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The Nose Knows: Influence of Colour on Perception of Wine Aroma

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ABSTRACT *The mental processes that enable a wine connoisseur to identify a favourite vintage have received little systematic study. Two experiments explored wine expertise by investigating perceptual processing in judgements of wine aroma. Specifically, we investigated olfactory perceptual bias, a cognitive construct concerned with how what we already know influences what we smell. Colour-induced olfactory bias was investigated in wine experts (Experiment 1) and in social drinkers (Experiment 2). We hypothesised that colour-induced perceptual bias was more likely to occur in wine experts than in social drinkers, leading experts astray. The task simulated a wine-evaluation situation where colour and aroma were open to evaluation by visual and olfactory senses. Experts were able to discriminate white wines that had been masked with colour to simulate an aged white wine and a red wine, although they did succumb to a degree of colour-induced olfactory bias. That is, experts' aroma judgements on the white wine that was coloured red were more accurate when the wine was presented in opaque glasses than when presented in clear glasses. Social drinkers found the task extremely difficult, demonstrating indiscriminate behaviour in some conditions. The data suggest that wine experts do indeed differ cognitively from novices in their approach to evaluating wine aroma. Theoretical and applied implications are discussed.*

Wine expertise has a long and great tradition, but what is wine expertise? Although the question was considered nearly 50 years ago by experimental psychologists J. J. Gibson and Eleanor Gibson (1955), it remains largely unanswered today. In short, when we use a human observer as an analytical tool to gather *information* about a wine sample (that is, to employ their senses to examine and make judgements about the qualities of a wine),[1] we know very little about what they are actually doing (Parr, 2002).

Wine expertise has not so much remained elusive; rather, it has been relatively neglected in the realm of scientific enquiry. Few researchers have studied wine expertise in a serious and systematic way. Those who have (Solomon, 1988, 1990, 1991; Morrot, 1999; Morrot *et al.*, 2001); Hughson and Boakes, 2002) have, in each case, taken as their major focus wine-relevant verbal abilities, namely semantic (verbal) memory and lan-

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guage (e.g., 'wine talk': Solomon, 1988). The present study aimed to extend the range of cognitive phenomena investigated to date concerning wine expertise.

In two previous experiments (Parr *et al.*, 2002, 2004), we demonstrated that wine experts have superior recognition memory for wine-relevant odours compared to novice wine judges and to those defined as having 'intermediate' wine experience. This result was interpreted in terms of superior perceptual skill in wine experts (e.g. enhanced ability to imagine or image the smells), rather than enhanced verbal ability, since wine experts were no better at accurately or consistently naming the odours than less experienced persons.

Ironically, wine knowledge and experience have potential to inhibit, as well as facilitate, accurate perceptual processing in some circumstances. The present experiments investigated a concept referred to as colour-induced olfactory bias (Morrot *et al.*, 2001) in expert wine judges and in social drinkers.

The initial judgement about the quality of a food or beverage is influenced by appearance of the product, notably its colour (Lawless and Heymann, 1998). Clydesdale (1993) comments that the aesthetics, safety, sensory characteristics and acceptability of food are all affected by colour. Wine is no exception, with colour and clarity often serving as the primary indicators of perceived quality and of wine style. Beyond the simple dichotomy of 'red' or 'white', quantitative and qualitative aspects of colour can serve as cues to factors such as cultivar (e.g. a salmon hue in a Pinot Gris wine) and the age or maturity of a wine. It follows that colour is likely to be correlated with aroma, taste and textural qualities of a wine. Colour therefore can assist us in classifying a wine sample by cutting down the cognitive load that would result if every wine sample we experienced needed to be treated as unique (Gawel, 1997). In this information-processing analysis, colour can be seen as a cue that can serve a facilitative function.

However, as well as providing some cognitive advantage, colour also has a potentially disruptive effect. That is, colour can influence perception of odour and taste so that we perceive flavours that are not objectively part of the particular food or beverage. Several researchers have argued that colour perception can result in inappropriate attribution of qualities such as odours to foods and beverages (e.g. Engen, 1972; Morrot *et al.*, 2001). The mediating mechanism is assumed to include expectations (Deliza and MacFie, 1996) that are generated on the basis of knowledge about the colour's relevance to the product. In the case of wine, this would include knowledge about factors that influence wine style, wine age and overall quality. Gawel (1997) argues that expectations, resulting from knowledge about typical characteristics of a product, can function to elevate the probability that a component or characteristic will be identified.

People in general are very poor at identifying substances by olfaction when they have no cues from other sensory modalities such as visual cues (Zellner *et al.*, 1991). It is interesting to note that very little wine tasting or judging is fully 'blind': that is, where no information other than that received via chemical senses of smell and taste, and trigeminal nerve stimulation, is available to the judge. In most wine-evaluation situations the colour of a wine may activate a set of information in our minds concerning fruit ripeness, oenological practice, wine age and so forth. Such information would typically be activated prior to smelling or tasting a wine. Further, research on implicit learning and implicit memory in olfaction suggests that colour-induced activation of potentially relevant information is not necessarily accompanied by a judge's conscious awareness of either the information itself, or its possible influence on subsequent wine-judging behaviour (e.g. Degel and Koster, 1999).

