividual variations, for each wine, the minimum and maximum 5 % of values were discarded.

Different studies demonstrated that these different electrodermal activity measures can be relevant in the study of sensory stimuli (De Wijk *et al.*, 2012; De Wijk *et al.*, 2014; Bensafi *et al.*, 2002).

#### 5.4. Motor measures

As motor expressions of emotions are known to be fast and dynamic (He *et al.*, 2014), all the moments of the tasting likely to induce changes in facial expression have been considered: after smelling the wine, after tasting the wine and after spitting it. The length of these moments was between 3 and 10 seconds, according to the time dedicated by each participant during these three sensory evaluations.

For each wine and each of these moments of the tasting experience, two measurements were performed to determine the motor expression of emotions induced:

- The total number of action units activated during the moment of tasting considered.
- The total maximum activation intensity of action units. This measurement was obtained using the following method. With a frame rate of 30, for each tenth of a second of the recording, FaceReader provides three measurements. For the action units, these measurements were activation intensity values between 0 and 1. For each action unit activated during the moment of tasting considered, the maximum activation intensity value was selected.

All of the maximum activation intensities of the activated action units were then summed to obtain the total maximum activation intensity of action units.

The same procedure was performed with the evaluation of the glass of water to provide a baseline for each participant.

To remove artefacts related to motor movements induced by drinking and smelling and not by emotions, motor measurements with the glass of water were subtracted from the motor measurements with the glasses of wine. The length of the baseline calculated with water was the same as with the wine. For example, if a participant smelled Wine 1 for 7 seconds, the baseline associated and the measurements subtracted were during 7 seconds of smelling water.

#### 5.5. Statistical analysis

The data were analysed using XLSTAT 2022.3.2 software (Addinsoft, Microsoft Excel, Paris, France).

To evaluate the difference between wines or groups of wines, t-test or ANOVA with Tukey post-hoc tests were conducted on valence, arousal, physiological and motor data. When the conditions of parametric tests were not satisfied, Mann–Whitney, Friedman (Nemenyi post-hoc tests) or Kruskal–Wallis (Conover–Dunn post-hoc) tests were applied. The Kruskal–Wallis test was applied when the number of missing data was too large to apply a Friedman test.

Comparisons were carried out for the proportions of the number of electrodermal responses using z-tests or  $\chi^2$  tests (pairwise comparison test using Marascuilo's procedure).

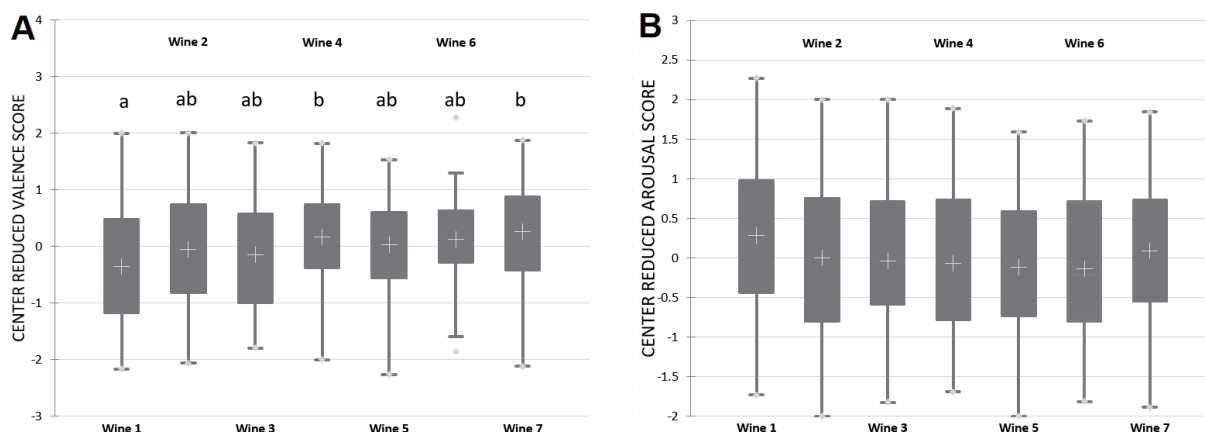
For the declarative data, Principal Component Analyses (PCA) were used to visually represent the relationships between valence ratings and arousal by each consumer for all seven wines.

