Perceived complexity in Sauvignon blanc wines: Influence of domain-specific expertise

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Abstract

Complexity is a multi-dimensional and poorly-defined term that is employed frequently when wine is characterised organoleptically. The present study's aim was to investigate the sensorial nature of perceived complexity in white wine as a function of domain-specific expertise. Eighty-seven French participants (16 wine professionals, 30 wine connoisseurs, and 41 wine consumers) evaluated thirteen Sauvignon blanc wines that had been produced in New Zealand. The wines were part of a wine innovation project aimed at increasing perceived complexity in Sauvignon wines. The within-subject design required each participant to evaluate all wines by two methods, free sorting and by judging complexity qualitatively and quantitatively. The latter involved measurement of perceived complexity and assumed sub-components of wine complexity via a questionnaire (Medel, 2011). Results showed that sorting behaviour across groups was similar qualitatively, with each group classifying the wines in much the same way. On the other hand, between-group differences were observed in variability with greater within-group consensus amongst oenologists than wine consumers. The complexity questionnaire data showed differences in ratings as a function of both participant expertise and wine. In terms of theories concerning cognitive processing associated with perception of wine complexity, the results are in keeping with the notion that complexity is associated with aspects of harmony and wine balance, rather than with perceptual separability of wine components.

Key words: complexity; Sauvignon blanc; wine; expertise

1. Introduction

The term complex is frequently employed to describe the sensory properties of wine (e.g., Cooper, 2008). Despite this, perceived complexity in wine remains a vague and ambiguous concept (Aron, 1999). From a physico-chemical perspective, wine is a complex food stimulus consisting of hundreds of volatile and non-volatile substances (Thorngate, 1997). However, such objective complexity does not necessarily translate into perceived complexity; that is, despite their chemical complexity not all wines are described organoleptically as complex, with terms such as "simple" employed to oppose complexity. The present study's aim was to investigate the sensorial nature of perceived complexity in white wine, specifically in the white wine varietal Sauvignon blanc.

Little published research has directly investigated perceived complexity in wine. On the other hand, several reported findings provide indirect evidence concerning the nature of perceived complexity. One variable regularly reported as positively associated with perceived complexity is wine quality; wines considered as complex are likely to be judged high in quality (Charters & Pettigrew, 2007; Singleton & Ough, 1962), and in turn to afford higher prices than less-complex wines. The positive associations reported by others between perceived complexity and perceived quality received further support from a study demonstrating that complexity is considered a positive attribute of wine by both wine professionals and wine consumers (Parr, Mouret, Blackmore, Pelquest-Hunt, & Urdapilleta, 2011). A second variable that has been shown to associate positively with perceived quality and perceived complexity in wine is wine perceived aging ability (Langlois, Ballester, Campo, Dacremont, & Peyron, 2010; Parr, Mouret et al., 2011; Saenz-Navajas, Campo, Sutan, Ballester & Valentin, 2013).

As distinct from objective complexity (i.e., complexity defined in terms of chemical composition), inherent in the notion of perceived complexity is the inclusion of a perceiver; that is, any analysis of perceived complexity in wine requires consideration of the nature of human sensory experience of wine, a cognitively sophisticated (Parr, 2008) and multi-modal process. In terms of perception, wine is a complex stimulus from several perspectives. First, it is complex in that odorants, tastants, and trigeminal stimuli all offer various components to experience at the same time (Auvray & Spence, 2008). Second, wine is complex in that it can be difficult to put chemosensory percepts into words, this factor interacting with domain-specific expertise (Melcher & Schooler, 1996). Several studies have provided data in support of the notion that ability of a perceiver to assess or analyse the objectively complex sensory stimulus that is wine is influenced by their relative degree of experience (type; quantity) with respect to wine (Melcher & Schooler, 1996; Parr, Heatherbell, & White, 2002; Langlois, Dacremont, Peyron, Valentin & Dubois, 2011; Urdapilleta, Parr, Dacremont & Green, 2011; Saenz-Navajas et al., 2013). In the present study, we considered the nature of perceived complexity in Sauvignon wines in relation to three categories of domain-specific expertise of the perceiver: wine professional/oenologist; wine connoisseur; wine consumer.

1.1. Factors associated with perceived complexity

In terms of factors that may be important to perception of complexity in wine, the fundamental literature on odour complexity (see Lawless, 1997) provides some indication. Odour complexity is associated with two factors in particular, one pertaining to the participant or perceiver, namely familiarity and domain-specific expertise, and the second pertaining to the stimulus itself, specifically the number of distinct components in the mixture. With respect to expertise, experience with wine has been associated with enhanced discrimination ability (e.g., Gibson & Gibson, 1955; Parr et al., 2002; Hughson & Boakes, 2009), as well as with higher-order cognitive components of wine evaluation such as semantic memory (Solomon, 1990; Zucco, Carassai, Baroni, & Stevenson, 2011). When a wider range of food and beverage products is considered, domain-specific expertise has been shown to influence both hedonics (i.e., liking) (Distel, Ayabe-Kanamura, Matinez-Gomez, Schicker, Kobayakawa, Saito & Hudson, 1999) and intensity judgments (Dalton, 2000).

Hence it is conceivable that perceived complexity in wine could be influenced by participant expertise. A study reported by Parr, Mouret et al. (2011) provides indirect evidence to suggest that perception of a wine's complexity could be influenced by domain-specific expertise. The study investigated complexity in wine in terms of how the concept is mentally represented. Employing interview-technique methodology rather than wine sampling, the authors investigated perceived complexity in wine as a function of wine expertise (wine professionals; wine consumers). Results showed that although both experienced wine professionals and less-experienced wine consumers considered complexity in wine to be a multi-dimensional construct, the groups differed markedly in terms of the components of their mental constructs. Wine consumers related complexity in wine to subjective experience, in particular the pleasure (e.g., enjoyment) related to drinking a wine, and to their notions of wine quality, brand and image. Wine professionals on the other hand linked wine complexity primarily to factors other than intrinsic factors associated with actual experience of the wine. These included both vineyard factors (e.g., vine type; soil; vineyard location) and oenological processing operations (e.g., use of oak; lees stirring) and decision-making (e.g., fruit ripeness at harvest).