Brochet (1999) argues that colour of a wine may activate a pre-established description profile of a wine based on a prototype (e.g. a 'typical' red wine), biasing the perception

of the taster to 'smell' or 'taste' something that is in fact not present in the wine sample. Brochet (1999) put forward a theory concerning the cognitive constructs that he believes underlie such colour-induced olfactory bias. He argues, in keeping with earlier models of cognitive dissonance (e.g. Festinger, 1957), that a type of cognitive coherence is required by the brain in terms of how it handles all sensory input. Therefore, a wine judge would be unlikely to refer to a white wine sample as 'plum' or 'raspberry'. Brochet (1999) argues that sight carries superior weight when humans make coherent their sensory input so that the categorisation of any wine sample will be set by its colour. In support of the cognitive emphasis in Brochet's (1999) theoretical analysis, Stillman (1993) reported data from a discrimination study from which she concluded that the integration of colour information into a flavour percept is cognitive, rather than physiologically based. She argued that light reflected from a tastant does not directly influence any of the nerve fibres activated by the chemical or textural properties of food or drink.

In several studies employing beverages, usually fruit juices, colour has been shown to influence perceived aroma and taste of the beverage (Pangborn *et al.*, 1963; Engen, 1972; DuBose *et al.*, 1980; Zellner and Kautz, 1990; Stillman, 1993; Kemp and Gilbert, 1997; Zellner and Whitten, 1999). An early study by Maga (1974) reported that colour influenced the taste threshold of the basic tastes of salt, sour, bitter and sweet. In another early study, and one of the few studies involving the sensory characteristics of wine, Pangborn *et al.* (1963) added food colourings to white table wines on which participants made sweetness judgements. Pangborn *et al.* (1963) reported that experienced wine tasters' judgements were more influenced by colour change than those of inexperienced wine drinkers. However, not all studies in the research field, particularly those investigating olfaction, have shown effects that are consistent or repeatable (Lawless and Heymann, 1998). Reasons for this state of affairs include the contrived nature of many studies (e.g. Zellner and Whitten, 1999) and the concept of appropriateness as it applies to relations between odour and colour.

What is clear from research to date is that conceptualisation and categorisation of a wine are not achieved under most circumstances solely by sensorial information from the nose and mouth (Brochet, 1999). Sensorial information is typically referred to as 'data-driven' or 'bottom-up' input (e.g. Reisberg, 1997; Dalton, 2000). The other major type of input that is assumed to be involved when we make an evaluation based on information from our sense organs is idea-based, or 'top-down', information processes. This refers to the influence of pre-existing information such as experientially gained knowledge, which in turn may influence perception via a person's expectations, motives, desires and so forth (Lawless and Heymann, 1998). Brochet and Dobourdieu (2001) reported that a lexical analysis of descriptions of four wine experts showed that the wine descriptions were based on general prototypes, such as colour-based prototypes (e.g. a 'typical' red wine). The wine experts' judgements were argued to be the result of components of a wine sample being initially compared to components of similar samples that the expert had experienced in the past. For example, a greenish hue in a young white wine may be linked by associative memory to a prototype that includes the attribute of unripe fruit, leading to the expectation that a beverage will be less sweet, or have enhanced vegetative notes. Such top-down processing may in turn serve to bias a person to 'perceive' vegetative notes in the wine.

The present study was aimed at investigation of the influence of top-down processing in wine sensory evaluation. Specifically, the study investigated a concept referred to as colour-induced olfactory bias (Morrot *et al.*, 2001) in expert wine judges and in social drinkers. We theorised that top-down information processing in the form of wine knowledge would render any particular colour more or less appropriate for association

with perceived odour(s). That is, the "color of odors" (Morrot *et al.*, 2001, p. 79) was not assigned by the experimenter in the study but was left to the experimental participant to express.

Individuals presumably differ in the type of expectations that they form when colour is provided as a cue and, consequently, the way(s) in which they are influenced by colour-induced expectations. One variable that the current study hypothesises will influence how colour affects perception of odour is domain-specific expertise. All 29 participants in Experiment 1 were classified under previously expressed criteria (Parr *et al.*, 2002) as wine experts. Due to the multifaceted nature of wine expertise, participants were further subcategorised on the basis of their major activity (e.g. wine judge, winemaker).

The issue of major interest was whether automatic use of wine-relevant knowledge places wine experts at risk of colour-induced olfactory bias. In other words, does expertise, in terms of wine-relevant semantic knowledge about the colour of odour (that is, what goes with what), have its own risks and disadvantages? One possibility is that the holder of such expertise may be more cautious than a social drinker and alert to the potential biasing aspects of their knowledge base should their data-driven input not match their expectations. On the other hand, Morrot *et al.* (2001) argue that colour-induced olfactory biases operate at an 'unconscious' level so that awareness of the potential for bias may not in itself be sufficient to protect a wine expert completely from exhibiting such bias.

In one of the few studies that specifically investigated the influence of colour on judgements of wine aroma, Morrot *et al.* (2001) coloured a Sémillon/Sauvignon Blanc white wine with 2 g l^{-1} of purified grape anthocyanins. A pilot study was carried out to determine the neutrality of the red colouring in terms of changes to the aroma profile of the wine. This consisted of a series of triangle tests involving the wines in opaque glasses. Results showed that participants were unable to discriminate the white wine from the white wine coloured red under these conditions. Undergraduate students in oenology were employed as participants in Morrot *et al.*'s (2001) experiment proper. Their task was to apply odour descriptors, which they had chosen during an earlier session where a red and a white wine were tasted, to the white wine and to the white wine that was coloured red. Results, in terms of the number of times that red and white wine descriptors were allocated to each of the wines, showed that the white wine was perceived as having the odour of a red wine when coloured red.