To study the use of the emotional lexicon, the citation frequencies of each term were calculated, i.e., the number of times each term was used by participants in relation to the total number of times it was possible to use it. Differences in the occurrence of a term between wines were evaluated using a Cochran test (Sheskin pairwise comparison test).

The alpha level was set to 0.05.

### 6. Ethical considerations

Detailed information regarding the experiment was given, and an informed consent form was signed by all participants prior to testing (in particular, indicating the availability of spittoons and breathalysers). For this study, the Local Ethics Committee of the EA4139 Psychology Laboratory issued a notice of compliance with the Code of Ethics for Psychologists (March 1996, updated in February 2012) and the Society's Code of Ethics for French Research of Psychology. All participants received financial compensation for their participation. They were paid 50 EUR by cheque for participating in the 2-hour session, and payment was received at the end.



**FIGURE 2.** Boxplots of the valence score distribution (2A) and the arousal score distribution (2B) for the seven wines. The white cross represents the mean score for each wine; the extremities represent the minimum and the maximum values for each wine. Values marked with different letters are significantly different (Tukey post hoc  $p$ -value  $\leq 0.05$ ).

## RESULTS

### 1. Differences between wines

#### 1.1. Valence score

The minimum valence score for all wines was 1, and the maximum was 9. The entire scale was therefore used, but a participant-dependent variability in the use of the scale was observed. Therefore, to compensate for these differences between participants in the use of the scale, the valence scores have been standardised (centred-reduced).

An ANOVA test with Tukey post-hoc tests showed that valence scores significantly differed between Wine 1 and Wine 4 and 7 ( $F(6,441) = 3.36$ ;  $p$ -value = 0.003) (Figure 2A). A continuum in the valence score attributed to the wines is observed.

#### 1.2. Arousal score

The minimum arousal score for all wines was 1, and the maximum was 9. The entire scale was therefore used, but a participant-dependent variability in the use of the scale was observed. Therefore, to compensate for these differences between participants in the use of the scale, the arousal scores have been centred-reduced.

An ANOVA test indicated no significant differences between the wines for the arousal scores ( $F(6,448) = 1.6$ ;  $p$ -value  $> 0.05$ ) (Figure 2B).

The low discrimination observed between the wines for the valence and arousal scores can be explained by a strong inter-individual variation in the scores.

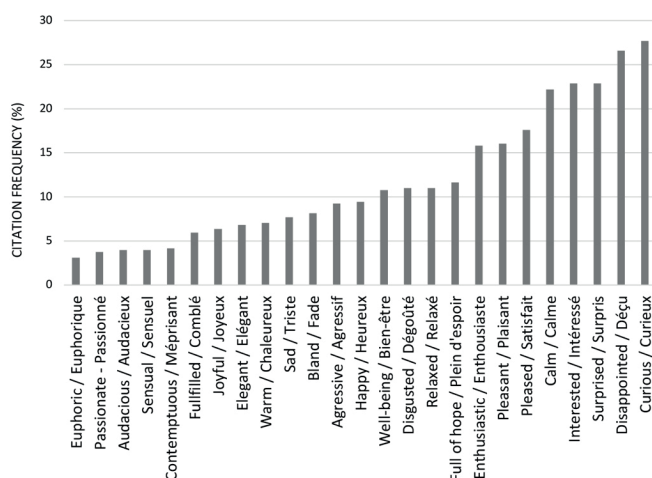
#### 1.3. Emotional lexicon

The citation frequency of each emotional lexicon term was calculated (Figure 3).

Five terms had a citation frequency below 5 % (“Euphoric”, “Passionate”, “Audacious”, “Sensual” and “Contemptuous”), 8 terms had a citation frequency between 5 and 10 %, and

12 terms above 10 %. The maximum citation frequency was observed for the term “Curious” (27.7 %).

