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Fine wine flavour perception and appreciation: Blending neuronal processes, tasting methods and expertise

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ABSTRACT

Background: Wine flavour has been methodically studied since the beginning of sensory research, with various purposes relating to product quality and consumer preferences. Recent advances in neuroscience have provided a deeper insight into how the perceptions elicited by flavour-active molecules are processed by the brain. In particular, the implications of the synthetic, emotional and mental imagery features of olfaction, together with the cross-modal influences on flavour perception, should be properly acknowledged in tasting methods.

Scope and approach: The purpose of this review is to present a critical appraisal of current tasting methods, with focus on those that are most frequently applied to assess fine wine. The remarkable ability to distinguish odours, and the emotional nature of the sense of smell, are the basis for the development of alternative tasting approaches that have lead to recent advances. The limitations of aroma and flavour descriptive analysis resulting from the synthetic nature of olfaction will be discussed and, in particular, those limitations that relate to the holistic evaluation of quality that constitutes the core of aesthetic judgements.

Key findings and conclusions: We argue that the conventional tasting sequence and the dominance given to descriptive analysis contributes to the subordination of the holistic nature of wine assessment. Further, expert quality judgements may be strongly biased by cognitive factors and wine preferences. Hence, the highest level of expertise may be attained when individuals are able to recognise a fine wine's synthetic properties (e.g. complexity, harmony, persistence) in association with socio-cultural aspects (e.g. origin, winemaking traditions), and then produce aesthetic judgements independently from wine enjoyment.

Overall, fine wines may be defined as those characterized by superior synthetic or holistic properties that are perceived and appreciated by individuals who understand, and in the context of, their cultural meaning.

1. Introduction

The description of sensory characteristics of foods and beverages started with the first written texts (Stanley, 1999), but the development of systematic tasting methodologies did not start until the middle of the 20th century, and then sensory analysis quickly became a discipline essential to the food industry (Doty, 2015). In wines, the process evolved in parallel and initially concerned the prevention of off-flavours by winemaking professionals (Amerine & Roessler, 1976; Ribéreau-Gayon & Peynaud, 1958).

Present basic tasting methods involve the sequential evaluation of visual, smell, taste, mouthfeel and then overall assessment, with additional gradations in each of these features when necessary (Jackson, 2017; Peynaud, 1987). The tasting protocols are widely available and deeply rooted in the minds of scholars, winemakers, sommeliers, critics and consumers, and those protocols reflect worldwide interest in wine consumption (Broadbent, 1979; Robinson, 2008; Schuster, 2017). However, there is no single standard for wine tasting training (Tempère, Revel, & Sicard, 2019). Grounded on tasting, sensory science has impressively evolved in methodologies and scope, from in-house quality control to consumer research (Ares & Varela, 2018; Heymann & Ebeler, 2017). The most analytic methodologies try both to use senses as chromatographic instruments and to replace senses with instruments (Lesschaeve, 2007). The advances have been remarkable (Baldovini & Chaintreau, 2020) but the increasing performance of machines, with the assistance of powerful statistical approaches (Welke et al., 2021), have not been accompanied by comparable development of human senses as genetic evolution so far pre-dates the dawn of civilization (Hoover, 2010). Therefore, the gap between chemistry and human sensory capabilities is not significantly reduced by acquired sensitivity due to

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extensive training. As a result, it is understandable to attempt to develop methodologies to reduce the burden of training as described by Lesschaeve (2007), especially when experienced professionals are not easily committed to participate in long tasting sessions (Thuillier et al., 2015).

Wine is a complex product not only in flavour or chemical composition, but also in its appreciation, which is strongly influenced by non-sensory, socio-cultural aspects (Charters, 2006). Indeed, while most beverages, and likely most wines, may have a standard of quality determined by the fulfilment of consumer preferences (Norris & Lee, 2002), certain wines ("fine wines" or "vins de garde") share characteristics with aesthetic objects and require different standards of quality evaluation (Burnham & Skilleås, 2012). These standards, even if not clearly stated and at first, appeared to be consensual among scholars and trade professionals (Broadbent, 1979; Peynaud, 1987). However, the development of sensory science did not properly address these standards, as illustrated by recent wine sensory reviews that focus on wine as an object for overall consumer appreciation (Welke et al., 2021; Yang & Lee, 2020) or on aromatic descriptions (Longo et al., 2020; McKay & Buica, 2020; Ruiz et al., 2019). The paucity of research dealing with the quality assessment of fine wines, and lack of a clear definition, probably explain that situation. In fact, while commercial wines are a fruitful object for analysis using cutting-edge analytical instrumentation (as exemplified in Baldovini & Chaintreau, 2020 and Welke et al., 2021), fine wines are better characterised by synthetic modalities (e.g. harmony, complexity) that are not so tractable using the standard methodologies of sensory chemistry and analysis.

The description of sensory perception mechanisms may be found in excellent monographs written by neuroscientists (Murray & Wallace, 2012; Rolls, 2019; Shepherd, 2017; Small & Green, 2012) and sensory researchers (Heymann & Ebeler, 2017). Therefore, the purpose of this review is to describe: (i) the neuronal phenomena underlying the function of the five senses (vision, gustation, olfaction, touch and hearing) with direct implications to wine tasting; (ii) the limitations of current sensory methodologies and progress due to novel approaches, particularly those applicable to fine wines; and (iii) the implications of expertise in fine wine assessment and appreciation.

Hopefully, the interpretation of sensory responses will be improved through the inputs from neuroscience, applied psychology and philosophy, and yield a better understanding of fine wine perception and appreciation.

2. Wine flavour is more than a perfume

The understanding of aroma perception in food and beverages owes many advances to perfumery, even if the sense engaged in this field is limited to orthonasal olfaction (Spackman, 2018). The relevance of aroma to wine appreciation probably explains the abundance of sensory research dealing only with orthonasal odours as if wine was a perfume. However, this is only a part of the overall sensory input defined as "flavour" that blends the information from vision, gustation, olfaction, and the somatosensory and trigeminal systems responsible for astringency, heat, and prickling sensations (Heymann & Ebeler, 2017). Moreover, the sense of hearing and non-sensory cues modulate flavour perception (Piqueras-Fiszman & Spence, 2015). Particularly in fine wines, the orthonasal pathway is clearly insufficient to capture the wholeness of appreciation (Parr et al., 2020) and it should not be dissociated from historical, social and cultural aspects of wine tasting experience (Charters, 2006).

2.1. The flavour is in the brain, the flavourant in the wine

Flavour is regarded as a multimodal neural construct, like a sort of new sense resulting from the other senses (Hannum et al., 2018). The entirety of neural mechanisms, although with different processes for each sensory modality, are interconnected and difficult to individualise (Lundström et al., 2012). Volatile molecules affect the sense of smell both in the olfactory and in the nasal trigeminal system (Müschenich et al., 2021) while the aspects of mouthfeel (e.g. texture, astringency, temperature, prickling) are represented in the brain areas that process taste (Rolls, 2019). Small and Green (2012) claim that during tasting a "flavour object" is formed by retronasal olfactory, gustatory, and somatosensory stimuli into a sort of perceptual *gestalt*. In addition, the process of "oral referral", by which smells seem to originate from the mouth, is further evidence of the multi-sensory nature of flavour (Spence, 2016).

The nature of flavour has been under debate. According to Small (2012), flavour is in the brain because flavour molecules only get their meaning when they are interpreted by the brain. Smith (2017) claims that the flavour perception system tracks the presence of flavours in foods and liquids because flavours are properties of the foods or liquids. Then, flavour is the sensory property (or sensory perception) resulting from the human response to a flavourant that is its material property or stimulus (Chen, 2020) as odour and odourant are defined by Hudson (2000).