Experiment 1

Experiment 1 extended Morrot *et al.*'s (2001) study in several ways. First, wine experts were employed as participants. Secondly, participants judged the bouquet of each wine when the wines were presented in standard, clear glasses and when the same wines were presented in opaque glasses. This provided the possibility for direct comparison of the aroma judgements of each participant when colour was a cue with the judgements given when colour was not a cue. Finally, the addition of non-odorous food colouring to wine samples, a procedure known as 'masking' in the literature on sensory evaluation of foods and beverages, involved simulation of an aged white wine as well as simulation of a young red wine. It was anticipated that masking a young Chardonnay wine so that it simulated an aged white wine and a red wine could serve to induce olfactory bias.

The theoretical basis for the study concerned the major source of information guiding wine experts' olfactory judgements. It was hypothesised that the three colours of the wine, namely pale gold (control white wine), gold (control wine masked with turmeric

and caramel) and red (control wine masked with anthocyanin), could lead a participant to form three separate cognitive constructs of the same wine. That is, a participant might form three distinctly different subjective representations, each based initially on colour. Theoretically, the study investigated whether wine experts' ratings of aroma notes, previously identified in a control wine, were primarily driven by data-driven olfactory perception (that is, emphasis on the actual volatile components of the wine in the glass) or by top-down processes involving knowledge (e.g. prototypes or models of typical wine styles) and knowledge-driven expectations. By investigating orthonasal olfaction only, experts were not able to engage in the more sophisticated tasting techniques (e.g. aerating the wine) that could advantage them when making aroma evaluations via their sensory and perceptual processes.

Materials and Methods

Participants

Twenty-nine wine experts, 18 males and 11 females, from six geographical regions across New Zealand took part in the study. Experts were defined in accordance with previous studies (Melcher and Schoeler, 1996; Bende and Nordin, 1997), using criteria outlined in Parr *et al.* (2002). A person was defined as an expert if they fitted at least one of the following categories:

- established winemakers;
- wine-science researchers and teaching staff who were regularly involved in winemaking and/or wine evaluation;
- wine professionals (e.g. Masters of Wine, wine judges, wine writers/critics, wine retailers);
- graduate students in viticulture and oenology who had relevant professional experience (e.g. had participated in *more than one* vintage, had run wine-tasting classes);
- persons with an extensive (>10 years) history of wine involvement (e.g. family history, extensive wine cellar, regular involvement in formal wine tastings).

The age range of the wine experts was 22–62 years ($M = 40.4$). Two participants were occasional smokers. The remaining participants were non-smokers. Participants were asked about their dietary habits, all reporting them to be within the range of current standard New Zealand eating patterns (Russell *et al.*, 1999), often with Mediterranean and Asian influences. Each person participated in the Ishihara (1990) test for colour vision. No participant was excluded as a result of failing to reach the Ishihara (1990) criterion (reading 10 of plates 1–11 correctly).

Materials

Two commercial table wines were selected for use, one white and one red. The white wine (W) was a Sacred Hill 2000 barrique-fermented Chardonnay and the red wine (R) was a Shingle Peak Marlborough 2001 Pinot Noir. Table 1 details important aspects of wine composition for each of the wines.

An informal pilot study, involving oenology academic staff and postgraduate students, was employed prior to the experiment proper to identify one red and one white wine that would be suitable for use in the experiment. The criteria employed for selection of the red wine were based on those associated with a relatively young, light, Burgundian style of Pinot Noir, with the aromatic profile dominated by fruit and oak influences. The white

Table 1. Important parameters of wine composition for each of the wines employed

Parameter	Chardonnay (white)	Pinot Noir (red)
pH	3.21	3.55
Titratable acidity (g l^{-1})	6.30	5.99
Alcohol (% v/v)	13.50	12.70
Residual sugar (g l^{-1})	1.30	2.60

wine was selected on the basis that it was a pale yellow/gold in colour and that its aromatic profile offered a range of primary notes (fruit characters) and secondary notes (e.g. oak, buttery, yeasty) that participants were likely to find accessible. It was also considered that the aromatic profile should not include any notes that were sufficiently intense as to make the wine such a salient stimulus that it was particularly distinctive and therefore highly discriminable under any conditions (as is frequently the case with a young Marlborough Sauvignon Blanc).

Preparation of Wine Samples

Half an hour prior to each testing session, a 750 ml bottle of each of the commercial table wines was freshly opened and checked for obvious cork taint, and eight wine samples were prepared, four in clear glasses and an identical four samples in opaque (black) glasses. Each sample involved 50 ml of the respective wine. Cover slips were employed to protect the wine samples as soon as they had been prepared.

The wine samples were prepared as follows. Two 50 ml samples of each of the Pinot Noir and the Chardonnay were prepared, one in a clear and the other in an opaque glass. The masked wine samples, white-gold (WG) and white-red (WR), were then prepared. Prior, informal experimentation had been employed to determine the concentration of colour additives that were used to simulate an aged or complex Chardonnay (WG). A precedent in the literature provided the concentration of anthocyanin employed (Morrot *et al.*, 2001) to simulate a young red wine (WR).