With respect to the second aspect, namely number of distinct components and degree of blendedness of the stimulus, the literature is less clear. Although complexity in wine appears to be mentally represented by wine consumers and wine professionals as a multi-component concept (Parr, Mouret, et al., 2011), the sensory property "complex" may be perceived as a single or blended percept, at least in some contexts (Auvray & Spence, 2008). Singleton and Ough (1962) comment that perceived complexity in products such as perfumes and foods may be the result of a product being made up of "many ingredients in amounts small enough to influence flavour or odour without being individually obvious" (p. 189). More recently, a review article by Auvray and Spence (2008) extends the ideas of Gibson (1966) to argue that multisensory interactions as occur when sampling wine can be combined to form a single percept (synthetic perception) or can be perceived in terms of their individual qualities (analytic perception) depending on the approach taken by the individual taster. This notion conceivably is one reason that the little research to date investigating blendedness or perceptual separability has produced equivocal results. For example, in a study of blended wines and judgments of wine quality, in which the authors assume 'quality' and 'complexity' to be synonymous concepts, Singleton and Ough (1962) reported data suggesting that quality was enhanced in the blended wines as compared with the non-blended wines. On the other hand, Lawless (1997) reported a result somewhat at odds with the notion that blendedness or perceived integration enhances perceived complexity. This study, involving olfaction, produced data that Lawless interpreted as indicating that rated complexity of odours reflected perceptual separability, or lack of blendedness of the components of the odorant mixture. That is, a highly blended or integrated mixture may be perceived as lower in complexity than if the individual components stood out.

The assumed underlying cognitive processes are often referred to as "configural" (e.g., Jinks and Laing, 2001; Le Berre, Jarmuzek, Beno, Etievant, Prescott, & Thomas-Danguin, 2010), and contrast with perceiving the separate qualities or elements in a mixture as distinct characteristics. There are several lines of olfactory research that support this notion. For example, in their many studies concerning human ability to discriminate and recognise components in multi-component mixtures, Laing and colleagues (e.g., Jinks and Laing, 2001; Livermore & Laing, 2008) have argued on the basis of both physiological and psychological evidence that integration of aromas in a multi-component mixture (i.e., a wine or a perfume) may, via a configurational process, give rise to a single percept described by the single word "complex". Similarly, Lawless (1997) has suggested that multiple odours may be recognised as a whole pattern, with the individual features not being accessible to consciousness. For this reason, our complexity-questionnaire methodology included quantitative judgments of wine familiarity, number of perceived distinct components, degree of harmony or integration, and ease of identifying the distinct components in each wine. Participants were also asked to make a global evaluation of each wine by providing an overall complexity rating, this judgment potentially being independent of ability to recognise and identify any individual components of the wine sample.

1.2. Methodologies employed

Two sensory methods were employed in the present study to draw on a range of sensory and cognitive processing by the study participants. The methods comprised a rating task involving a recently-developed questionnaire for investigation of perceived wine complexity (Medel et al.

2009; Medel, 2011) and a free sorting task. The complexity questionnaire, developed in French, has subsequently been translated and used in Spanish and English (Parr, Mouret, Urdapilleta, Schlich, & Green, 2012). In Meillon et al. (2010), this questionnaire was used to understand the sensory impact of reducing alcohol content in wines. The complexity questionnaire comprises an overall quantitative judgment or rating of complexity for each wine, and ratings to seven assumed sub-components of perceived complexity. The eight continuous scales are anchored with pictures (Appendix 1), these aimed at clarifying the concept under evaluation. The seven assumed attributes of perceived complexity in wine include wine familiarity, number of perceptible flavours, ease of identification of the separate flavours, harmony, balance, persistence of wine in mouth (length), and concentration (strength of flavour). Of particular importance, the questionnaire contains items that investigate perceived blendedness (e.g., evaluation of harmony) or lack of blendedness (e.g., ease of separability of the flavours/components).

Sorting tasks require participants to group or classify objects into classes. The task is assumed to require holistic or global wine assessment (Green et al., 2011), drawing on both sensory and top-down cognitive skills (Dalton, 2000) of participants. Sorting-task methodology was employed to assist in highlighting any differences in domain-specific expertise amongst the participant groups. To make a classification in a sorting task, participants need to favour some criteria (i.e., characteristics of the wines) and neglect others (Manetta, Sales-Wuillemin, Gaillard, & Urdapilleta, 2011). Such discrimination behaviour is likely to be influenced by qualitative (type) and quantitative (amount) of relevant expertise or familiarity with the products to be sorted, making the sorting task an effective methodology to employ when investigating wine sensory evaluation involving participants of different expertise levels. However, in a recent study reported by Chollet, Lelievre, Abdi and Valentin (2011) that involved sorting beers, non-trained participants performed similarly to trained participants in terms of sorting task behaviour, although there was greater within-group agreement amongst those with domain-specific expertise (the trained participants) than those without (non-trained participants). Chollet et al. (2011)'s study is of further interest in that the authors reported data to demonstrate the robustness of the sorting task with respect to reliability (replicate data), especially for participants with expertise (i.e., prior training). The particular sorting task employed in the present study was a free sorting, involving study participants being asked to sort the thirteen wine samples in terms of their similarities and differences with the major criterion on which to base classification of the wines not specified by the experimenters.

The final methodological point to elaborate upon concerns the nature of the wines employed in the experiment. Thirteen Sauvignon blanc (*Vitis vinifera* L. cv. Sauvignon blanc) wines, produced in Marlborough, New Zealand, were the chosen stimuli for the current study. The wines were considered to be relatively novel stimuli for the French participants in the current study, irrespective of their general level of wine expertise (oenologist, connoisseur, or consumer).

The wines were produced by a large wine producer, in commercial quantities, specifically with the aim of investigating perceived complexity in Sauvignon blanc wine by producing wines that varied, either viticulturally or oenologically, from standard-production technique (see Table 1). Standard production technique in Marlborough, New Zealand, involves production of fruit-driven wines by machine harvesting fruit, reductive processing, and use of inert vessels such as large stainless steel tanks; that is, the wines are relatively free of wine-maker influence (see Parr, Schlich, Theobald, & Harsch, 2013). These same wines had been evaluated by New Zealand wine professionals via non-directed sorting and descriptive rating two months prior to the current, French experiment. The data from the New Zealand study showed that the major point of difference amongst the 13 wines was the influence of type of harvesting of the fruit that produced the wine (hand or machine harvesting) (Parr, Schlich, et al., 2013).

Insert Table 1 about here

To summarise, the present study's major aim was to investigate differences in perception of Sauvignon blanc wine complexity amongst participants as a function of general wine expertise. We formed several hypotheses. First, we predicted that domain-specific expertise would influence sorting behaviour and judgments of perceived complexity, with wine professionals' ratings demonstrating less within-group variability and greater discriminability amongst wines than those of less-experienced participants. Second, it was expected that judgments of overall complexity in a wine would associate differentially with the assumed sub-components of perceived complexity, in particular with perceived blendedness (harmonious nature) or lack of blendedness (ease of identifying different flavours; poor balance) of a wine. This hypothesis was non-directional, given the equivocal nature of prior literature.