A Cochran test for comparison of citation frequencies per wine revealed that the terms “Contemptuous”, “Elegant” and “Surprised” were used differently to describe the wines (Cochran test,  $p$ -values of 0.029; 0.007 and 0.0002, respectively). Note that these terms were, respectively, associated with 4.2 %, 6.8 % and 22.8 % citation frequencies on all wines. Only the term “Surprised” had a citation frequency superior to 10 %. Sheskin’s pairwise comparison tests showed only significant differences in occurrence for the terms “Contemptuous” and “Surprised”. There was no difference between the pairs of wines for the term “Elegant”, although its citation frequency was higher for Wines 5 and 6. The term “Contemptuous” was significantly more common for Wine 1 than for Wine 5 ( $p$ -value = 0.029), and the term “Surprised” was significantly more common for Wine 1 than for Wines 2, 4, 5 and 7 ( $p$ -value  $< 0.001$ ).



**FIGURE 3.** Percentage of participants who used each emotional term ( $n = 65$ ). The lexicon was presented to the participants in French.



## 1.4. Physiological measures

Recording artefacts required the exclusion of 16 of the 65 participants from heart rate measurements. Heart rate variation rates ranged from -6.7 to 29. A Kruskal–Wallis test between wines revealed that heart rate measurements did not significantly differ between wines ( $Q = 6.33$ ,  $ddl = 6$ ,  $p$ -value = 0.387).

For the measurement of electrodermal activity, 14 % of participants were excluded because they did not respond to this measurement. This corresponds to data in the literature, according to which 10 % of participants may be “non-responders” (Biopac Systems Inc). In other words, participants fail to elicit SCR oriented to a stimulus. In addition, recording artefacts forced the exclusion of two participants from all electrodermal analyses and four additional participants for skin conductance level measurements.

A Friedman test indicated a significant difference in the amplitude of electrodermal responses between wines (Friedman test,  $F = 13.22(6)$ ,  $p$ -value = 0.04), with Wine 1 having the highest score and Wine 6 having the lowest score. However, Nemenyi’s post-hoc tests did not reveal any significantly different pairs of wines. A  $\chi^2$  test revealed that the number of electrodermal responses differed between wines ( $\chi^2 = 14.78$ ,  $ddl = 6$ ,  $p$ -value = 0.011), with a maximum for wine 1 and a minimum for wine 6. However, the Marascuilo procedure fails to identify pairs of wines that are significantly different ( $p$ -value > 0.05).

Finally, a Friedman test indicated no significant differences in skin conductance level variation between wines ( $F = 4.78$ ,  $p$ -value = 0.573).

## 1.5. Motor measures

Recording artefacts required the exclusion of 15 of the 65 participants from the motor measures. Friedman tests indicated no significant differences in the different measures of the motor component between the different wines ( $p$ -value > 0.05).

## 2. Relationship between subjective feelings and physiological and motor components of emotions

### 2.1. Relationship between subjective feelings and physiological component

#### 2.1.1. Heart rate variation ratio and valence score

For each participant, and to take into account possible interindividual variation in emotional assessment, the valence scores given to the different wines were transformed into ranks. For each subject, each wine was assigned a rank ranging from 1 to 7. Finally, three groups were formed:

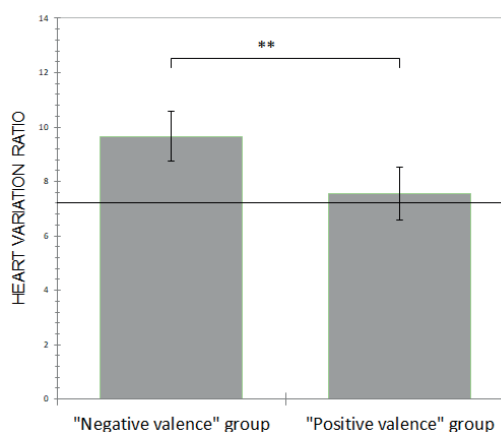
- ▶ The wines classified from 1 to 3 were categorised in the “negative valence” group.
- ▶ The wines classified in rank 4 were excluded: wine not providing neither pleasure nor displeasure. These wines were excluded from the analysis to avoid having neutral wines

and include only wines for which an opinion towards one extreme or the other was made.

- ▶ The wines classified from 5 to 7 were categorised in the “positive valence” group.

For both groups of wine, an increase in the heart rate variation ratio after tasting was observed. The increase observed with wines in the “positive valence” group was barely greater than the increase observed with water (baseline with a neutral stimulus). Moreover, a significant difference was observed between the groups (Mann–Whitney test,  $U = 10762$ ,  $p$ -value = 0.008). The heart rate variation ratio was significantly higher for the wines providing unpleasant emotions, in other words, in the context of rejection (Figure 4).