Wine WG was prepared by addition of 2 μl natural caramel (product number 2240) and 2 μl turmeric natural colour (product number 2415) per 100 ml of wine. Wine WR was prepared by addition of 2 g l^{-1} anthocyanin (grape skin extract) natural colour (product number 2441) to the Chardonnay. This was the same concentration of anthocyanin that was employed by Morrot *et al.* (2001) to mask their Sémillon wine. The non-odourous colorants used in the present study were supplied by Formula Foods Corporation Limited, Christchurch, New Zealand. The masked samples were thoroughly mixed by gently swirling the glass flask. They were then poured in equal portions into clear and opaque glasses, each glass comprising a 50 ml solution.

Spectrophotometer (Unicam UV4–100) measurements of colour were recorded for each wine sample at 420 nm (brown hue), 520 nm (red hue) and 620 nm (colour intensity: $(A_{420\,nm} + A_{520\,nm} + A_{620\,nm})$) according to the methods of Somers and Evans (1977) and Zoecklein et al. (1995) in a 2 mm path-length quartz cell against a deionised water blank. All values were converted to a 1 cm (10 mm) light path. The data reported in Table 2 show that there were obvious differences in colour parameters across the four wine samples as measured by instrumental analysis.

The eight glasses, with cover slips, were placed on the experimenter's side of a booth, out of the view of a participant. To ensure that the pH of the wines did not change across

Table 2. Spectrophotometry colour parameters for the four wine samples

Wine	Colour density ($A_{420\,nm} + A_{520\,nm}$)	Colour hue/tint ($A_{420\,nm}/A_{520\,nm}$)	Colour intensity ($A_{420\,nm} + A_{520\,nm} + A_{620\,nm}$)
W	0.22	2.13	0.28
WG	0.42	2.36	0.50
WR	2.18	0.69	2.47
R	4.58	0.79	5.27

a testing session, and therefore potentially alter the aromatic profile of the wines, the pH of each wine sample was recorded prior to the first participant of the day and at the end of the testing session on two different occasions during the experiment. Table 3 shows that pH remained relatively constant across the day for all four wine samples.

Materials for Data Collection

Data were collected in 16-page booklets, one for each participant. One page of each booklet was allocated for each of the 16 wine samples that were to be rated (eight in clear glasses, eight in opaque glasses). Each page of the booklet featured four rating scales, evenly spaced on each page. The type of rating scale employed comprised a 100 mm visual analogue scale (VAS), anchored with the words 'absent' printed under the left-hand end and 'extreme' under the right-hand end of the scale. The four descriptors to be rated via the four rating scales per page comprised each participant's unique set of four descriptors (two white, two red) that the participant provided to the commercial table wines during phase I of the study.

Design

There were two orders for presentation of wine glasses (clear first, opaque first). There were also two orders for presenting the wine samples (wines W, WG, WR and R). Each wine-sample order included one replication of each of the four samples in the clear and opaque glasses (order 1: WG, R, WR, W, WG, R, WR, W; order 2: W, WR, R, WG, W, WR, R, WG). The two wine-sample orders, one the reverse of the other, were employed to control for order effects. The two orders of glass colour and the two orders of wine sample presentation gave four possible stimulus presentation conditions: A, clear glasses first, wine sample order 1; B, clear glasses first, wine sample order 2; C, opaque

Table 3. Measurements of wine pH across two test sessions

	I		II	
Wine	Pre-testing	Post-testing	Pre-testing	Post-testing
W	2.95	2.99	2.95	2.99
WG	2.95	2.99	2.95	2.99
WR	2.95	2.99	2.95	3.00
R	3.26	3.30	3.25	3.28

glasses first, wine sample order 1; D, opaque glasses first, wine sample order 2. Consecutive participants were allocated to conditions A, B, C or D in turn so that over the 29 participants, eight experienced condition A and seven experienced each of conditions B, C and D.

Procedure

Participants were tested individually at a pre-arranged location. They were advised that the study involved an investigation of wine aroma. In each geographical region, a location was established that simulated a sensory evaluation laboratory that was designed according to the guidelines of the American Society for Testing and Materials (ASTM) (1986). In particular, ambient temperature at each venue was maintained at 20°C, ± 3°C, and the environment was kept free of distracting factors such as noise, ambient odours and particularly salient furnishings. A booth-like structure was erected on a plain table top at each testing venue that did not already have booths in place. This served to standardise the experimental environment as much as possible. It was clearly not possible to control lighting across the different venues. In some situations, natural daylight was adequate, while in others artificial lighting was needed. In each case, the experimenter ensured that the wines were presented to each participant on a plain white surface, and with adequate lighting such that the wines were easy to discriminate on the basis of colour using the naked eye.

There were two phases to the procedure. Participants were first asked to smell each of the two commercial table wines. The white and red wines were presented to them consecutively in standard, clear glasses. They were advised that their task was to provide two descriptors that, in their view, best represented the particular sample of wine. Participants were first instructed to sniff the white wine birhinally, and to provide two salient descriptors based on olfaction alone. It was emphasised that the aroma characters or notes that they provided as descriptors were to be those that would help them identify that particular wine at a later stage. Two minutes were allocated for this task. All participants were able to do this within the time limit. The white wine was removed and the red wine was then presented after a 30 s interval. The participant was again reminded that the descriptors provided were to assist in later identification of the particular wine. Two minutes were again allocated for the task. The experimenter recorded the four descriptors provided by the participant across the two wines (two white, two red). The red wine sample was removed from the participant's view. The wine samples were recovered and positioned on the experimenter's side of the booth.