2. Methods and Materials

2.1. Participants

Participants were 16 French wine professionals (Experts), 30 French wine connoisseurs, and 41 French wine consumers. The 16 wine professionals were oenologists, employed in wine production in Burgundy, France and were recruited on the basis of their known employment situations and in keeping with criteria specified by Parr, Heatherbell, & White (2002). They reported that they tasted wines almost every day. The participants who were not wine professionals were recruited in Burgundy by invitations to participate in research wine tasting at the Centre des Sciences du Goût et de l'Alimentation (CSGA).

2.1.1. Consumer and connoisseur participants

The participants who were not wine professionals were allocated to either the consumer or connoisseur group on the basis of two measures. First, wine experience of each person was assessed. Wine experience was operationalised by measuring two behavioural parameters: (i) frequency and place(s) of wine consumption, and (ii) number of wine bottles owned in their wine cellar, the latter assumed to reflect wine purchase frequency. These data were employed to allocate participants to the wine consumer or wine connoisseur category. In terms of frequency of consumption, the selection criterion for wine consumers was a minimum consumption of white wine once per month. Participants were designated connoisseurs and allocated to that group on the basis that they reported regular participation in a wine-tasting club involving technical tastings once a month. The second measure obtained involved participants providing information about their wine knowledge (as separate from their reported experience) via a questionnaire that they completed in their second session. The questionnaire, designed specifically for the present study, comprised 25 items about wine (e.g., technology, appellation, grape variety) and was aimed at investigating general wine knowledge of each participant. Results from this wine-knowledge questionnaire served to validate that participants were accurately classified as consumer or connoisseur. This resulted in 30 wine connoisseurs (15 M; 15 F), and 41 wine consumers (20 M; 21 F). Participants also provided basic demographic details via the questionnaire. The percentage of connoisseur participants within the following age ranges was: 25-39 = 4; 40-49 = 10; 50-64 = 43; >65 = 43. The percentage of consumer participants within these age ranges was: 25-39 = 20; 40-49 = 22; 50-64 = 46; >65 = 12.

2.2. Materials

2.2.1. Wines

Thirteen 100% Sauvignon blanc wines from the 2009 New Zealand vintage were evaluated in the experiment. All wines were produced in commercial quantities by the same large, commercial wine producer and spanned a range in terms of price points and wine styles. The wines, listed in Table 1, comprised three wines made employing standard wine practices for production of Sauvignon blanc wine in Marlborough, New Zealand (see Parr et al., 2013), and ten wines that were produced innovatively with the aim of increasing Sauvignon wine complexity via various grape-growing and winemaking practices. The ten non-standard or innovation wines were classified in terms of the dominant factor (viticultural or oenological) that distinguished the particular wine. Factors such as vineyard site or viticultural management were dominant in four of the innovation wines, these wines termed ‘Experimental/Viti’. Six of the 10 innovation wines involved oenological manipulations (e.g., type of pressing; older oak maturation; indigenous yeast fermentation) and these wines were categorised as ‘Experimental/Oeno’. The specific details regarding each of the 13 wines and how they were classified into three Wine-Type categories (Standard production; Expe/Viti; Expe/Oeno) can be seen in Table 1. Four of the wines were produced from fruit harvested by machine (3 Standard; 1 Expe/Oeno) and the remaining nine wines were produced from grapes that were predominantly hand-harvested. The New Zealand wines were freighted to France for the empirical component of the study to be conducted.

2.2.2. Materials

Written materials in the form of an instruction booklet for the Sorting Task and the INRA complexity questionnaire (see Appendix 1) were provided to each participant.

2.3. Procedure

The study was conducted at the sensory facilities of the ChemoSens Platform, CSGA, Dijon, France. Two sessions were conducted for each participant, separated by a one-week interval. Each session lasted approximately one hour, and involved one task only, either sorting or complexity-rating. Sessions took place with a maximum of 16 participants at any one time and were held at common wine-consumption times, namely either before lunch (12md) or in the evening (18h), depending on the availability of participants. Participants were seated in separate booths, with the environment controlled as advised for sensory experimentation (ASTM, 1986).

In each session, the wines were served at ambient temperature, and were first checked for faults by at least one experienced wine professional. Forty-mL samples were then poured into standardised tasting glasses (ISO, 1977) that were opaque (black) to eliminate visual cues as sources of information. The glasses were coded with 3-digit numbers and were covered with plastic Petri dishes. In order to limit carry over effects and memory biases, all wine samples were presented in a different order specific to each participant according to a Williams Latin square arrangement generated by FIZZ software (Biosystems, Courtenon, France). Evian water was available throughout each session and participants were invited to have a break whenever they wanted and to rinse their mouths with water.

At the beginning of each session, participants were presented with their unique order of the 13 wines and advised that they would taste and make judgments about these thirteen wines and that all wines were Sauvignon blanc. They were not given any other information about the wines. The experimental design was a fully within-subject design where every participant evaluated every wine via both the free sorting task and via the complexity-rating scale, employing a full tasting procedure (i.e., evaluation by orthonasal olfaction, retronasal olfaction, and palate stimulation). Half of the participants evaluated each wine via the INRA complexity questionnaire (see Appendix 1) in their first session and a free sorting task in Session 2. The other half of the participants undertook the tasks in the reverse order. Participants were advised that expectoration of all wine samples was a requirement of participation. For the sorting task, specific instructions to participants were to smell and taste each wine, in the order presented, and then to classify the wines in any way that made sense to them, drawing on similarities and differences amongst the wines. The task was not directed further. For example, the number of groups or categories that a participant could employ was not specified.

In their second session, all participants who were not designated oenologists/experts completed the knowledge questionnaire at the beginning of the session.

2.4 Data analysis

2.4.1. Sorting task data

The sorting task data were analysed globally (87 subjects) and separately for each of the 3 groups of subjects: 41 consumers, 30 connoisseurs and 16 experts. An ordinal multidimensional scaling was computed for each of the four corresponding co-occurrence matrices (size 13 x 13) containing the number of subjects having grouped together each pair of wines. A two-dimensional map was retained for each of these four analyses resulting in stress values just lower than 0.20. The maps from the three groups of subjects were compared by the RV coefficient and the normalized RV coefficient, the latter providing us with an analytical permutation test allowing to assess significance of the similarity of two maps towards noise generated by product permutations within one of them (Schlich, 1996).