3. The peculiarity of olfaction

Among the senses contributing to flavour, the singularity of olfaction (ortho- and retronasal pathways) lies in the straightforward transmission of stimuli from the receptor cells in the nose to the orbito-frontal cortex (OFC) where conscious processing takes place without passing through the thalamus (Shepherd, 2017). Briefly, odourant molecules aspired by both nostrils reach the olfactory receptors (ORs) in the olfactory mucosa. The perception of an odour's quality is then a result of combinatorial coding, whereby an odourant can interact with several of the active ORs corresponding to about 400 intact genes. ORs can also be activated by several structurally diverse odourants (Kurian et al., 2021). The receptor neurons send the electric signals to the olfactory bulb (OB), where a "smell image" is formed, and then different signals are further assembled in the piriform cortex (PC) or primary olfactory cortex (Blazing & Franks, 2020). The OB also sends information, without passing through the PC, directly to other brain areas in the OFC that regulate cognition, emotion, memory, and behaviour (Blazing & Franks, 2020). Thus the signals of volatile molecules go directly to the OFC, and the OFC is the most evolved part of the brain where higher cognitive functions make us human (Shepherd, 2017).

The inputs from the eye, tongue (taste and mouthfeel) or ear cross the thalamus, are then processed in different cortical areas in the middle and back of the brain, and are ultimately sent to the OFC (Shepherd, 2017). The retronasal pathway may also have nerves through the thalamus, giving rise to the perception that the odour has a taste (Small & Green, 2012). Indeed, for food flavours, the orthonasal route elicits sensations different from those delivered retronasally despite activating the same receptors in the olfactory epithelium (Hannum et al., 2018; Wilkes et al., 2009), and that leads to a complementary concept of physiological and experiential modalities relating to the sense of smell (Wilson, 2021).

3.1. Smell as a synthetic, emotional and imagery sense

The perception of odour stimuli as odour objects can produce two main types of percepts that include intermediate nuances: (i) heterogeneous percepts in which the specific odour qualities of several individual odourants can be identified within the mixture, corresponding to an analytical or elemental processing of olfactory information; or (ii) homogeneous percepts in which a single odour is perceived from the mixture, being the perception described as robust configural or synthetic (Thomas-Danguin et al., 2014). The particularities of odour perception with direct implications in tasting are presented below.

3.1.1. The odour object is essentially synthetic

In an odourant mixture, when the number of aromatic molecules rises to 3, only about 5% of trained individuals recognised all of them, with lower percentages for mixtures of 4 or 5 (Laing & Francis, 1989). These authors posited that odours in mixtures blend to form a new odour with few of the characteristics of the original ones; this is being corroborated by further research (Frank et al., 2017; Marshall et al., 2006), some of which is related to wine (Ferreira, 2012). Therefore, the sense of smell is essentially synthetic and not analytic supporting the configural functioning of olfaction. Indeed, the food olfactory world is constituted by about 10,000 volatile molecules but there is evidence that about 230 odours contribute anything to the aroma of most foods (Dunkel et al., 2014). That number roughly matches the number of ORs (circa 400) suggesting that the foodborne stimulus space has co-evolved with the human olfactory system (Dunkel et al., 2014). Studies with large mixtures of odourants (formulated to be of equal potency) showed that a subject's ability to detect individual odourants in these mixtures was vanishingly small and that supports the synthetic nature of olfaction (Rochelle et al., 2018).

Configural processing makes odour recognition analogous to facial and object recognition (Jinks & Laing, 2001). Recently, Romagny et al. (2018) proposed a perceptual model where the elemental perception of odour mixtures relies on the perception of key odourants individually within the mixture, whereas configural perception relies on key associations of odourants that lose their individual identity when mixed at specific concentration ratios. The number of key odourants is relatively small ranging from 3 to 40 for each food (Dunkel et al., 2014). This model is consistent with the perceptual flavour wine model described by Ferreira (2010). According to this concept, the aroma of wine is characterised by a few molecules (about 30) that act as a buffer (the "aroma base") because differences in their concentrations are not reflected in different aromatic perceptions. These molecules are the same in white or red wines and only the so-called "impact molecules", or families of molecules, may break the aromatic "buffer". Examples of impact volatiles are terpenes in varieties like Muscat or off-flavours. In the absence of impact molecules, wines may be described as odourless and different varietals are then indistinguishable (Campo et al., 2008) and have a light, sweet, pungent, alcoholic, and somewhat fruity aroma (Ferreira, 2010).

3.1.2. Implications in sensory analysis

3.1.2.1. The limited significance of "odour activity values" (OAV's). The impact of aromatic molecules on odour perception is frequently measured by OAV's obtained by the ratio between the odourant concentration in a mixture and its sensory detection threshold (see a discussion of its conceptual errors in Baldovini & Chaintreau, 2020). For instance, OAV's do not consider the synthetic nature of odour objects. The simple binary mixture of ethyl isobutyrate (strawberry-like odour) and ethyl maltol (caramel-like odour), for example, is perceived as more typical of a pineapple odour, like allyl hexanoate (pineapple-like odour), than the odours of the individual components (Tromelin et al., 2020).

In complex samples, the broad utilisation of OAV's to predict the flavour does not seem reasonable, because several odours act as suppressors or enhancers of aromatic notes, even at sub-threshold concentrations (Ferreira et al., 2016). Then, the so-called single aroma vectors composed by several molecules seem to be more appropriate to describe wine flavour (Ferreira et al., 2016; Fuente-Blanco et al., 2020), and that is probably due to their similar chemical structure (Snitz et al., 2013). Moreover, cross-modal interactions occur between aroma, taste and texture perception, changing the perception of equal odourant concentrations (Baldovini & Chaintreau, 2020). This is particularly relevant in the aroma of fine wines not dominated by single aromatic molecules or aroma vectors (McKay & Buica, 2020) and strongly dependent on the astringency sub-qualities that make sensory prediction from chemical composition rather difficult (Goodstein et al., 2014; Pittari et al., 2020; Rinaldi et al., 2020).

3.1.2.2. The development of "olfactory conceptual spaces". The neuronal ability to synthetize olfactory perception has been illustrated by the development of "olfactory conceptual spaces" to explore the similarities between diverse groups of wines (Ballester et al., 2005). Experts base the task on sorting pairs of different wines in relation to a memorised prototype, possibly followed by flavour description. Through this approach, matching a complex product to a description may not be obtained (Lelièvre et al., 2008) and boundaries are not always clear-cut (Jaffré et al., 2011). Nevertheless, various typicality concepts have been successfully addressed for variety profiling (Ballester et al., 2005; Garrido-Bañuelos et al., 2020; Loison et al., 2015; Schüttler et al., 2015), aged wine (Picard, Tempère, et al., 2015) and regional characterisation (Kustos et al., 2020). This approach has been recently corroborated through the definition of "local conceptual spaces" (Jraissati & Deroy, 2021).

3.1.3. Efficient odour distinction and difficult odour naming

The human detection and discrimination ability among different smells is remarkable and it outperforms that of vision and audition (Bushdid et al., 2014). The claimed number of more than one trillion discriminable olfactory stimuli is not tenable (Gerkin & Castro, 2015; Meister, 2015), but the question here is not the exact number but the limited ability to assign a name to an odour. The difficulty in verbalising the odour perception is comparable to the difficulty in describing faces or emotions and it is explained by the incompatibility between human conceptual semantic resources and the olfactory system, even in cultures where the identification ability is higher (Young, 2020a).

The effort to name a flavour makes its recognition more difficult (Melcher & Schooler, 1996). Sensory training may diminish this difficulty, but it may be an illusion when fluent vocabulary is used together with memory to describe expected flavours (Thomas-Danguin et al., 2014). In fact, flavour descriptors are metaphors (Joy et al., 2020) in the sense that a wine smells "like a rose" and not smells "to roses". Then, fluency in wine description may just be a matter of literary practice and not of sensory acuity (Brochet & Dubourdieu, 2001). Furthermore, the same flavour may result in different descriptors according to a memorised flavour object (Williamson et al., 2017).