Each participant was then invited to talk about their experience of wine in relation to their current lifestyle and their family and employment history. Ten minutes was allocated for this part of the session. Participants had been invited to participate in the study based on the experimenter's knowledge of their wine-relevant activities. This history-gathering component of the experimental procedure provided a forum that was aimed at achieving two purposes. First, the information that was gathered would assist the experimenter to validate their initial assumption that the participant met at least one of the criteria for inclusion in the category 'wine expert'. Secondly, the gathering of historical information would permit the participant to be loosely classified in terms of their major, current, wine-relevant activity. While a participant chatted about their wine-relevant history, the experimenter discreetly applied the participant's previously chosen descriptors to the four VASs to be rated for each wine sample. That is, the experimenter wrote in the four descriptors (two white, two red), one descriptor under

each of the four VASs on each page of the data collection booklet. This personalised the rating task for each participant, and completed phase I of the procedure.

Following the 10 min of conversation, participants were advised of the final phase of the task. They were advised that they would be provided with some wine samples, and some rating scales based on the descriptors that they had provided to the white and red wine samples. They were advised that their task involved rating each wine on all four descriptors, irrespective of a wine's colour. They were familiarised with the rating scale, including the ability to rate 'absent' if they perceived none of the odour note specified underneath the rating scale. Participants were advised that the references for the descriptor ratings were their memories of the wines experienced in phase I of the session where they had initially produced their unique set of descriptors. Physical reference samples were not provided for direct comparison during phase II of the task.

Sixteen wine samples were then presented to each participant, eight samples in clear glasses and eight samples in opaque glasses, in the order A, B, C or D as previously outlined. The eight presentations in each of the glass colours (clear or opaque) involved presentation of each of the four possible wine samples (W, WG, WR, R) in their specified order with one replication of each. Each wine sample was presented for 60 s for rating, and a 30 s inter-trial interval occurred between wine sample presentations. When all 16 wine samples had been rated, phase II of the task was complete and the participant was thanked and debriefed.

Results and Discussion

Participants were classified into four groups on the basis of their major current role or involvement in wine-relevant activities. There were six wine judges/critics, 14 winemakers and viticulturists, four persons involved in wine marketing and retail and five wine connoisseurs. The 64 ratings ($2 \times 4 \times 4 \times 2$) provided by each participant on the 100 mm VASs were tabulated. The variables comprising the 64 scores were two levels of glass (clear, opaque), four descriptors (two white, two red) and four wine samples (W (control), WG, WR, R), each presented twice. Ratings to the two white descriptors and the two red descriptors were collapsed within colour to give a mean rating for white descriptors and a mean rating for red descriptors to each wine sample.

The first analysis involved a $2 \times 2 \times 2 \times 4$ mixed-model analysis of variance (ANOVA) that was performed on the data collapsed over type of wine expertise. Independent variables in the analysis were order (two levels: clear glasses first, opaque glasses first), wine glass colour (two levels: clear, opaque), wine descriptor (two levels: white, red) and wine sample (four levels: W, WG, WR, R). Order was a between-group variable and the other factors were within-subject variables. The dependent variable was the number between zero and 100 that was given by participants to each of the 64 VASs, averaged over replication and over descriptor (red or white) to give 16 data points per participant (2 descriptors $\times$ 4 wine samples $\times$ 2 glass colours).

The analysis showed the main effects of descriptor, $F(1, 27) = 21.18$, $p = 0.00009$, and of wine sample, $F(3, 81) = 25.98$, $p < 0.00000$, demonstrating that participants discriminated among the four wine samples and between the red and white descriptors. These effects require qualification in light of the interaction of descriptor and wine sample, $F(3, 81) = 93.47$, $p = 0.0000$. Figure 1 shows that, as expected, higher ratings were given for white descriptors when the white wine was rated than when the red wine was rated, while red wine descriptors were rated more highly when the sample of wine being rated was red. The interaction of descriptors and wine samples demonstrates that the red and white wines were clearly distinguishable to participants in terms of the

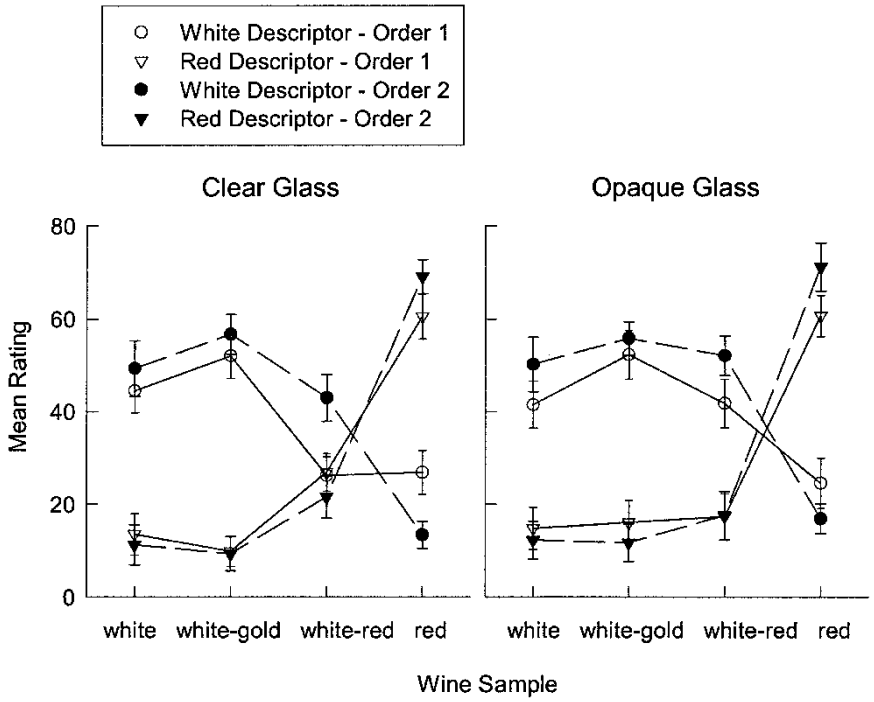

Figure 1. Mean VAS ratings as a function of descriptor, wine sample and glass presentation order.