The Rand index, measuring the level of similarity between two partitions of the same set of products, was computed for each pair of subjects. The mean values of these Rand indices within groups allowed comparing group heterogeneity in terms of product perception as measured by the sorting task. The mean values of the Rand indices over every pair of subjects, a pair comprising one subject from a given group and one subject from another group, allowed comparing individual perception between these two groups. However, the expected Rand index under the null hypothesis of no similarity between two individual partitions is larger than 0 since the same wines can be categorized together in both partitions just by chance. To take this into account, it is possible to compute the so-called, adjusted Rand index (Hubert & Arabie, 1985) or to conduct a permutation test ($n = 100$) for each Rand index in order to derive significance ($p = 0.05$) of similarity between partitions generated by two subjects. For the first application of the Rand index on sensory data the reader is referred to Callier and Schlich (1997). The proportion of subject pairs being assessed as having a similar perception was produced within and between groups as a complementary criterion to the mean Rand indices.

The three groups of subjects were also compared in terms of the average number of categories produced in their sorting task. A one-way analysis of variance on these individual numbers was used for that purpose.

2.4.2. Analysis of the complexity questionnaire

The following ANOVA model was computed for each of the 8 items of the complexity questionnaire:

*Group + Subject(group) + Wine Type + Wine(Wine Type) + Group*Wine Type + Group*Wine(Wine Type)*

The Group effect expresses the extent to which the consumers, the connoisseurs and the experts differ in their mean score of the item. The Subject factor is nested within the Group factor since a subject belongs to a single group; thus the Group factor is tested against the Subject factor. Similarly, the Wine factor is nested within the Wine Type factor (Standard; ExpeOeno; ExpeViti) and thus the Wine Type factor is tested against the Wine factor. It thus considers both subject and wine as two random factors. The four other effects in this model are tested against the residual means square. The Group-by-Wine-Type or by-Wine interactions are of paramount importance, since their significance would denote the fact that the wine type or the wine within wine type differences would not be the same for the 3 groups of subjects. Following the results of this ANOVA, mean scores of groups of subjects were compared using a Least Significant Difference (LSD) procedure at $p = 0.10$. The same procedure was used for comparing the three type of wines.

In order to get a map of the three Wine Types, summarising their complexity differences, a Canonical Variate Analysis (CVA) of the table composed of the 13 wines times the 87 subjects as observations and the 8 complexity items as variables was run. The level of significance of the MANOVA F ratio of the Wine Type factor allows assessing the extent to which the three wine types are perceived with different complexity. This is illustrated by the CVA map and the extent to which the three confidence ellipses are not overlapping on this map. The Hotteling T2 statistics were computed for each of the three pairs of wine types, providing us with a p-value for each of these three multivariate, pairwise comparisons of wine types. Also a maximum likelihood test indicated whether one or two dimensions was necessary for discriminating the three wine types in the complexity space. For a comparison of MANOVA and CVA to Principal Component Analysis, the usual way of mapping descriptive sensory data, the reader is referred to Peltier, Visalli and Schlich (2014).

Although the superimposition of the questionnaire items as arrows on the former CVA map (bi-plot representation of observations and variables in CVA) helps in understanding the correlational structure amongst the items, it is just an overall picture at population level with no consideration of the subject groups. To investigate deeper the relations between each of the 7 sub-component items and the final, overall complexity item, individual correlation coefficients were computed and assessed for statistical significance at the 5% level. This article reports the numbers of subjects by group with significant *positive*, *non-significant*, and *significant negative* correlation coefficients between each item and the overall complexity item.

3. Results

3.1. Sorting task

Figure 1 shows the outcome from the sorting task. The MDS product map at general population level (Figure 1a) exhibits a very neat structure with the four machine-harvested fruit wines (3 Standard wines and wine MES) being clustered together at the top left, the wines WF3yob and

OldVines isolated at the bottom left and the bottom right respectively, and the remaining innovation wines grouped together at the top right. This structure is fairly well recovered by the individual groups of consumers (Figure 1d), connoisseurs (Figure 1c) and experts (Figure 1b) as measured by the RV coefficients. These were equal to 0.87, 071 and 0.84 respectively (Table 2), with corresponding normalised RV largely higher than 1.645 (Table 2), thus significantly better than the chance level defined by permutation. However, it is also quite clear from observing the maps that the wines are clustered more tightly by experts compared to connoisseurs, and more tightly in connoisseurs compared to consumers; that is, the experts were more discriminating of the wine differences.

Insert Figure 1 and Table 2 about here

The Rand indices within groups of subjects go from 0.747 for experts to 0.713 in connoisseurs and 0.613 in consumers (Table 3a), this denoting a decreasing level of similarity between individuals' categorisations as level of domain-specific expertise decreases. Further, the highest similarity of individual categorisation is obtained between expert and connoisseur categorisations (0.723), whereas consumers' similarity towards connoisseurs and experts results in Rand indices of 0.652 and 0.662 respectively. The results of the permutation tests exemplified these findings since 42 % of the expert pairs were significant, whereas only about 15 % of the pairs from consumers or connoisseurs were significant. Across groups, 23.5 % of pairs composed of a connoisseur and an expert were significant, whereas there were 14.6 % and 18.6 % respectively when comparing a consumer to a connoisseur or to an expert (Table 3b).

Insert Tables 3 & 4 about here

The final sorting task result to report can be seen in Table 4. Table 4 shows that the consumers were less discriminating in that their categorization was less complex in terms of number of categories formed than was the categorizing of experts or connoisseurs. Indeed, the consumers formed on average 3.83 categories, whereas the experts and the connoisseurs formed 5.25 and 5.00 categories respectively. This difference between consumers on one hand and experts and connoisseurs on the other hand is significant according to a t-test at $p = 0.05$, while the difference between experts and connoisseurs is not. Again, the current data show greater similarity between performance of wine professionals and designated connoisseurs than between consumers and either of the other expertise-level groups.

3.2. Complexity questionnaire

Table 5 gives the p-values of the ANOVA model described in the Data Analysis section**.** First, the two interactions between Group (i.e., participant expertise) and Wine Type, or Wine nested within Wine Type, are both virtually never significant. This simplifies considerably the subsequent interpretation which can thus be conducted separately between groups of subjects, and then between types of wines. Indeed these two factors exhibit significant *p*-values in Table 5 for a number of items. The lack of interaction between participant group and the wines, whether the latter were classified in terms of wine type or not, shows that all participant groups found the same qualitative differences amongst the wines when making their complexity ratings; i.e., there were no qualitative differences in rating the eight complexity items as a function of domain-specific expertise. On the other hand, there were quantitative differences as described below.

Insert Tables 5 & 6 about here

Table 6 shows Group effects. The first result of interest is that all groups scored familiarity of the wines similarly, validating our notion that the New Zealand wines would serve as novel stimuli for all participants, irrespective of participant differences in general wine expertise. Second, experts gave significantly lower scores on average over the 13 wines to overall complexity, balance, harmony, and lingering (palate length), but higher scores to the item 'easy to identify the flavours' than the other two participant groups. These results suggest that the experts, compared to the other participants, found the set of wines less complex, but were more able to deconstruct the wines in terms of ease of identifying the various flavour components.