The same approach was repeated with the arousal note, and no significant difference was observed ( $U = 8645$ ,  $p$ -value > 0.05).



**FIGURE 4.** Mean variation ( $\pm 5\%$  confidence interval) of heart rate variation ratio for wines in “Negative valence” ( $n = 206$ ) and “Positive valence” groups ( $n = 213$ ).

The black line represents baseline measures with water (Mann–Whitney test). \*\*  $p$ -value < 0.01

#### 2.1.2. Electrodermal activity and arousal score

Figure 5 below represents the relationship between the weighted mean number of sensory event-related SCRs (across all participants) and the average arousal score for each wine. A positive correlation was observed between the arousal score and the total number of sensory event-related SCRs by wine (linear regression,  $R^2 = 0.87$ ). Although arousal scores were not significantly different between wines, the wine showing the maximum number of electrodermal responses was the one associated with the maximum average arousal score, wine 1. The same observation was made for the minimum with wine 6.

To account for possible interindividual variation in arousal, the same approach as described for valence above was used to study the relationship between SCR and SCL measures. For each participant, the arousal scores given to the different wines were transformed into ranks. For each subject, each wine was assigned a rank ranging from 1 to 7. Finally, three groups were formed:

► The wines classified from 1 to 3 were categorised into the “low arousal” group.

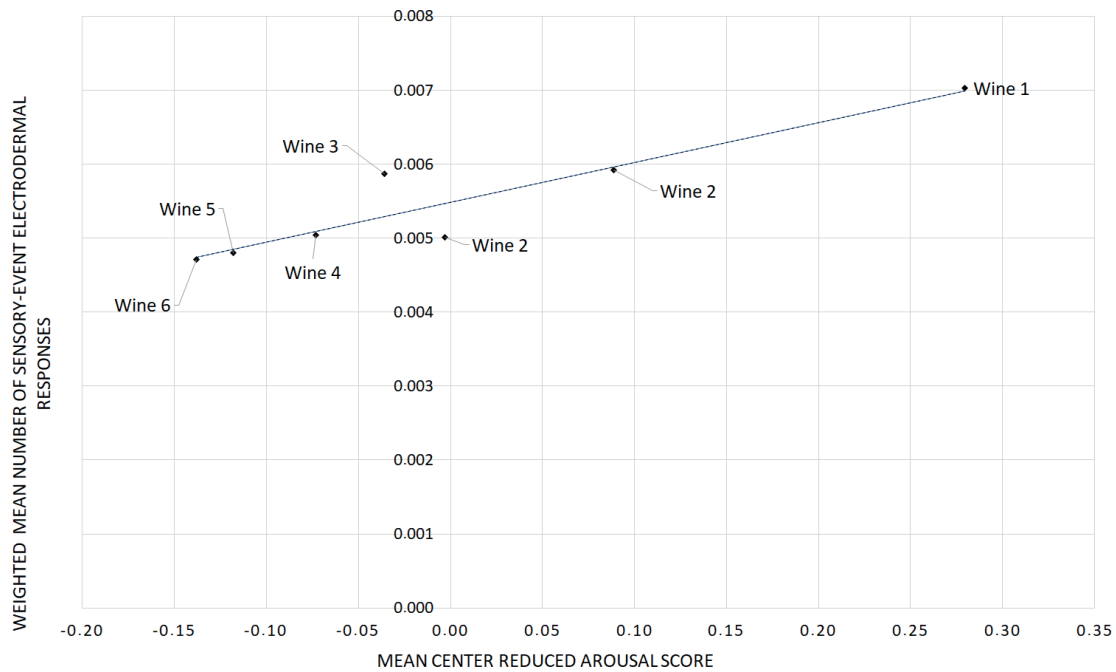
► The wines classified in rank 4 were excluded: wine not providing either low or high arousal. These wines were excluded from the analysis to avoid having neutral wines and only wines for which an opinion towards one extreme or the other was made.

► The wines classified from 5 to 7 were categorised into the “high arousal” group.

Mann–Whitney tests were carried out between the “low arousal” group and the “high arousal” group to see if the wines of these groups would induce different variations of SCL and different amplitudes of SCRs.