descriptors that they had provided to the base or standard wines that were presented prior to the aroma rating task.

Descriptor and wine sample were also involved in a triple interaction with order, $F(3, 81) = 3.76$, $p = 0.013$. However, as Figure 1 shows, the effect of order appears to be minimal in that the pattern of results was similar for the two orders. That is, participants performed similarly irrespective of whether they received wine samples in opaque or standard clear glasses first. Order failed to produce a main effect, $F(1, 27) = 0.36$, $p > 0.05$, and the data were collapsed over order in subsequent analyses.

Wine glass colour failed to reach significance as a main effect but was involved in a triple interaction with descriptor and wine sample, $F(3, 81) = 7.32$, $p = 0.0002$. A separate, three-way repeated-measures ANOVA was performed on the data that were collapsed over both type of expertise and order. Glass colour failed to reach significance, but there were main effects of descriptor, $F(1, 28) = 21.59$, $p = 0.00007$, and of wine sample, $F(3, 84) = 26.11$, $p = 0.0000$. There was an interaction between descriptor and wine sample, $F(3, 84) = 84.14$, $p = 0.0000$, and a triple interaction between descriptor, wine sample and glass colour, $F(3, 84) = 7.52$, $p = 0.0002$.

To disentangle the effects involved in the three-way interaction, *post hoc* Newman–Keuls tests were conducted. Figure 2 shows that when white descriptors were being rated, ratings to the W, WG and R wines were uninfluenced by whether the colour of the wine could be observed. On the other hand, the WR wine sample was rated higher on the white descriptors when presented in opaque glass than when presented in clear glass, suggesting that the red colour influenced ratings. This was confirmed in a separate, repeated-measures ANOVA on a subset of the data involving ratings to WR wine only.

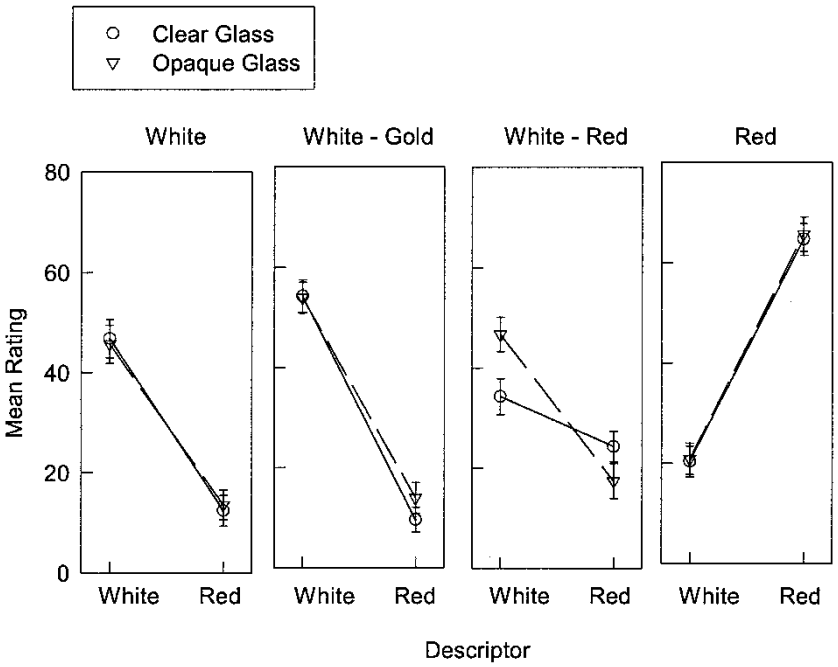

Figure 2. Mean VAS ratings as a function of descriptor, wine sample and glass colour (clear or opaque).

The ANOVA results are graphically presented in the third panel of Figure 2 and show a main effect of descriptor, $F(1, 28) = 18.74$, $p = 0.0002$, and an interaction between descriptor and glass colour, $F(1, 28) = 15.76$, $p = 0.0005$. This demonstrates that participants more accurately discriminated the white wine that was artifically coloured red when they could not see its colour. In other words, opaque glasses enhanced olfactory performance of the wine experts when the wine sample was masked by artificially colouring it red with grape anthocyanin.

Artificially enhancing the depth of yellow/gold of the white wine failed to produce a similar effect, namely increased incidence of false positive judgements. This null result requires qualification on methodological grounds. The descriptors provided by participants to the Chardonnay wine would in some cases be expected to increase in intensity as yellow/gold colour deepened (e.g. buttery, oaky), while in other cases the particular descriptors would be expected to correlate negatively with colour intensity (e.g. some of the fruity and fresh notes). The consequence of this is that the positively correlated ratings and the negatively correlated ratings with colour may have cancelled each other out. Further research is warranted concerning this type of manipulation (that is, colour masking to simulate oenological treatments and/or wine maturation) with a procedure that avoids the problem described here.