The Wine Type effects are shown in Table 7. The first result of interest is that perceived intensity was the only judgment that was similar across participant groups. Table 7 demonstrates that the Standard wines were perceived as having a larger number of flavours and that the flavours were easier to identify than those of the two other types. The Standard wines were also reported as being more harmonious, familiar, and balanced than the two types of innovation wines. On the other hand the Expe/Oeno wines were perceived as similar in complexity to the Standard wines, and more complex and more lingering than the Expe/Viti wines, the latter generally scoring poorly on all attributes. The CVA bi-plot (Figure 2) illustrates these data geometrically. The sizes of the 90 % confidence ellipses show that the differentiation between the three types of wines is not huge and lies on a single dimension (horizontal axis) as confirmed by the likelihood ratio test. This result is further confirmed in that Hotelling's T2 tests significantly split the Standard wines from Expe/Viti wines (p = 0.005) and from the Expe/Oeno wines (p = 0.069) in the complexity space, whereas the Expe/Viti and Expe/Oeno wines were not split (p = 0.162).

Insert Table 7 & Figure 2 about here

As reported in the Data Analysis section, the relations between each of the 7 sub-component items and the final, overall complexity item were investigated for each group. Individual correlation coefficients were computed and assessed for statistical significance at the 5% level. Table 8 shows the numbers of subjects by group with significant *positive*, *non-significant*, and *significant negative* correlation coefficients between each item and the overall complexity item. It is clear from the data in Table 8 that experts related more items to overall complexity than did connoisseurs or consumers. The items associated with complexity by expert participants were number of flavours, harmony, balance, linger, and familiarity. For the other two groups, harmony and intensity were associated positively with complexity by connoisseurs, and linger (palate length) the only factor to associate positively with complexity by consumers. These results suggest that overall complexity is a concept less consensual in connoisseurs and consumers than in experts.

Insert Table 8 about here

4. Discussion

The aim of the present study was to investigate influence of domain-specific expertise on judgments of perceived complexity in white wine, specifically Sauvignon blanc. The most important outcome of the experiment is demonstration of significant differences in performance, both in sorting and in rating of perceived wine complexity, as a function of wine expertise. In keeping with our first hypothesis, data from both the sorting task and the complexity-rating task showed more consensual behaviour amongst wine professionals than wine consumers. Wine connoisseurs at times produced data more in keeping with the experts than with the consumers (sorting), and under other task conditions (complexity rating) performed more similarly to the consumers.

In terms of sorting or classification, results demonstrate qualitative similarity amongst participants in that their sorting produced structurally-similar outcomes. However, higher discriminability of wine differences by the experts was evident in that they grouped the wines more tightly than the other participants and formed a larger number of categories than the wine consumers. These data, demonstrating increased variability in wine consumers relative to more experienced participants, are in keeping with those reported in Chollet et al. (2011). They are also compatible with results reported in several other recent publications. For example, Urdapilleta et al. (2011) demonstrated greater variability amongst wine consumers than wine professionals in their use of descriptors considered important to Sauvignon blanc wine, both when considering the wine from memory (semantic condition) and when actually experiencing the wines (perceptive condition) in a study where participants hierarchically organised 67 descriptors commonly employed to describe Sauvignon blanc wine. The authors argued that this result likely reflected idiosyncratic knowledge about the Sauvignon wines by wine consumer participants as opposed to stronger homogeneity amongst wine professionals in terms of how they structured their knowledge about the wine varietal.

Also relevant to the discussion of domain-specific expertise are results reported by Langlois et al. (2011). In the present study, our data show that domain-specific wine expertise may interact with type of task that a participant undertakes. That is, our data show that wine professionals (experts) and wine connoisseurs performed more similarly under free sorting task instructions, with consumers performing differently, whilst under complexity-rating task conditions, consumers and connoisseurs performed more similarly, with the wine experts' performance differing from that of the other two groups. Langlois et al. (2011), in one of the few studies to consider wine connoisseurs separately from either wine consumers or wine professionals, investigated verbal behaviour (the lexicon and type of discourse) of wine professionals, wine connoisseurs, wine consumers, and trained panellists. Their results showed the multi-dimensional nature of wine expertise, with participants of the various types of expertise performing differently: the wine connoisseurs showed much in keeping with the wine professionals in terms of their discourse about wine, but the lexicon (i.e., words) they employed was more in keeping with that of wine consumers.

In terms of what aspects of the wines drove the structurally-similar, sorting behaviour demonstrated by the three groups of participants, the present data are very much in keeping with those reported by Parr, Schich et al. (2013). In their study, where the same wines employed in the current study were evaluated by New Zealand wine professionals two months' prior to the conducting of the current experiment, Parr, Schich et al. (2013) reported a perceptual map obtained by multi-dimensional scaling of free sorting data (Parr, Schich et al., 2013, Figure 1) that is almost identical to the map produced by the French wine professionals in the current study. Clear separation of the four wines that were produced from machine-harvested fruit (the three Standard wines, plus one Expe/Oeno wine) was considered the result of wine composition differences. Parr, Schich et al. (2013) reported both sensory and chemical data, demonstrating that the thiol compounds considered important to varietal expression of Sauvignon blanc, namely 3-mercaptohexan-1-ol (3MH), 3-mercaptohexyl acetate (3MHA), and 4-mercapto-4-methylpentan-2-one (4MMP), were significantly higher in concentration in the machine-harvested-fruit wines than in the wines produced from hand-harvested fruit. The influence of grape-processing operations including type of harvesting has been reported by other researchers (e.g., Capone & Jeffery, 2011).

Several results address our second hypothesis concerning the drivers or underlying factors that influence perception of complexity in wine. First, although ease of identifying the separate flavours in the wines was a significant factor in assisting participants to discriminate or separate the wines (Wine Type effect), this factor did not associate with judgments of overall complexity in the wines. On the other hand, wine attributes that are associated with integration or blendedness, namely 'harmony' and 'balance', positively associated with judgments of perceived complexity, in particular for wine experts and to a lesser degree for wine connoisseurs. Hence, the present data provide no evidence in support of the notion that perceptual separability enhances perception of complexity. The data do support the notion that blendedness, or harmonious integration of a wine's components, positively influences perception of complexity in wine, in particular for those participants high in domain-specific expertise. Our data therefore are in agreement with those of

Singleton and Ough (1962) who interpreted their data to argue that quality/complexity (the authors used these words synonymously) was enhanced in the blended wines as compared with the non-blended wines. With respect to within-group variability in judgments of complexity, wine experts' complexity-scale ratings were more consensual than those of the other two participant groups, again showing differences in within-group variability as a function of domain-specific expertise.