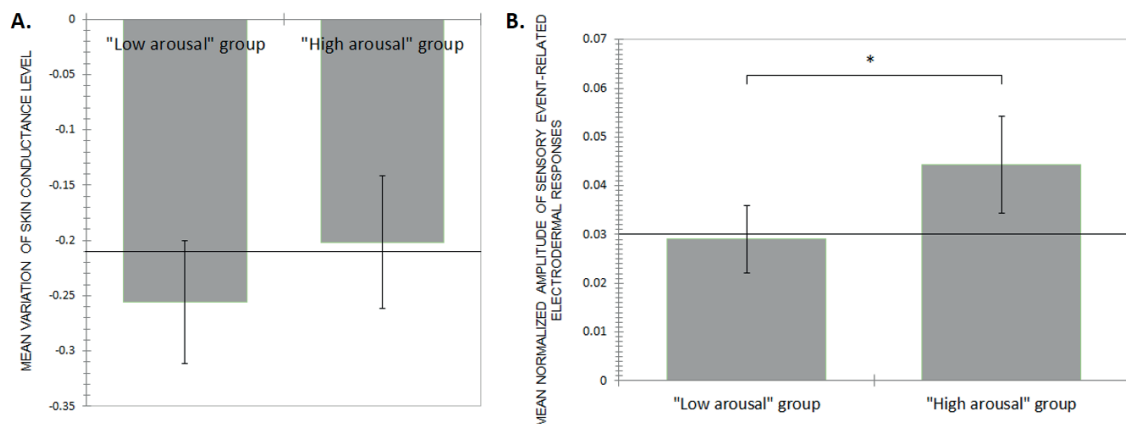
The average SCL level decreased for the two wine groups after tasting, but this decrease was greater for the “low arousal” group, although not significant ( $U = 13578.5$ ,  $p$ -value = 0.101) (Figure 6A). A significantly greater amplitude of the sensory event-related SCRs for the wines in the “high arousal” group was observed compared to the “low arousal” wines ( $U = 12027.5$ ,  $p$ -value = 0.05) (Figure 6B).

The same approach was repeated with the valence note, and no significant differences were observed for the mean variation of SCL ( $U = 13362$ ,  $p$ -value = 0.2) or for the mean amplitude of normalised sensory event-related SCRs ( $U = 13270$ ,  $p$ -value = 0.991).



**FIGURE 5.** Weighted mean number of sensory event-related electrodermal responses for all participants for each wine according to the average centred-reduced arousal score.

Linear regression ( $R^2 = 0.87$ ).



**FIGURE 6.** Mean variation of SCL ( $\pm 5\%$  confidence interval) for wines in “low arousal” and “high arousal” groups (A), mean amplitude ( $\pm 5\%$  confidence interval) of the normalised sensory event-related SCRs for wines of “low arousal” group and “high arousal” group (B).

The black line represents the baseline measures with water. Mann–Whitney tests. \*  $p$ -value < 0.05.

## 2.2. Relationship between subjective feelings and motor components

The same rank data transformation described above was used on the valence score. Mann–Whitney tests were used to test for differences in the number of action units between the “negative valence” group and the “positive valence” group.

The total number of action units activated during smelling, tasting, or after spitting the wine didn’t show any significant differences between the “negative valence” and “positive valence” groups (Mann–Whitney tests,  $p$ -value > 0.05).

The total maximum activation intensity of action units during smelling or tasting the wine didn’t show any significant differences between the “negative valence” and “positive valence” groups (Mann–Whitney tests,  $p$ -value > 0.05).

A marginally significant difference was observed between the “negative valence” and “positive valence” groups for the total maximum activation intensity of action units after spitting the wine, in other words, when the tasting was complete ( $U = 14045$ ,  $p$ -value = 0.086). The “negative valence” group displayed higher total maximum activation intensity than the “positive valence” group. This value is higher for the “negative valence” group than for the “positive valence” group. The mean value of the “positive valence” group is negative (-0.044) (the mean value of this measurement after spitting water was greater).

The same approach was repeated with the arousal note, for which no significant differences were observed (Mann–Whitney tests,  $p$ -value > 0.05).

## DISCUSSION

The main purpose of this study was to determine if wine tasting induces a concomitant activation of the different components of emotion (subjective feelings, physiological and motor components).