3.1.3.1. Implications in sensory analysis.

The limits of descriptive analysis (DA)

DA or profiling methods are regarded as the gold standard for sensory scientists (Heymann & Ebeler, 2017) despite the synthetic nature of olfaction. In fact, Lawless (1999) warned that sensory scientists should question the validity of descriptive data and avoid the simplistic mistake of equating data with perception. The use of simple and apparently independent intensity scales may produce the illusion that the odour experience is a collection of independent analysable "notes" when it is not (Lawless, 1999). Not surprisingly, Hughson and Boakes (2002) found that one could better match flavours and wines with a short list (14) of wine descriptors than with a long list or no list. Alegre et al. (2017) only required one to three descriptors, cited by at least 20% of the panellists. Likewise, Brand, Valentin, et al. (2020) in DA by frequency of citation (FC) restricted the possible choices to four or five descriptors because large numbers added biases to the statistical analysis. Nevertheless, the number of assessors increases the low number of descriptors, and the most frequent descriptors may number more than 20, giving the false idea that each one can be sensed individually. Furthermore, the use of extended lists of smells in questionnaires has a psychological effect of adding flavours (Lelièvre et al., 2008) while appropriate verbal labels enhance performance (Russell & Boakes, 2011).

Sensory validation of chemical composition differences

The differences in flavour chemical composition obtained by analytical instruments and statistical analysis may not represent differences in the aroma perceived by a trained sensory panel (Lawless, 1999). To overcome this limitation, one alternative is to first use sorting methods that group similar flavour profiles followed then by chromatographic analysis (Alegre et al., 2017). Another way is to include the classical forced choice triangle or paired tests to validate *a posteriori* the results previously obtained by chromatography or DA (Baldovini & Chaintreau, 2020; González-Centeno et al., 2019).

The development of sensory comparative methods

The restriction of DA to highly trained individuals to standardise perceptions and vocabulary requires considerable resources and taster availability (Lesschaeve, 2007). Familiarity with the profiling method also influences taster performance and that may explain differences among experts and experienced and trained panellists (Barton et al., 2020). Long and periodic training sessions have been pointed out as a serious impediment to the participation of experienced wine professionals who are reluctant to commit to such courses. To overcome this drawback, methodologies based on comparisons to standards (e.g. Napping, Flash Profiling, Pivot Profiling, Polarised Projective Mapping, Ultra-Flash Profiling) have earned increasing interest due to the highly efficient neuronal ability to discriminate different "odour objects" (Table 1).

3.1.4. *Emotion is part of the sense of smell*

The unique properties of the sense of smell led Yeshurun and Sobel (2010) to define it as an emotional sense, where the emotion is not a result from the sensory stimuli but an integral part of the perception (Table 1). For these authors, the odour object is the integration of its pleasantness, induced by its external state (volatile molecules), with the subjective internal state when it is sensed. In fact, the first spontaneous reaction to odourants is a verbal description related to pleasantness (e.g. "it is good" or "I like it") in accordance with the processing of emotional information in the olfactory bulb (Kermen et al., 2021) or in the human piriform cortex even before odour perception (Schulze et al., 2017). Interestingly, better olfactory performance by sommeliers was related to larger insula and entorhinal cortex, with roles in emotion and memory processing (Banks et al., 2016).

Table 1
Characteristics of the sense of olfaction with direct implication in tasting methodologies.

Characteristics [a]	Implication	Illustrative references
Superior detection and discrimination of odour objects	Utilisation of methods comparing samples with well-defined standards (pivots or poles) or by sorting	Dehlholm et al. (2012), Thuillier et al. (2015), Alegre et al. (2017), Wilson et al. (2018), Pearson et al. (2020), Hayward et al. (2020)
Poor verbalization of odours	Restrict descriptive analysis to highly trained individuals and little number of descriptors	Campo et al. (2008), Alegre et al. (2017), Brand, Panzer, and Buica (2020)
Pleasantness is the main dimension of perception	Assessment of sensory and emotional scores in parallel	Loureiro et al. (2016), Coste et al. (2018), Souza-Coutinho et al. (2020)
Memory is based on a given pleasantness	Past sensory experiences influence flavour perception (e.g background culture and training)	Rodrigues and Parr (2019), Croijmans and Majid (2016)
Influence of internal factors (satiety, mood, ambient temperature) on pleasantness	Assess tasting in different contexts (e.g. immersive ambient, during meals, domestic consumption)	Orth and Bourrain (2005), Tempère, Pérès, et al. (2019), Hannum et al. (2020), Mahieu et al. (2020)

[a] According to Yeshurun and Sobel (2010).

3.1.4.1. *Implications in sensory analysis.*

Inclusion of emotions in sensory descriptions

The use of DA only provides an idea of the complexity of food choices (Jaeger et al., 2019). Similarly to DA, several lists of emotions and feelings are now available together with emotion wheels through which liking, preference or appreciation are assessed (Coppin et al., 2021; Desmet & Schifferstein, 2008; Niimi et al., 2019). The sensory drivers of emotions may not correspond to the sensory drivers of liking because they depend on the type of food and on consumer groups (Spinelli et al., 2019), but because they are considered to go "beyond liking" they become more stable indicators of day-life behaviour (Köster & Mojet, 2015). Therefore, it seems appropriate to include emotions when constructing olfactory conceptual spaces (Alegre et al., 2017; Sáenz-Navajas et al., 2021). In addition, subjective self-reported responses may be circumvented by complementary biometric measurements of liking, preference and emotional states (Mehta et al., 2021; Álvarez-Pato et al., 2020).

The use of emotions in tasting learning

Beyond emotion description, the contrast between odour-induced expectations and aftertaste deceptions, or surprises, may be used as a rapid learning approach. The process includes comparison with examples of two opposite wine styles, one consistent with the international commercial wines and the other illustrating the classical European wines (e.g. Burgundy Pinot Noir or Chardonnay) tasted blind (Coste et al., 2018; Loureiro et al., 2016; Souza-Coutinho et al., 2020). According to these authors, the unpleasant responses elicited by the aroma of high-quality Burgundy wines are compensated for by the aftertaste surprises and their rapid recognition is probably mediated by cognitive dissonance.

3.1.5. *"Guessing the rest" and the effect of mental imagery*

In smelling, the recognition of initial odours may anticipate the rest of the experience because odour object processing allows "guessing the rest" of the pattern when degraded inputs arrive (Shepherd, 2017). Spence and Wang (2018) described this effect as the phenomenon of "filling-in". According to both authors, the odour object is seen as complete which promotes perceptual stability when the context is familiar. The process may be compared to facial recognition where a glimpse is enough for identifying an acquaintance in a familiar context. Similarly, an expert knowing what he/she is drinking may apply cognitive resources to describe accurately what he/she is perceiving even if part is not indeed perceived (Lesschaeve, 2007). Further, neuroimaging has shown that imagined stimuli can interact with those that are truly sensed in a process known as mental imagery as reported by Spence and Wang (2018) and Tempère, Revel, et al. (2019).

3.2. *The process and implications of olfactory mental imagery*

Mental imagery is defined as the creation of a neural representation in the absence of an external stimulus and it is accessed from memory (Kosslyn et al., 2001). The perception of the external world results from the interaction and integration of multiple senses that improve the awareness of the reality or lead to distortions (Berger & Ehrsson, 2013). These authors posited that neuronal signals from real stimuli integrate with those from imagined stimuli to create a new multisensory percept processed in the same brain areas. In relation to olfactory mental imagery, this phenomenon has been described as the ability to sense a smell in the absence of any olfactory stimulus (Mainland & Sobel, 2006). Memory based on the conscious accumulation of experiences enables the brain to imagine smells without indeed having perceived them (Croijmans et al., 2020).

The nature of the olfactory illusions is an issue of actual philosophical debate. Stevenson (2011) argued that olfactory illusions are not accompanied by an awareness of their illusory nature, while Batty (2014) considered that there are no olfactory illusions because olfaction, contrary to vision, has no object. Zucco and Job (2012) proposed the term "ambiguity" instead of illusion when the same pattern allows two possible alternate percepts. These authors give the example of tasters who describe a supposed red wine that is actually a white wine. Ultimately, Young (2020b) presented the arguments that justify the similarity of olfactory mental imagery with that of the other senses.

Independently from these arguments, olfactory mental imagery has been described as a core ability that explains the acquisition of wine expertise through perceptual and semantic training or learning (Tempère, Revel, et al., 2019). Moreover, although with different nuances, imagery also shapes novice perceptions of wine as assuredly as taste (Joy et al., 2020). Then, the question is what share belongs to an increased awareness of reality and what share to the imaginary world.