A final point that deserves mention is that the current data show that in general the French participants did not find the wines in this study particularly complex. This should be qualified by noting that the wines typically produced and consumed in Burgundy, France are Pinot noir and Chardonnay, rather than Sauvignon blanc. Conceivably our result could be due, at least in part, to the fact that Sauvignon blanc is considered a relatively 'simple' white grape variety in terms of the number of impact compounds important to its varietal expression (Masneuf-Pomarede, Mansour, Murat, Tominaga, & Dubourdieu, 2006). The aim of providing relatively novel stimuli to the present study's participants in the form of Sauvignon blanc wines was to investigate perceived complexity in wines as a function of wine expertise in the absence of the confounding factor of differences in familiarity specific to the wine type under consideration. That is, we made the a priori judgment that Marlborough Sauvignon blanc from New Zealand would present as a relatively novel stimulus to all participants, irrespective of their overall level of general wine expertise.

5. Conclusion

The multi-dimensional construct of wine complexity has been shown via behavioural data to associate with several key wine attributes, in particular perceived harmony and balance of a wine, these aspects linked more to blendedness or integration of a wine's parts than to perceptual separability. Although ease of identifying separate components of a wine, in this case the different flavours, was a significant factor in allowing participants to separate the wines, it was not a factor that associated positively with perceived complexity by any of the participant groups. In terms of the influence of domain-specific expertise, our data not only demonstrate behavioural differences in wine assessment as a function of expertise, but also show an interaction between domain-specific expertise and task to-be-accomplished. More specifically, data from the non-directed sorting task suggest that connoisseurs have more in common with wine professionals than they do with less-serious wine consumers, while connoisseurs had more in common with consumers than they did with oenologists when evaluating perceived complexity. Hence the present data reinforce the importance of not considering 'wine consumers' as an homogenous group in research investigations.

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Table 1. Sauvignon wines employed in the study. All wines were Marlborough, New Zealand, Sauvignon blanc from the 2009 vintage. TA = total acidity expressed as g/L tartaric acid equivalent; RS = residual sugars.

Wines	Description	Wine Type	Ethanol % v/v	TA g/L	pH	RS	Dry extract g/L
WF3yob	Wild ferment in 3 year old, 228-L Vicard barrel; Awatere Valley fruit; hand harvested	Expe/Oeno	13.7	9.56	3.16	5.5	24.5
X5Yst	Yeast X5; hand harvested fruit	Expe/Oeno	14.8	8.48	3.18	4	19.8
LgWood Fe	Large wooden ferment: Vicard cuve; hand harvested fruit	Expe/Oeno	14	10.29	3.13	2.3	20.1
StainLSt	Stainless Steel tank; hand harvested fruit	Expe/Oeno	14.3	9.71	3.12	3.5	20.1
PichiYst	*Pichia kluyveri* yeast; hand harvested fruit	Expe/Oeno	14.6	8.24	3.16	5.8	20.3
MES	4.5% in French oak for 150 days; machine harvested fruit	Expe/Oeno	13.9	7.43	3.3	3.1	17.2
Awatere F	Awatere Valley fruit; hand harvested fruit	Expe/Viti	14.1	7.89	3.19	1.5	15.7
Oldvines	Old vines (planted 1982); hand harvested fruit	Expe/Viti	12.3	10.63	3.07	5.5	23.5
ShadEW V	Shaded-side fruit of east-west vine; hand harvested fruit	Expe/Viti	14.7	8.38	3.19	2.7	18.3
EWVCo qP	All fruit east-west vines; hand harvested fruit; Coquard press	Expe/Viti	14.5	9.81	3.07	3.3	20.1
MVS	Standard wine production; machine harvested fruit	Standard	12.8	7.1	3.39	4.2	18.3
MRS	Standard wine production; machine harvested fruit	Standard	13.6	6.97	3.35	2.8	18.3
STS	Standard wine production; machine harvested fruit	Standard	13.2	7.32	3.36	3.4	16.7

Table 2. RV coefficients (normalized RV coefficients)

	Connoisseur	Consumer	Expert	ALL
Connoisseur (n=30)	1			
Consumer (n=41)	0.50 (3.5)	1		
Expert (n=16)	0.66 (5.0)	0.67 (5.1)	1	
ALL (n=87)	0.71 (5.5)	0.87 (7.2)	0.84 (6.9)	1

Table 3a. Mean of Rand indices within and between groups of subjects

	Consumer	Connoisseur	Expert
Consumer	0.613		
Connoisseur	0.652	0.713	
Expert	0.662	0.729	0.747

Table 3b. Percentage of significant (*p*=0.05) Rand indices within and between groups of subjects

	Consumer	Connoisseur	Expert
Consumer	15.6		
Connoisseur	14.6	14.9	
Expert	18.6	23.5	41.7

Significance was tested by a permutation (n=100) test for each pair of subjects

Table 4. Average number of categories formed in the sorting task and their standard error by group of subjects

Group	Average	StdErr
Consumer	3.83	0.16
Connoisseur	5.00	0.17
Expert	5.25	0.36

Table 5. *P*-value of the *F* statistics from the ANOVA model:
WineType + Wine(WineType) + Group + Subject(Group) + Group*WineType + Group*Wine(WineType)

Item	WineType	Wine(WineType)	Group	Group*WineType	Group*Wine(WineType)
EasyIdFl	**0.0088**	0.2688	**0.0227**	0.6386	0.7931
NbFlav	**0.0335**	**0.0567**	0.5317	0.8548	**0.0713**
Complex	**0.0528**	0.4482	**0.0002**	0.2941	0.5881
Linger	**0.0615**	0.1809	0.2402	0.4367	0.8702
Harmony	**0.0673**	**0.0004**	0.1270	0.7871	0.6393
Familiar	0.1150	**0.0057**	0.3625	0.3593	0.3650
Balance	0.1223	**0.0000**	**0.0869**	0.9542	0.3121
Intensit	0.5491	**0.0041**	0.8592	0.6222	0.7417

p-values lower than 0.10 are in bold

Table 6. Mean scores of complexity items (sorted by significance) by groups of subjects with their multiple comparison

Item	*p*-value of Group effect	Consumer	Connoisseur	Expert
Complex	**0.0002**	4.95 a	4.66 a	3.46 b
EasyIdFl	**0.0227**	4.16 b	4.95 ab	5.42 a
Balance	**0.0869**	4.94 a	4.93 a	4.03 b
Harmony	0.1270	5.13 a	4.83 ab	4.17 b
Linger	0.2402	5.40 ab	5.51 a	4.69 b
Familiar	0.3625	4.65 a	5.22 a	5.19 a
NbFlav	0.5317	4.33 a	4.32 a	3.83 a
Intensit	0.8592	5.46 a	5.53 a	5.28 a