Wine Expertise

To consider the variable of wine expertise, a $4 \times 2 \times 2 \times 4$ mixed-model ANOVA was conducted. The data were collapsed over order (clear or opaque glass first) in this analysis. The independent variables included were nature of wine expertise (four levels,

between-group factor) and glass colour, descriptor and wine sample as within-subject factors. There was no main effect of type of wine expertise, $F(3, 25) = 0.59$, $p > 0.05$, and expertise did not interact with any other variable. The remaining effects were as described in the prior analysis.

Wine Descriptors

The descriptors provided by participants in phase I of the study, two descriptors per participant to each wine, were collated and are reported in Table 4. The data show that the white and red wines were highly discriminable in that the descriptors provided show clear differentiation between the two wines. The lists of descriptors that were provided by the 29 wine experts also demonstrate that a large number of descriptors were provided to each wine. This presumably reflects individual differences in olfaction that have their basis in both nature (differences in olfactory receptors) and nurture (domain-specific prior experience). The descriptors provided in the present study are in agreement with terms usually employed to describe white Burgundy wines (e.g. Arrhenius *et al.*, Le Fur, *et al.*, 1998; 1996) and red Burgundy wines (e.g. Chollet and Valentin, 2000).

Conclusion

Wine experts demonstrated colour-induced olfactory bias, namely increased allocation of red wine descriptors to a Chardonnay that was artificially coloured red with grape anthocyanin, when the wine's colour was available as a potential cue. The results are interpreted within a cognitive model that assumes that wine experts would initially classify a wine on the basis of its colour by comparing it with established subjective models in memory (that is, prototypes) of wine styles that they had previously encountered. Further, it has been argued that recall of wine style memories could result in 'false positives' where the olfactory system 'perceived' characters that were in fact not present in the wine sample.

Experiment 2

In the previous experiment, wine experts demonstrated colour-induced olfactory bias when a Chardonnay wine was masked with grape anthocyanin to visually resemble a light red wine. The theoretical arguments expressed in that study, in particular the importance of wine knowledge and/or experience in the formation of expectations concerning wine aroma, suggest that wine novices may demonstrate a different type or degree of colour-induced olfactory bias than do wine experts.

Theoretically, it could be assumed that relatively low levels of domain-specific knowledge would protect a wine novice from the knowledge-driven olfactory bias demonstrated by wine experts in the prior study. Social drinkers, who are relative novices with respect to the discipline of oenology and the practices of winemaking, wine judging and viticulture, are presumably less knowledgeable and less experienced than the wine experts in the prior study. A relative lack of wine-relevant knowledge and experience could be translated in terms of cognitive processes to argue that novices would be limited to the degree to which they would have established subjective models in memory (that is, prototypes) of wine styles that they have previously encountered. As a consequence, recall of wine style memories would be expected to be less frequent. Further, any wine

Table 4. Descriptors provided by the 29 experts in Experiment 1 to the Chardonnay and Pinot Noir wines

Chardonnay		Pinot Noir	
Descriptor	Frequency	Descriptor	Frequency
Milk	1	Raspberries	1
Wood	1	Sun-dried tomatoes/savoury	1
Minerally	2	Plum(s), plummy	7
Toasty	1	Spicy	2
Aged flowers	1	Good sausages	1
Lime	2	Berry/berries	4
Mealy	1	Fresh	1
Oak/oaky	10	Cherry/plum	1
Honey/floral	1	Savoury/mealy	1
Grandmother's talc	1	Violet/floral	1
Sweet	1	Berry/fruity	1
Fruity	4	Fresh/clean	1
Butter/buttery	4	Volatile/acetone	1
Ripe peach	1	Cassis	1
Honey	1	Dark berry	1
Honey dew	1	Strawberry	3
Creamy	1	Nutmeg/spice	1
Nuts/cereal	1	Cherry/cherries	3
Vanilla	1	Black pepper	2
Lemons	1	Smoky	1
Banana	1	Leafy	1
Sizzled butter	1	Blackberries	2
Syrupy	1	Jammy	2
Herbal	1	Black cherry	3
Youthful/fresh	1	Geranium leaves	1
Malo/oak	1	Sweetness	1
Apricots	1	Tannins	1
Citrus	1	Currant	1
Butter/cream	1	Buttery	1
Fresh/crisp	1	Nutty	1
Fresh	1	Oaky	1
Peachy/buttery	1	Earthy	1
Stonefruit	2	Spicy oak	1
Peach	1	Pinot-like/Ribena	1
Defined fruit	1	Liquorice	1
Smoothness	1	*Brettanomyces*	1
Ripe fruit	1	Oak char	1
Oak/vanilla	1	Green capsicum	1
Nectarine	1	Red currants	1
Alcohol/hot	1		

style memories that were recalled would presumably differ both qualitatively and quantitatively from those of experts.

Experiment 2 replicated the prior experiment with a group of social drinkers. It was hypothesised that wine novices, with less top-down information to contribute to a judgement than wine experts, would be guided primarily by data-driven processing. It would therefore follow that they would be less likely than experts to be influenced by the visual cue of colour such that novices would be less likely than experts to 'perceive' characters that are not actually present in the wine sample.