3.2.1. *Wine tasting scripts: the thin line between mental imagery and the imaginary*

The ability to "guess the rest" or "filling in" and the question of how much of the imagery is a fantasy is still to be answered because the expert cognitive valences (e.g. memory associations, semantic fluency) may be engaged instead of truly perceiving diverse flavours. Cognition may affect perception and what appears to improve sensory and cognitive resources may actually be a source of unaware self-illusion (Stevenson & Mahmut, 2013).

This situation is particularly evident when experts have memorised what is expected to be perceived. Brochet and Dubourdieu (2001) observed that experts described wines based more on linguistic prototypes than on their sensory properties. Accordingly, experts identify the characteristics of a wine by comparing models and by matching those features previously associated with those models (Hughson & Boakes, 2002). Honoré-Chedozeau et al. (2020) explained that experts and novices who are familiar with those models activate a "wine tasting script" to describe wines. For instance, the perception of volatile thiols may create the image of a typical Sauvignon Blanc and the descriptors may then be straightforward ('I smell gooseberry therefore it is a Sauvignon Blanc and I should also smell grapefruit and cat urine') as pointed out by Lesschaeve (2007). Indeed, the dependence of varietal descriptions on memory leads experts to guesses that correspond to familiar "tasting scripts" (Wang & Spence, 2019a).

3.2.2. *The top-down and bottom-up processing information in expertise*

The role of expertise in olfaction, depending on extensive training, has been explained in terms of functional and structural modifications in the neural processing of odours (Royet et al., 2013). Olfaction involves a significant amount of high-level processing including experience, memory, attention, expectation and intention that are subjected to cognitive influences through education, knowledge, imagination and culture (Chen et al., 2014). Therefore, it is reasonable to interpret the sensory responses, just as in other areas of human behaviour, where only cognitive factors are involved (e.g. economy, psychology). The strategies to process information to obtain knowledge are known as "top-down" and "bottom-up". The first one dominates when the conceptual information (top) influences the sensory response (down) while the second corresponds to the cases where the sensory information (bottom) determines the conceptual response (up) (Shepherd, 2017). Briefly, in the presence of a new wine, the intuitive question asked by the expert would be "have I tasted it before?", trying to find by memory similar examples. The novice would ask "what is this?" as he/she has no previous wine experience. However, the same person may use both processes depending on the task to be performed and on his/her level of knowledge or expertise.

4. The constitutive characteristics of expertise

Evaluation of wine quality should not be dissociated from the dimensions of expertise, as quoted by Peynaud (1987): "Quality only exists in relation to the individual and then only in as far as he has the ability to perceive it and approve it". However, what constitutes expertise is still to be fully answered (Ashton, 2016). Popular wine press focusses on the ability to guess flavours, origin or grape, but when subjected to well-controlled experiments experts fail to discriminate wines on this basis or regarding age, quality, or price (Spence & Wang, 2019). Indeed, the so-called deductive approach to blind tasting is based on matching a limited range of wines to memorised prototypes (Burton, 2019). The possibility of heightened flavour sensitivity has also no justification because there is little evidence to support changes in sensory threshold accompanying wine expertise (Brand & Brisson, 2012; Parr et al., 2002). Indeed, experts only have a limited better sensitivity over non-experts which the experts acquire by perceptual and linguistic training (Croijmans & Majid, 2016).

Charters and Pettigrew (2007) affirmed that quality is a mental construct that depends on the degree of involvement with wine. Experts are regarded as highly involved individuals relying more on cognition and on gustatory dimensions of synthetic nature like body, drinkability, balance, or complexity. Besides these features, Charters and Pettigrew (2007) added paradigmatic qualities that represent something extraneous but that a fine wine is supposed to have, such as typicality (related to a given *terroir*) or varietal expressiveness, that are a dimension of a quasi-aesthetic experience. Going further, the philosophers Burnham and Skilleås (2012) argued that fine wine is indeed a true aesthetic

Table 2
Experienced attributes of aesthetic objects present in wine.

Attributes [a]	Definition [a]	Justification [a]	References
Vagueness	Presence of characteristics difficult to assess	Variation in individual perception	Hayes and Pickering (2012), Parker et al. (2019)
		Odour or flavour description	Noble et al. (1984), Gawel et al. (2018)
		Synthetic properties	Peynaud (1987)
		Cross-modal interactions between senses	Goodstein et al. (2014), Pittari et al. (2020)
Moving target	Evolve with time	Develop in the glass	Ferreira et al. (2006), Poveromo and Hopfer (2019)
		Aging potential	Langlois et al. (2010)
		Change with food or the occasion	Eschevins et al. (2019)
Richeness	Valorisation of properties beyond a physical object	Paradigmatic characteristics (e.g. typicality, *terroir*, varietal purity, naturalness)	Charters and Pettigrew (2007), Parr et al. (2020)
		Cultural, historical and social influences	Charters (2006)

[a] According to Burnham and Skilleås (2012).

object and they enumerated a series of characteristics in common with literature, painting, music or landscapes (Table 2). Therefore, the rules of aesthetic evaluation may, and should be, applied to fine wine tasting (Taylor, 2019).

Overall, as described below, the different sorts of wine qualities and taster competences listed in Table 2 may be systematised in order to explain the dimensions of expertise at three different levels with mutual interactions (Fig. 1).

4.1. Perceptual expertise

Perceptual expertise concerns the ability to detect, recognise and categorize the different sensory stimuli elicited by the chemical constituents of wine. In practice, perceptual expertise is defined by the ability to separate aromas and in-mouth perceptions into different families and sub-families, as illustrated by aroma (Noble et al., 1984) and mouthfeel wheels (Gawel et al., 2018).

4.1.1. The informal acquisition of skills to categorize and name aromas

The fact that odours are perceived as synthetic objects seems to be in contradiction with their possible segregation using numerous descriptors, even by experienced perfumists. Barwich (2017, 2019) addressed this issue by postulating that olfaction affords perceptual categorization without the need to form odour objects when experts are involved, thus being different from visual objects. Overall, this expertise builds on the analytical ability to separate sensory information and focus on salient features by experts who must overcome the synthetic nature of olfaction using a process called figure-ground segregation. Then, different experts may describe the bouquet of a wine in separate qualitative terms simply because different features in the wine appear salient to them (Barwich, 2017, 2019).

However, this hypothesis to explain expertise collides with the recent observation that consumers can acquire this categorization ability with less time than previously supposed (Koenig et al., 2020). Spence (2019) showed that the level of wine expertise is more related to conceptual knowledge than to improvements in flavour sensitivity. Likewise, Parr et al. (2002) showed that the higher odour recognition among wine experts was not due to enhanced semantic memory and linguistic capabilities but to the fact that they were less susceptible to verbal overshadowing than novices. Indeed, short training made tangible changes to olfactory performance, supporting the idea that generalised perceptual learning can take place for odour (Wang et al., 2021) and also for gustatory attributes (Veríssimo et al., 2021). Accordingly, Croijmans et al. (2020) showed that, once expertise has been acquired, language did not influence odour recognition memory. Moreover, consumers may not be so naïve and experts may be somewhat less experienced (Aqueveque, 2018). This approximate semantic behaviour between experts and novices is understandable given the present familiarity with the popular fancy aroma representations (e.g. aroma wheels, fruit and flower drawings inside glasses) that make spontaneous training easily accessible. This argument found support in the fact that odour categories produced by a cohort of 156 subjects, composed by 72% of consumers and 28% of experts, were well ascribed to the categories of Noble's aroma wheel (Koenig et al., 2021).

In summary, simple aroma categorization appears to be prone to informal learning. Then, perceptual expertise in wines should also include, besides the ability of perceptual grouping, the knowledge to assign meanings to olfactory stimuli in order to form context-sensitive associations (Köster et al., 2014). This process requires prolonged olfactory training in a complex mixture to make the required inferences from the perceived aromas (Croijmans & Majid, 2016), thus constituting the core of perceptual expertise.