Two means in the same line with the same letter are not significantly different (LSD, p=0.10)

Table 7. Mean scores of complexity items (sorted by significance) by Wine Type (Standard; Expe/Oeno; Expe/Viti) with their multiple comparison

Item	***p*-value WineType**	**Standard**	**ExpeOeno**	**ExpeViti**
EasyIdFl	**0.0088**	5.08 a	4.58 b	4.45 b
NbFlav	**0.0335**	4.70 a	4.23 b	3.91 b
Complex	**0.0528**	4.55 ab	4.69 a	4.42 b
Linger	**0.0615**	5.40 a	5.46 a	5.00 b
Harmony	**0.0673**	5.42 a	4.85 b	4.43 b
Familiar	0.1150	5.39 a	4.86 b	4.74 b
Balance	0.1223	5.30 a	4.80 ab	4.34 b
Intensit	0.5491	5.48 a	5.55 a	5.29 a

Two means in the same line with the same letter are not significantly different (LSD, p=0.10)

Table 8. Number of non-significant (NS), positive significant (S +) and negative significant (S -) individual correlations between the overall complexity item and each of the other items

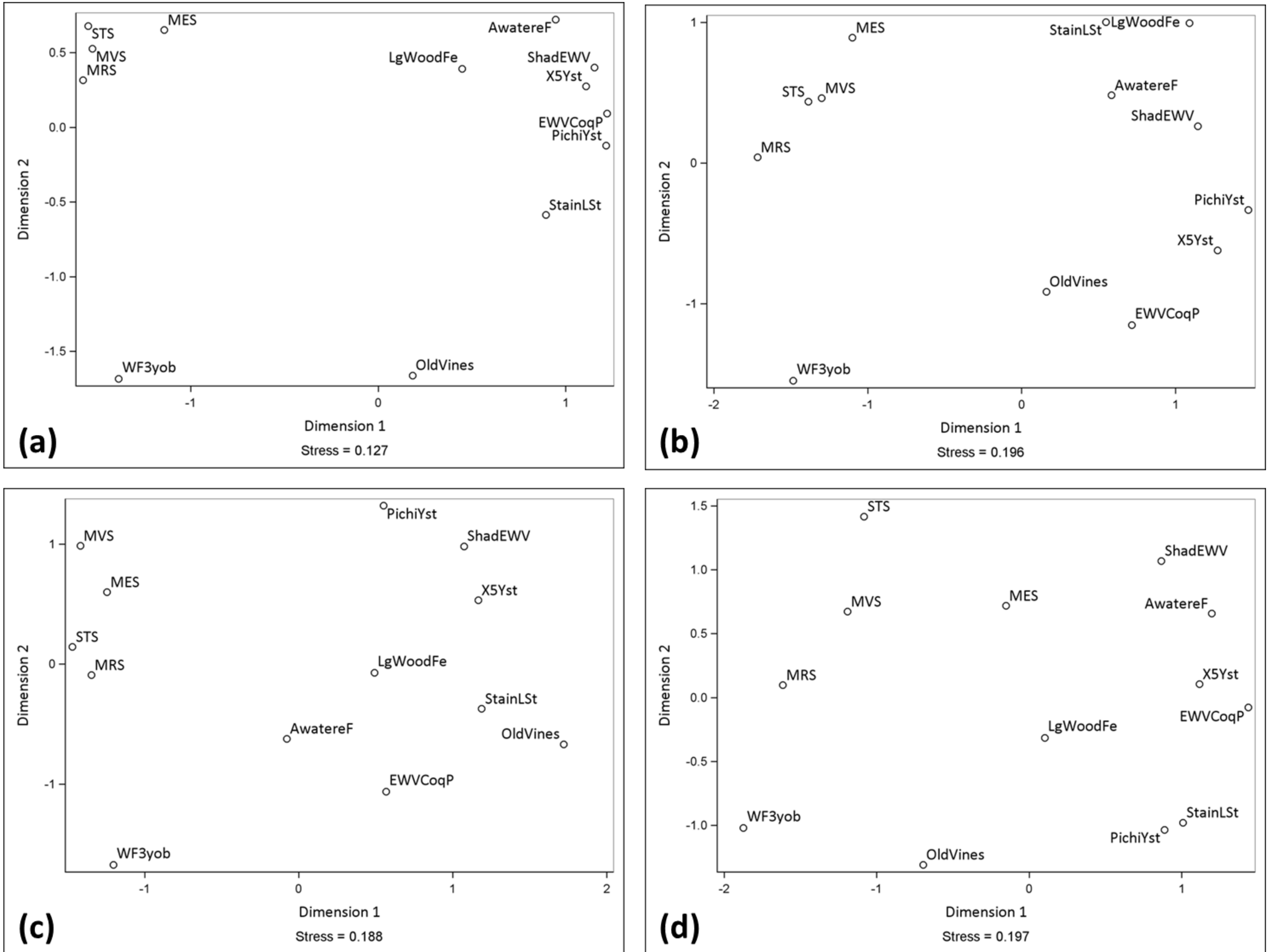
Group	**Item**	**NS**	**S +**	**S-**
Consumer	**Linger**	20	20	0
Consumer	NbFlav	21	18	2
Consumer	Harmony	22	12	7
Consumer	Familiar	27	10	4
Consumer	Balance	28	9	4
Consumer	EasyIdFl	29	7	5
Consumer	NbFlav	8	21	1
Connoiss	**Harmony**	8	18	4
Connoiss	**Intensit**	14	16	0
Connoiss	EasyIdFl	14	13	3
Connoiss	Balance	16	12	2
Connoiss	Linger	18	12	0
Connoiss	Familiar	17	9	4
Connoiss	Intensit	18	22	0
Expert	**NbFlav**	2	14	0
Expert	**Harmony**	3	13	0
Expert	**Balance**	4	12	0
Expert	**Linger**	5	11	0
Expert	**Familiar**	8	8	0
Expert	EasyIdFl	11	4	1
Expert	Intensit	11	3	2