This study revealed that only the subjective component (valence and emotional lexicon) and electrodermal measurements differed between wines. Wine 1 with a defect seemed to be the common denominator of these discriminating measures. No differences were observed for heart rate or motor measures. Pichon *et al.* (2015) highlighted the difficulty of discriminating different products of the same family (in this case, fragrances) and of a close range of pleasantness with measurements such as physiological measurements (heart rate and SCR). These authors assume that, in the case of a range of closely related products, variations in these different physiological parameters may occur but are too subtle to be measured with easy-to-set-up measurements such as the ones used in this study. Furthermore, according to De Wijk and Noldus (2021), automatic measurements reflect the experience of consumption as a whole, taking into account the food product itself but also the context and the social interactions surrounding the consumption. This last assertion may explain the low discrimination capacity of wines by action unit measurement. De Wijk and Noldus (2021) suggest that, with well-liked food, these implicit measurements

would present advantages over explicit measurements in a real-life situation outside of a controlled laboratory setting. However, the many signal disturbances related to the movements of the participants during the taking of these measurements (particularly the electrocardiogram) seem to make it complex to take these measurements in a less controlled context. Beyts *et al.* (2017) obtained similar results for beer and suggested that if their samples were well discriminated by declarative but not physiological measures, this could be due to the fact that the beer aromas might be too similar to induce differences at the physiological level. In the present study, to assess the association between motor components of emotion and valence, motor expression was studied through facial expressions. In previous work with juice samples, Danner *et al.* (2014) showed that the intensity of different facial expressions allowed them to differentiate liked samples from disliked ones. Our results displayed a marginally significant difference between wines providing pleasant emotions and wine providing unpleasant emotions for the total maximum activation intensity of action units after spitting the wine. This value is higher for wines providing unpleasant emotions than for wines providing pleasant emotions. Although these results are consistent with those of Danner *et al.* (2014), this measurement provides only moderate discrimination. The first limitation of measuring facial expression in a wine-tasting context can be a logistical limitation. For instance, the fact that participants had the glass in front of their faces, especially when smelling the wine, resulted in several biases, and the software could not manage to acquire measurements. Furthermore, Mahieu *et al.* (2019) evaluated the measurability of emotions through facial expressions for food products. Their study showed that facial expression measurements are more suitable for stimuli such as video advertisements, in other words, standardised stimuli designed specifically to elicit emotions. According to the authors, facial expressions seem to not allow for the discrimination of food products of the same type. The subjective feelings measurement (emotional lexicon), which is much less expensive and laborious to set up, seems to be sufficient within the framework of the study of emotions in wine tasting. Physiological and motor measurements could, however, prove to be a useful tool in the context of certain studies, for example, on people who are unable to identify and describe emotions felt.

Finally, although these measures are more or less discriminating, the correlates found between subjective and physiological data validate the approach and the measurements carried out. Indeed, correlates reported in the literature for other sensory stimuli are also observed for wines.

## CONCLUSION

The results presented in this study, therefore, show that there is a measurable physiological and motor output in tasting. Out of the five components of emotion in the appraisal theories identified by Scherer (2001), our study validates three: the physiological component, the motor component,

and subjective feelings. However, research remains to be done to validate the remaining two (cognitive evaluation of stimuli and motivational (action tendencies) in the context of wine tasting, in accordance with the appraisal theories. The relationships established between these components, as well as their concomitant activation, validate the reality of the emotion felt during tasting. That is, the link between these different emotional components implies that participants do not declare feeling a specific emotion because they were asked to choose among different emotional terms but because they really feel them. Especially since a link with automatic physiological measurements was found. This same link, conversely, also makes it possible to conclude that the observed physiological variations are indeed to be attributed to an emotional response.

Finally, wine is indeed a purveyor of emotions, an emotional object. The wine sector has a real interest in appropriating this measure to use the emotional impact of the organoleptic characteristics of wines as a lever of characterisation, differentiation and valuation. The innovative point of this study is highlighting the inter-relationship between the different emotional components. This offers perspectives for better understanding the intertwining relationship between emotions and wine and opens scientific doors to the oenological sector by providing a promising basis. A recent study by Caissie *et al.* (2023) has shown that emotions can be one of the dimensions of the organoleptic quality of wines. It, therefore, seems important to be able to find the tools to characterise them.

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