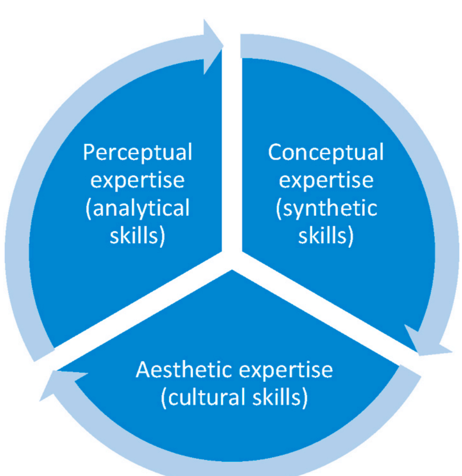

Fig. 1. The three dimensions of expertise and related main sensory and cognitive skills.

4.1.2. The inference of quality from aroma recognition

The aromas or flavours recognised in a wine may serve as indicators of quality under the previously described process of "filling-in" or mental imagery. The expert perceives an aroma and infers the remaining properties of the wine. However, a particular aromatic molecule, or group of molecules, may have several qualitative connotations depending on the context. For example, experts know that the best wines deserve barrique aging, even though oak flavours are not necessarily restricted to fine wines (Gambetta et al., 2017; Sáenz-Navajas et al., 2012). A more elaborate example may be drawn from the results of the perceptual indicators of Bordeaux red wines with aging ability (vin de garde). Table 3 shows that the undergrowth or truffle aromas best describing these wines may be considered to be off-flavours in other contexts, while mint and spiciness may be associated with other wines of less aging ability. Further, different aromatic molecules for the same descriptor have different origins and thus technical significance (e.g., undergrowth elicited by rotten grapes).

The underlying cognitive process of perceptual experts is a top-down type where knowledge influences perception (Mainland & Sobel, 2006). Indeed, spotting a particular flavour may be a necessary fine wine quality condition, but it is not sufficient because the flavour may either dominate the aroma or be present in wines that are not truly fine. Similarly, the identification of off-flavours, to which wine experts are rather sensitive (Tempère et al., 2016), should only be an indicator of spoilage when they are impact molecules and dominate wine flavour. Otherwise, for instance, high quality oak aged red wines with leather notes associated to microbial spoilage by experts may be regarded as defective (Sáenz-Navajas et al., 2015).

4.1.3. The subordinate role of taste and mouthfeel descriptions

Overall, the analytical mindset of perceptual experts appears to rely almost exclusively on aromatic profiles to make distinctions between similar products (Gambetta et al., 2016; Gros et al., 2017; Schüttler et al., 2015). Taste and trigeminal descriptors are more prone to disagreement (Pelonnier-Magimel et al., 2020). These authors justified the absence of consensus among judges by the need for improved training or lack of differences between samples. In fact, while the determination of aromas seems to be well established, sensory researchers still recognise the need to develop methods of dealing with in-mouth attributes (taste and mouthfeel) (Agorastos et al., 2020; Arvisenet et al., 2016; Gawel et al., 2018; Laguna et al., 2017; Rinaldi & Moio, 2018) and respective flavour cross-modal interactions (Pittari et al., 2020; Sáenz-Navajas et al., 2020). In addition, time-intensity determinations are required to deal with a product that evolves during tasting and the time that it is in the glass (Goodstein et al., 2014; Kemp et al., 2019; Meillon et al., 2009; Poveromo & Hopfer, 2019). These methodological improvements are particularly pertinent when high quality aged wines with similar aromas may be better distinguished by

Table 3
Inference of wine quality determined by sensory descriptors and significance of aromatic molecules in high quality Bordeaux red wine and in other wines.

Descriptors	Significance	Tasting conditions	Reference
Main: undergrowth, truffle, and spicy Secondary: toasted, liquorice, mint, fresh red- and black-berry fruits	Typical ageing bouquet of red Bordeaux wines, all subjected to oak aging and free of off-flavours	Clear glasses, ortho- and retronasal smell, local wine experts	Picard, Tempère, et al. (2015)
Undergrowth, truffle, and empyreumatic	Elicited by dimethyl disulphide (DMS), 2-furanmethanethiol (2FM), and 3-sulfanyl-hexanol Part of the typical ageing bouquet of red Bordeaux wines	Clear and dark glasses, ortho- and retronasal smell, local wine experts	Picard, Thibon, et al. (2015)
Mint	Elicited by the molecule piperitone Part of the typical aging bouquet of Bordeaux Cabernet Sauvignon	Dark glasses, ortho- and retronasal smell, local wine experts	Picard et al. (2016)
Cooked/candied fruits, red and black fruits, cooked cabbage	Elicited by DMS Young red wine model	Orthonasal smell, trained assessors	Franco-Luesma et al. (2016)
Canned vegetables	Elicited by DMS Oaked red wine model	Orthonasal smell, trained assessors	Franco-Luesma et al. (2016)
Roast coffee, toasty	2FM Presence in red Bordeaux wines and Petit Manseng sweet white wines, probably originating from toasted oak	Trained assessors in triangle test	Tominaga et al. (2000).
Spicy, clove, smoke	Vanillylthiol White wines and red wines aged in oak barrels	Trained assessors in triangle test	Floch et al. (2016)
Mint, eucalyptus	Vegetative flavour	Clear glasses, orthonasal smell, local trained tasters	Hein et al. (2009)
Mint, eucalyptus	Aroma and flavour of several young wine varietals from Cabernet Sauvignon, Carmenére, Malbec, Merlot, Syrah, and Tannat from Chile, Brazil, Uruguay, and Argentina	Clear glasses, ortho- and retronasal smell, local wine experts	Llobodanin et al. (2014)
Mint, Mallee leaf	Distinctive aroma of Cabernet Sauvignon from Coonawarra region	Australian experts	Souza-Gonzaga et al. (2020)
Animal, leather	Distinctive aroma of Cabernet Sauvignon from Bordeaux compared to Australian C. Sauvignon	Australian experts	Souza-Gonzaga et al. (2020)
Mushroom, earthy	Elicited by geosmin, 1-octen-3-ol, 1-octen-3-one, and 2-methyliso-borneol Off-flavours in wines form ripe rot affected grapes of C. Sauvignon	Chemical analysis	Sadoughi et al. (2016)
Musty, earthy	Elicited by geosmin Treatment to reduce the off-flavour in wines from grey rot affected grapes	Trained assessors	Lisanti et al. (2014)
Vegetal, leather, animal, undergrowth, or mushroom	Unfavourable descriptors Spanish white wines	Dark glasses, orthonasal smell, Burgundy trained assessors	Campo et al. (2008)
Animal Woody	Negative influence on quality in all red wine quality standards Positive influence on quality in all red wine quality standards	Orthonasal smell, local wine experts	Sáenz-Navajas et al. (2012)

in-mouth sensations (Rinaldi et al., 2020). Furthermore, aroma and in-mouth sensations can be conceived as a wine sensory *gestalt* leading to the next level of expertise.

4.2. Conceptual expertise

The conceptual expertise concerns the ability to perceive a wine's synthetic properties that are also known as holistic (Ashton, 2016), emergent (Barwich, 2021; Burnham & Skilleås, 2012), abstract, high-order, umbrella (Parr et al., 2020) or multimodal (Sáenz-Navajas et al., 2021). Lezaeta et al. (2018) labelled these attributes as extrinsic but different from the usual extrinsic cues such as label, bottle, or price. In opposition to analytic descriptors, these synthetic properties may be characterised as follows (Burnham & Skilleås, 2012):

(a) they are not a measure of individual molecules or cannot be obtained by the sum of several molecules;
(b) they depend on chemical nature of the wine but cannot be predicted by wine physical-chemical analysis;
(c) they are not individual sensations, or groups of sensations, but to a certain extent are relations among sensations.