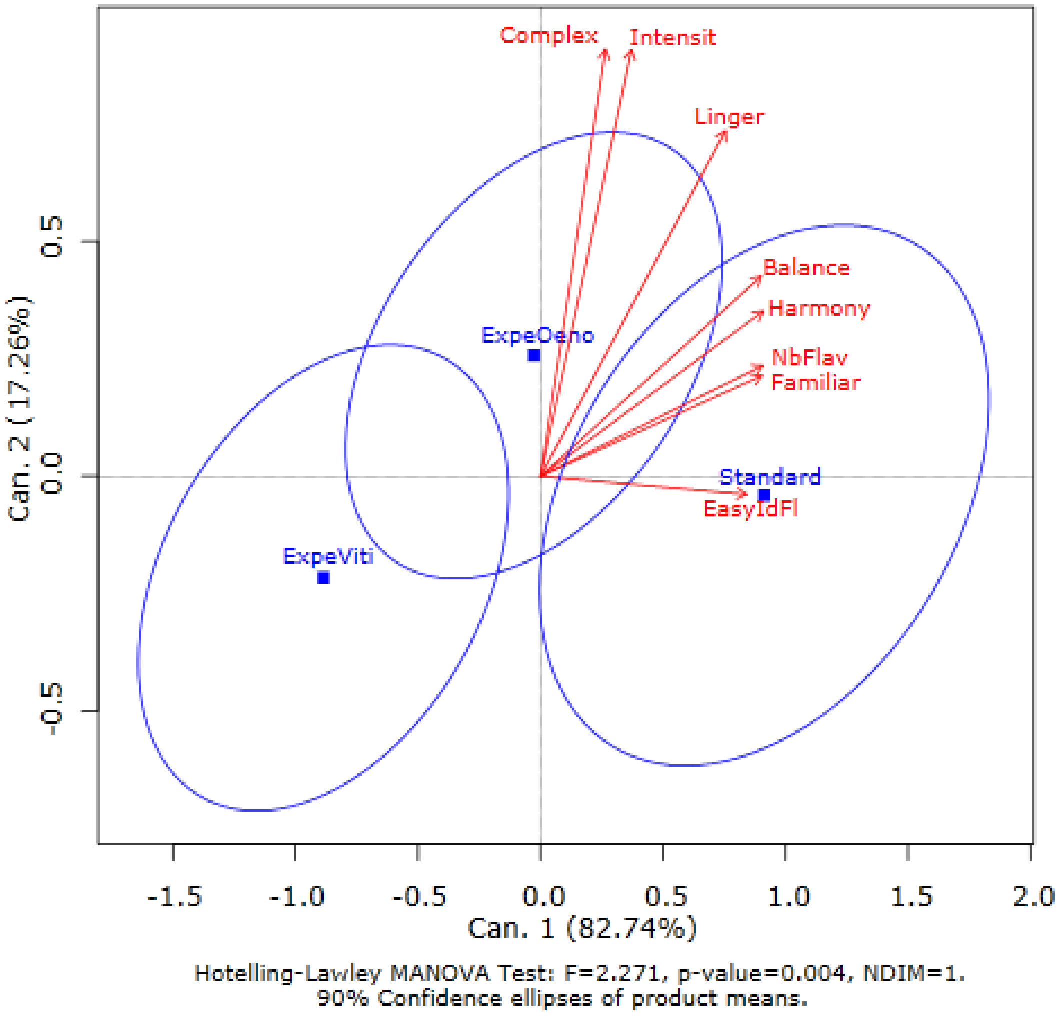
Significance is assessed at p=0.05
Items in bold are more often positively correlated than non-correlated with overall complexity

Figure Legends

Figure 1. Non metric ordinal multidimensional scaling (MDS) of numbers of wine co-occurrences in individual categories from a free sorting task: (a) based on all 87 subjects; (b) based on 16 experts; (c) based on 30 connoisseurs; and (d) based on 41 consumers.

Figure 2. Bi-plot from a Canonical Variate Analysis of the Wine Type factor.


STS
MES
MVS
MRS
AwatereF
LgWoodFe
ShadEWV
X5Yst
EWVCoqP
PichiYst
StainLSt
WF3yob
OldVines
0.5
0.0
-0.5
-1.0
-1.5
-1
0
1
Dimension 2
Dimension 1
(a)
Stress = 0.127
MES
StainLSt
LgWoodFe
STS
MVS
AwatereF
ShadEWV
MRS
PichiYst
X5Yst
OldVines
EWVCoqP
WF3yob
1
0
-1
-2
-1
0
1
Dimension 2
Dimension 1
(b)
Stress = 0.196
PichiYst
MVS
ShadEWV
MES
X5Yst
STS
MRS
LgWoodFe
StainLSt
AwatereF
OldVines
EWVCoqP
WF3yob
1
0
-1
-1
0
1
2
Dimension 2
Dimension 1
(c)
Stress = 0.188
STS
ShadEWV
MVS
MES
AwatereF
MRS
X5Yst
EWVCoqP
LgWoodFe
WF3yob
StainLSt
PichiYst
OldVines
1.5
1.0
0.5
0.0
-0.5
-1.0
-2
-1
0
1
Dimension 2
Dimension 1
(d)
Stress = 0.197


Complex
Intensit
Linger
Balance
Harmony
NbFlav
Familiar
ExpeOeno
Standard
EasyIdFl
ExpeViti
Can. 2 (17.26%)
0.5
0.0
-0.5
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Can. 1 (82.74%)
Hotelling-Lawley MANOVA Test: F=2.271, p-value=0.004, NDIM=1.
90% Confidence ellipses of product means.

Appendix 1. The INRA Complexity Questionnaire

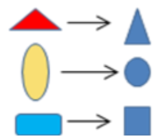
How **familiar** are you with this wine?
(does it remind you of wines you have already tasted)?

ที
Ю 德
Unfamiliar — *Familiar*
A
b C

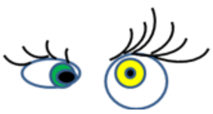
How **many flavours** can you identify in this wine?


A few — *A lot*


How **easy is it for you to identify** or describe the different flavours of this wine?


Difficult — *Easy*


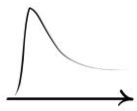
Are the different sensations and flavours **harmonious**; do they go well together?


Not harmonious — *Harmonious*

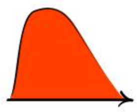

Are the different sensations and flavours well **balanced**, without any being overpowering?


Unbalanced — *Balanced*

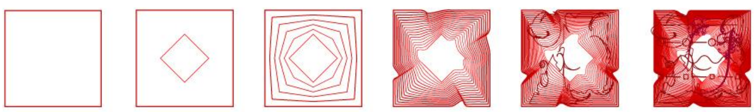

How long do the different sensations and flavours **linger** in your mouth?


Short — *Long*


Are the sensations and flavours of this wine **strong and powerful**?


Weak — *Strong*


You have just described this wine; you know its characteristics.
Now we would like you to score its **overall complexity** on the scale below:

Low complexity

High complexity