The classical manuals of Broadbent (1979), Peynaud (1987) and Buffin (2002) illustrate the preponderant role of synthetic properties in wine evaluation. The list is long, including classical accepted terms of harmony, intensity, transparency, texture, finesse, body, richness, complexity, persistence, elegance, depth, gracefulness, delicacy, typicality, memorability, and aging potential. Relevance is mainly given to the balance among taste or flavour and mouthfeel sensations for which Peynaud (1987) defined a "souplesse" indicator based on acidity and astringency. Broadbent (1979) stated that "quality can be assessed by the length of time the flavour lingers in the mouth, by its richness and subtlety and by its aftertaste". These properties are barely acknowledged in wine sensory research (Sáenz-Navajas et al., 2016). Probably, the difficulty to capture the essence of synthetic qualities by chromatographic instruments and successive predictive models, as in odourant analysis, explains why published research has just begun to flourish. Indeed, a global concept of wine quality would be the result of the integration of perceptual and cognitive information rather than a collection of independent stimuli (Sáenz-Navajas et al., 2016). Most likely, methods based on sample comparison would help to solve many of the ambiguities found in sensory research dealing with the synthetic properties of fine wines, as described below.

4.2.1. The ambiguities of holistic assessments

The perception of synthetic properties shows several inconsistencies, even if experts agree on their definition, that reflect the difficulty in their assessment and precluding the establishment of mental prototypes based on taste and trigeminal sensations (Sáenz-Navajas et al., 2016). Hence, the primary achievement should be to distinguish clearly what is an analytic (taste or mouthfeel) or a synthetic modality. For instance, texture is not mentioned in the tasting manuals of Baldy (2009) and Jackson (2017), while it is a synonym of mouthfeel for Cheynier and Sarni-Manchado (2010) and a category of the mouthfeel wheel for Gawel et al. (2018). Moreover, Rinaldi and Moio (2018) considered, as sub-qualities of astringency, some synthetic parameters like persistence, body and flavour richness that were assessed together with the different grades of astringency.

The choice may also fluctuate according to the popular trend of the moment (Temmerman, 2017). In wines, the best example is "minerality; " it should be considered a synthetic property due to the vagueness of the concept even among experts (Rodrigues et al., 2015). Typical reductive notes are recognised by some experts (Ballester et al., 2013) but are not necessarily perceived as such by others (Parr et al., 2015). In order to minimise these ambiguities, the use of appropriate sensory descriptors (e.g. gunflint, wet stone, salty, acidity) (Rodrigues et al., 2015, 2017) instead of "minerality" could be advantageous, although experts use it interchangeably (Schüttler et al., 2015).

Complexity is considered as a major indicator of food, beverage and fine wine quality (Palczak et al., 2017; Schlich et al., 2015; Tempère et al., 2018). However, its definition also has several ambiguities (Spence & Wang, 2018; Wang & Spence, 2019a). Complexity, measured by the number of aroma descriptors (Meillon et al., 2010), collides with the poor neuronal ability to distinguish more than three or four of them. The similarity with sensory intricacy was ruled out by Spence and Wang (2018), but it is interesting to note that Burgundy *connoisseurs* use the term "la dentelle" (the lace), an intricate piece of fabric, to describe the essence of the best Pinot Noir wines. Complexity may also be defined by the difficulty in perceiving different odours or in the number of different odours arising with time as wine breaths in the glass (Spence & Wang, 2018, and reference cited therein). Further, complexity was regarded as a sub-quality of astringency influenced by flavour (Pittari et al., 2020). Despite the difficulty in its definition, consumers with different degrees of expertise recognise the complexity of wines when tasted in comparison with prototypes from Burgundy Premier Crus (Pinot Noir or Chardonnay) (Coste et al., 2018; Souza-Coutinho et al., 2020).

A strategy to understand these expert inconsistencies was presented by Sáenz-Navajas et al. (2021) concerning the ill-defined holistic, or multimodal, "green" character. These authors, by using questionnaires depending on long-term memory, showed that the core of this concept corresponded to the sensory dimensions of "vegetal aroma" and "bitter" and to the emotional response "unpleasant". Once the conceptual flavour space is well defined, the sequent work would be to check if the long-term memory could be reflected in actual consistent wine evaluations.

4.2.1.1. Inconsistencies evidenced from chemical composition. In Table 4 are listed several chemical parameters regarded as predictors of wine quality. The established correlations, or their absence, show several ambiguities among experts when assessing synthetic properties:

(a) Increased ethanol content is known to reduce aroma complexity, increase the hotness sensation and the body (King et al., 2013 and references cited therein), and therefore it should not be related with increased complexity, harmony, balance or flavour richness;
(b) Higher in-mouth concentration reflects a fuller body which is not consistent with higher harmony (Buffin, 2002; Peynaud, 1987) and may be easily obtained by higher residual sugar, a winery manipulation technique used to smooth and enhance mouthfeel without inducing sweetness perception (Sena-Esteves et al., 2018);
(c) Higher flavour intensity reduces wine finish (Goodstein et al., 2014) and thus provokes a reduction in persistence.
(d) Wines with lower total acidity perception have a reduced persistence (Buffin, 2002).

Interestingly, colour intensity was a positive characteristic when a large variety of red wines were assessed (Ferreira et al., 2009; Niimi et al., 2018); however, when experts evaluated Pinot Noir, known to be of light colour, intensity had the opposite effect (Serni et al., 2020), showing a top-down induced behaviour. In this work, experts also showed the usual inconsistencies driven by higher ethanol (up to 15% (v/v)) and residual sugar at a level (up to 9 g/L). These inconsistencies are also seen in the relation of visual and flavour sensory perceptions to synthetic properties, as discussed below.

4.2.1.2. The effect of the initial glimpse. The most relevant sensory predictors of wine quality are listed in Table 5, and together with the sensory data in Table 4, they show the dominance of the analytical flavour

Table 4
Chemical and sensory predictors of wine quality among wine experts (winemakers, sensory students, sommelliers, critics).

Synthetic predictors of quality	Correlation with wine chemical analysis	Correlation with flavour	Observations[a]	Reference
Not relevant: in-mouth stimuli, age	Positive: ethanol, residual sugar, colour intensity Not relevant: total polyphenols	Positive: intense fruity sweet flavours Negative: off-flavours (e.g., animal, cork, vegetative, reduced)	Clear glasses Premium Spanish red wines (>15€/bottle) Local wine experts Quality scores: 1 to 5	Ferreira et al. (2009)
Not relevant: palate quality	Not evidenced relation with ethanol, titrable acidity, residual sugar, or pH	Positive: passion fruit, asparagus, peas, green pepper (all part of a green character, not including grass) Positive less frequent: grapefruit, cat pee	Clear glasses Premium and unoaked SA Sauvignon Blanc SA wine experts Quality scores: 1 to 20	Brand et al. (2018)
Positive: complex, potential, body	Positive: ethanol	Positive: spicy, dried fruit Negative: green vegetative, red berries	Grand Gold awards of red wines 5 editions of wine challenges OIV tasting sheet	Malfeito-Ferreira et al. (2019)
Positive: complex, body	Positive: ethanol Negative: total acidity	Positive: exotic fruits Negative: acidity, astringency	Grand Gold awards of white wines 5 editions of wine challenges OIV tasting sheet	Malfeito-Ferreira et al. (2019)
Overall quality	Positive: ethanol, reducing sugars, total acidity Negative: colour tonality and intensity, total phenols	Not assessed	Competition scores of Italian Pinot Noir with 3-years old 3 challenge editions OIV tasting sheet	Serni et al. (2020)

Table 5
Sensory predictors of wine quality among wine experts (winemakers, sensory students, sommelliers, critics).

Synthetic predictors of quality	Correlation with flavour	Observations[a]	Reference
Positive: surface texture, drying, adhesive, hotness and persistence	Positive: darker in overall colour, higher in red berries, mint, pepper, spicy, woody, coconut, vanilla, fruit flavour	Cabernet Sauvignon and Shiraz wines	Lattey et al. (2010)
Negative: none	Negative: vegetal, coffee, smoky, earthy, leather, reduced, barnyard and bandaid	Australian and NZ wine experts	
Considered positive but with no relation to flavour: balance, volume/body, round/smooth tannins, persistency	Positive: dark red colour, herbal, lactic, roasted	Dark and clear glasses	Sáenz-Navajas et al. (2016a)
Considered negative but with no relation to flavour: excessive astringency and sourness, unbalanced, light/short, coarse tannins	Weak positive relation with sourness	Ortho- and retronasal	
	Negative: more yellow and lighter colour, vegetal, animal, green, bitterness	Several Spanish red wines	
		Local experts Quality scores: 0 to 10	
Positive: balance, structure, and perceived typicality	Positive: Intensity of black fruits, red fruits, ripe fruit and oakiness	Clear and dark glasses	Valentin et al. (2016)
	Negative: perceived bitterness, astringency, and acidity	French and NZ Pinot Noir wines	
		French and NZ tasters	
Positive: complexity as measured by number of flavours, harmony, balance, familiarity, ease of identify, varietal typicality, expressiveness, overall structure, concentration in mouth, elegance, precision	Positive: fruit ripeness, attractive fruit aromatics, oak influence, freshness, attractive floral aromatics	Clear glass	Parr et al. (2020)
	Balanced acidity, sweetness	Labelled Pinot Noir wines	
	Negative: reductive notes	NZ expert tasters	
Overall quality	Positive: blackcurrant, plum, cinnamon, woody/oak	Clear glasses	Brand, Valentin, et al. (2020)
	Negative: acetone, smoky, geranium, green/herbaceous/leafy	Top 10 Pinotage wines in SA challenge	
		SA wine experts Quality scores: 1 to 20	
Overall quality	Positive: marmalade, oak, orange blossom	Clear glasses	Brand, Valentin, et al. (2020)
	Negative: lemon, grapefruit	Top 10 Chenin Blanc wines in SA challenge SA wine experts Quality scores: 1 to 20	

[a] SA, South Africa; OIV, International Organisation of Vine and Wine; NZ, New Zealand.

descriptors in the inference of quality by experts. Those results are consistent with the features of perceptual expertise previously mentioned.

The effect of colour on perception of flavour is well-known (Heatherly et al., 2019; Morrot et al., 2001; Wang & Spence, 2019b) and may explain tasters' better sensory discrimination of red over white wines (Niimi et al., 2018). Not surprisingly, the first salient consensual cue to infer red wine quality by experts is elicited by the colour, followed by smell, and lastly by in-mouth attributes (Caissie et al., 2021; Sáenz-Navajas et al., 2016). This result was also found for highly involved consumers (Rahman & Reynolds, 2015). Indeed, all sensory perceptions may be complimentary (Jaffré et al., 2009; Niimi et al., 2018), but the significance given to colour may be further illustrated when the attributes of Pinot Noir (red fruits, black fruits, silkiness, and typicality) were judged higher when clear rather than dark glassware was used (Valentin et al., 2016). Later, Parr et al. (2020), for the same variety, reported that expert judgements were triggered by visual cues but were not dominated by them. Overall, experts infer from deep red colour the remaining in-mouth quality properties related with high polyphenolic concentration (Aleixandre-Tudo & du Toit, 2020 and references cited therein) under a top-down process which remains to be validated by neuronal activity measurements. Interestingly, these observations are consistent with the sensory and chemical drivers of consumer liking (Dooley et al., 2012).

4.2.1.3. The last position given to holistic evaluations. The apparent minor importance of taste and mouthfeel, and sequent holistic parameters, to wine quality was pointed out with surprise by Parr et al. (2020), who questioned why these percepts were not elected as essential in the definition fine wine concept by professional and experienced tasters.

One explanation for this observation might be variation in taste and mouthfeel sensitivities, which should not be considered as "error in the machine", that abolishes the mean response of the panel when averaging individual scores (Parr, 2019). Indeed, Brand, Panzer, et al. (2020) stated that mouthfeel and taste may be unpractical to assess by frequency of citation or check-all-that-apply (CATA), being conceivable that synthetic modalities are even more difficult to assess (Niimi et al., 2018).

The second explanation concerns the likely top-down processes influenced by olfactory cues in addition to the visual ones. For instance, Sauvignon Blanc flavours are among the most preferred (see Table 4), but when Chenin Blanc is evaluated, grapefruit perception was disqualified (Brand, Panzer, et al., 2020). Moreover, olfaction modulates the perception of in-mouth sensations like astringency, complexity, sweetness and bitterness (Pittari et al., 2021). Further positive correlations were found by these authors that support the effect of a cognitive dimension (spicy and complex; dehydrated fruits and drying mouthfeel; vegetal and unripe mouthfeel) while in the absence of volatiles, for instance, the spiciest wine was significantly less complex.

Moreover, a third hypothesis about quality based on the emotional attractiveness of the wine sensory features to experts is explained below.

4.2.2. The emotional nature of quality judgements

When some indicators of fine wine quality show clearly an emotional attachment (e.g., "attractive fruit aromatics" related with "fruit ripeness" and "oak influence") (Parr et al., 2020) or rejection (e.g. "unpleasantness" related with "green") (Sáenz-Navajas et al., 2021), a plausible argument is that the definition of holistic qualities is driven by individual preferences. In other words, highly esteemed descriptors, or the reverse, define the object of attraction or rejection. Then "quality" correlates with "complexity" and "varietal typicality" even if the aromas are intense and easy to identify (Kustos et al., 2019; Meillon et al., 2010; Niimi et al., 2018; Parr et al., 2020) or dominated by oak flavours (Wang & Spence, 2019a), and neither of those characteristics are consistent with complexity. Likewise, off-flavours reflecting poor winemaking practices (e.g., reduction, barnyard) are negative quality predictors.

The positive role of familiarity in defining quality (Meillon et al., 2010; Parr et al., 2020) is also indicative of a most likely emotional bias. This does not mean that these most preferred wines are not of truly superior quality, but that experts rely on the initial cues to make the necessary inferences and do not pay as much attention to the holistic variables. As Shepherd (2017) explained, "guessing the rest" is a neuronal strategy to spare the energy dedicated to the cognitive process, which was detected in several brain areas of wine experts (Pazart et al., 2014). Then, the effort to define the last overall quality parameters under the classical wine tasting sheets is minimised by using top-down processes.

We argue that experts tend to associate the first perceptions (visual or olfactory) to the memorised prototypes of different quality levels. These first perceptions include an emotional reaction of pleasantness, or unpleasantness, which determines the score given to the holistic attributes. Then, the highest level of an expert's competence should be assessed by the ability to separate personal preferences, driven by sensory attractiveness and familiarity, from aesthetic evaluation.

4.3. Aesthetic expertise

Unlike vision and audition, olfaction has been considered removed from traditional philosophical aesthetics because of its subjective and affective character without a sufficient cognitive dimension (Barwich, 2017). However, recent advances in neuroscience have shown that the strict distinction between perception and cognition is no longer valid (Keller, 2017). That finding debunks the myth that olfaction is an unsophisticated sense (Barwich, 2017). Indeed, the aesthetic appraisal of artworks appears to have evolved first for objects of survival such as foods (Brown et al., 2011). Later, Skov (2019) showed that aesthetic objects (e.g., art, faces, landscapes) are appreciated by the orbito-frontal cortex using the same neurobiological mechanisms as food, drinks or money, coining the process as a "common currency" to deal with pleasure and reward. The sensory phenomena should also be applicable to flavour given that its processing resides in neuronal areas common to emotion, reward and pleasure (Dalenberg et al., 2017).

Burnham and Skilleås (2012) postulated that to make aesthetic judgements the assessors must have competence and to give a proper justification. Thus, according to these authors, the nature of competence includes:

(a) Experiential competence (e.g., tasting expertise improved by practice), corresponding to the perceptual expertise;
(b) Aesthetic competence (e.g., perception of synthetic or emergent properties); corresponding in this case to the conceptual expertise;
(c) Cultural competence (e.g., knowledge of wine types, regions, winemaking techniques), including the paradigmatic qualities (e.g., typicality, varietal expression), built on perceptual and conceptual skills and corresponding to the aesthetic expertise;
(d) Communication intelligibility (e.g., understand consumer reactions to explain wine sensations), to give an understandable justification of the judgements.

These competences show the weight of educational factors on quality evaluation, although Spence and Wang (2019) considered that these factors mediated by learning were not so impressive when compared to other food and beverages. Smith (2019) posited that fine wine tasting is a hard task requiring years of practice to improve perception and categorization of the various wine sensory facets. However, the expertise as measured by qualitative categorization constitutes a necessary but not sufficient element in training the aesthetic appraisal of odours, because categorization is not primarily an aesthetic activity (Barwich, 2017). Further, Joy et al. (2020) by explaining the significance of embodiment in shaping perception, showed that both novices and experts reacted to tasting wine as an aesthetic experience.

Overall, the coincidence between the cortical domains of pleasure and aesthetic evaluation (Skov, 2019) probably explains the difficulty in separating one from the other. This cognitive task should then be very hard, and we argue that here lies the core of expertise in recognising fine wines.

4.3.1. The intricate relation between preference and aesthetic evaluation

The definition of expertise including aesthetics appreciation implies that the judgements of quality are strongly dependent on the individual preferences for salient wine sensory characteristics. In opposition to Burnham and Skilleås (2012), Sackris (2019) posited that experts or non-experts are unable to separate enjoyment from aesthetic evaluation. When wine appreciation is driven by pleasant flavours and mediated by familiarity, it is probably difficult to conceive of a division between preference and aesthetic judgement. Overall, both experts and consumers, by different cognitive processes, match their preferences in fine wine quality evaluations (Brand et al., 2018; Rinaldi et al., 2020; Torri et al., 2013; Wang & Spence, 2019a) sharing the same aesthetic appreciation for familiar flavours (Joy et al., 2020). Indeed, the overall sensory profiles of Gold awarded wines in wine competitions, dominated by aroma richness and full smooth body (Malfeito-Ferreira et al., 2019), are consistent with the intrinsic quality parameters reported by experts and consumers (Hopfer & Heymann, 2014; Jover et al., 2004). Moreover, the scores assigned by judges have inherent variability and should not be seen as objective and replicable quality evaluations, but rather as a reflection of individual neurology, preferences and tasting conditions (Bodington, 2020).

However, experts do not share a homogenous standard of fine wine quality as shown by Grohmann et al. (2018) who compared the behaviour of two tasting panels. The panel composed of individuals with wine university or WSET (Wine & Spirit Education Trust) diplomas preferred the international style, illustrated by the high scores given to a wine with intense red colour and noticeable sweetness. The other cohort dominated by older experts with a more classical approach to wine appreciation (Union des Sommeliers de Paris, established in 1907) considered that same wine as the worst, seemed more forgiving of off-flavour perceptions, and gave more weight to balance in its assessment of overall quality. In general, preferences and quality evaluation coincided for both panels but some wines were differently appreciated in accordance with their opposite styles. Then, it appears justified to distinguish the individual preferences of experts mainly when the same wine flavour has different quality inferences (Franco-Luesma et al., 2019; Tempère et al., 2014).

4.3.2. The distinction between preference and aesthetic properties

The hypothetically rare ability to separate preference from aesthetic evaluation was demonstrated by Romano et al. (2020) using experts (experienced viticulture and enology students) in blind and informed tastings of organic and conventional wines. Assessors clearly perceived off-flavours as such, but still preferred the faulty wines in the organic wines where a higher frequency of inferred flavours (e.g., earthy) was observed. Under blind tasting, this cognitive effect would not be present, and the emotional response of unpleasantness arose as the cue to identify organic wines and elicited higher appreciation and willingness to pay. This sort of behaviour was shown by Coppin et al. (2021) with experts that used more positive feelings when unaware of wine's reputation. Then, the absence of extrinsic cues that could trigger a cognitive top-down process appears to be compensated for by emotional or affective responses in expert judgements.

The question of off-flavours illustrates a case where appreciation may be disentangled from aesthetic judgements among experts, but it is arguable to accept off-flavours simply because of the mode of production. Nevertheless, there are wines bearing inherent "faulty" sensory features that may be valorised from a cultural perspective.

4.3.3. The emergence of ancient wine types

The recognition of ancient or past wine styles is an example of how, without proper cultural competence, flavour profiles may be perceived as defective. These wines bear sensory features that are often easily acknowledged and require communication skills to explain their unfamiliar sensory features (Costa et al., 2021). Logically, tasting methodologies should be adapted by emphasizing the comparison with well-defined prototypes for each modality. Under these conditions, classical examples of Burgundy Premier or Grand Crus may be easily recognised by their salient unpleasantness to most consumers (Ballester et al., 2018; Coste et al., 2018; Souza-Coutinho et al., 2020). Very old sweet wines may have noticeable ethyl acetate flavours that are highly valorised by *connoisseurs* (Miranda et al., 2017). Clay jar fermented wines have heightened astringency, especially in whites due to skin maceration (Martins et al., 2018). Aged wines with obvious acetaldehyde, salty and sour perceptions, corresponding to the classical sherry-style wines (Zea et al., 2015), may have an umami taste that is rarely mentioned in wine science (Vilela et al., 2016). Further, attention should be given to the rediscovery of past styles, some of which are wine-based flavoured beverages, like the vermouths (Morata et al., 2019).

5. Conclusions

The definition of a fine wine requires both the object and the subject of appreciation. For the taster, there are three dimensions of expertise; the highest level of competence corresponding to those highly involved subjects to whom the fine wine quality perception is a cognitive process influenced by its aesthetic properties, blending the perception of holistic properties, and consideration of wines' inherent cultural and historical backgrounds. Then, a tentative fine wine definition would be: "wines characterized by superior holistic properties that are perceived and appreciated by individuals understanding their cultural meaning".

The classical tasting methods begins with visual appraisal, followed by smell and taste or mouthfeel, and ends with an overall evaluation. This sequence does not take into consideration the perception mechanisms in the brain. The first reaction, even if not acknowledged, is emotional in nature and triggered by visual cues. The next perceptions reflect the first glimpse, shaping flavour and in-mouth descriptions, synthetic evaluations, and aesthetic judgements. We hypothesise that this overall classical tasting approach promotes top-down processes through mental imagery with a conceivable loss of consistency in the holistic perception of fine wines by experts. The perceptual expertise is essential to analytical descriptions (smell, taste and mouthfeel) but, because this function has limited aesthetic value, it should not blur the perception of synthetic properties. Then, we propose that, when the purpose is to define fine wine quality, tasting should begin with holistic assessments. Otherwise, these emergent features tend to be inferred as a simple sum of the analytic properties and as subordinate attributes of quality definition.

Another issue concerns the relationship between quality assessment and enjoyment. This issue is at the source of occasional misconceptions about evaluation of fine wines, probably explaining why classical high-quality whites and reds are disregarded when tasted blind. The use of emotional reactions may be a first step to unravel if holistic characteristics are being driven by individual preferences, benefiting from tasting wines with opposite styles in parallel. Hence, an alternative tasting approach could have an emotional response at first, followed by synthetic determinations and then ending with a colour and flavour description if necessary. In this way, synthetic properties are not overlooked by putting them at the beginning of tasting, and they benefit from the comparison with superior quality prototypes. Attention to flavour should be directed to its changes during prolonged tasting (about 30 min) and to the differences between ortho- and retronasal perceptions, thus lessening the relevance of aroma descriptions. This represents a change in the paradigm of wine tasting methodologies and is proposed here as an alternative to characterise and simplify the recognition of fine wines.

In conclusion, the progress of wine tasting and sensory analysis has been remarkable in recent years. However, when it comes to fine wines and as remarked by Marks (2015) and Parr et al. (2020), the analytical sensory approaches have shortcomings that need to be tackled by the scientific community to lessen the risk that others more oriented to trade may take the lead without the necessary scientific background. Indeed, the globalization of the wine trade triggered the proliferation of empirical wine education in latitudes where tasting learning only now begins to be easily available. Hopefully, the evolution of tasting methods will blend the inputs from sensory and cognitive sciences together with those who are highly involved in wine (e.g., winemakers, *connoisseurs*, *sommeliers*, critics) to advance the goal of increasing the understanding of fine wine perception and appreciation.

Declaration of competing interest

None.

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