Materials and Methods

Participants

Twenty-three wine novices took part in the study, 10 males and 13 females. Wine novices were defined as those individuals who drank wine at least once per month but had no formal training in wine evaluation or winemaking. Participants were recruited from environments where they could reasonably be considered to be of a similar socio-demographic background to that of the experts in the prior study. Participants were recruited primarily from institutions where their major occupation could be defined as scientist and/or technician, but not in a wine-related field. The participant pool comprised wine novices from four geographical regions of New Zealand. The age range was 26–56 years ($M = 39.4$). Three participants were occasional smokers. The remaining participants were non-smokers. Participants were asked about their dietary habits, all reporting them to be within the range of current standard New Zealand eating patterns (Russell *et al.*, 1999). Each person participated in the Ishihara (1990) test for colour vision. No participant was excluded as a result of failing to reach the Ishihara criterion (reading 10 of plates 1–11 correctly).

Materials

The commercial table wines used throughout the experiment, the wine samples developed from them, the clear and opaque glasses and the data collection booklets were identical to those employed in Experiment 1.

Design

The experimental design, in terms of variables controlled and manipulated, was identical to that described in Experiment 1. Of the 23 participants, five experienced the order effects via condition B, while six participants experienced each of conditions A, C and D.

Procedure

The procedure was identical in all major respects to that employed in Experiment 1. Participants took part in the study at pre-arranged locations in each geographical region where the testing venue was established to simulate a sensory evaluation laboratory (ASTM, 1986). The nature of the participants' relative inexperience with respect to wine aroma evaluation, however, introduced several necessary adjustments to the procedure.

It was apparent to the experimenter from the outset that novice participants found the task much more difficult than had those people defined as experts. The first adjustment in procedure to result from this involved some leniency with the temporal parameters. During phase I of the procedure, where each participant provided two aroma descriptors to each of the white and red wines, a small number of participants required more than the allocated 2 min. An extension of this temporal parameter was permitted to ensure that participants were able to provide two descriptors to a wine that they felt would assist them to subsequently identify that wine. In no case did a participant require more than 3 min to complete the task. Similarly, in phase II of the task, occasionally a participant exceeded the 60s interval allocated for rating a wine sample. This was permitted, given that it appeared the preferred option to the reporting of

missing data, with the proviso that 90 s was not exceeded. The interval of 30 s between wine presentations remained as per Experiment 1's procedure.

During the final part of phase I of the procedure, where participants chatted about their wine-relevant history, the present novice participants were invited to talk about their wine-relevant histories in terms of their enjoyment and experience of wine (e.g. what styles of wine they preferred, how often they drank wine).

Results and Discussion

The 64 ratings ($2 \times 4 \times 4 \times 2$) provided by each of the 23 participants on the VAS 100 mm scales were tabulated and replications were averaged to give 32 data points per participant. The variables comprising the 32 scores were two levels of glass (clear, opaque), four descriptors (two white, two red) and four wine samples (W (control), WG, WR, R). Ratings to the two white descriptors and the two red descriptors were collapsed within colour to give a mean rating for white descriptors and a mean rating for red descriptors to each wine sample.

The first analysis involved a $2 \times 2 \times 2 \times 4$ mixed model ANOVA. Independent variables were order (two levels: clear glasses first, opaque glasses first), wine glass colour (two levels: clear, opaque), wine descriptor (two levels: white, red) and wine sample (four levels: W, WG, WR, R). Order was a between-group variable and the other factors were within-subject variables. The dependent variable was the number between zero and 100 that was given by participants to each of the 64 VASs.

The analysis showed a main effect of wine sample $F(3, 63) = 8.79$, $p = 0.00006$, demonstrating that participants discriminated among the four wine samples. There was no main effect for the variables order, $F(1, 21) = 0.34$, $p = 0.57$, glass colour, $F(1, 21) = 0.0001$, $p = 0.99$, or descriptor, $F(1, 21) = 0.65$, $p = 0.43$.

There was a significant interaction between descriptor and wine sample, $F(3, 63) = 26.03$, $p = 0.0000$, showing that for the white wine, higher ratings were given to white descriptors than to red wine descriptors, while red wine descriptors were rated more highly when the sample of wine being rated was red rather than white (Figure 3). This demonstrates that the social drinkers were able to discriminate the red and white wines and to allocate their self-selected descriptors reasonably well. There was no triple interaction between descriptor, wine sample and glass colour as in the prior study involving wine experts.

It is interesting to note that participants in the present study were more limited in their use of the entire VAS scale than the experts in the prior study. Specifically, their mean ratings spanned a narrower range of scores (25–50 for white descriptors, 15–55 for red descriptors) than those provided by wine experts in Experiment 1.

The interaction between order and descriptor, $F(1, 21) = 5.63$, $p = 0.03$, can be seen in Figure 3 as higher aroma ratings to the white descriptors when clear-glass wine samples preceded those presented in opaque glasses than when the reverse order occurred. This interaction could be interpreted in terms of confidence. A not unreasonable interpretation is that wine novices, on being presented opaque glasses at the beginning of their experimental session, displayed cautious or reserved judgements across the entire task, due to the novel situation. Anecdotal evidence provided information to the effect that opaque (black) glassware was not something they were either used to or expecting and that they found the aroma judgement task extremely difficult. This effect, however, is small, and the data were collapsed over order in subsequent analyses. Further, the relatively limited use of the entire range of scores on the VAS by the social drinker participants could presumably also reflect a lower confidence in their judgements

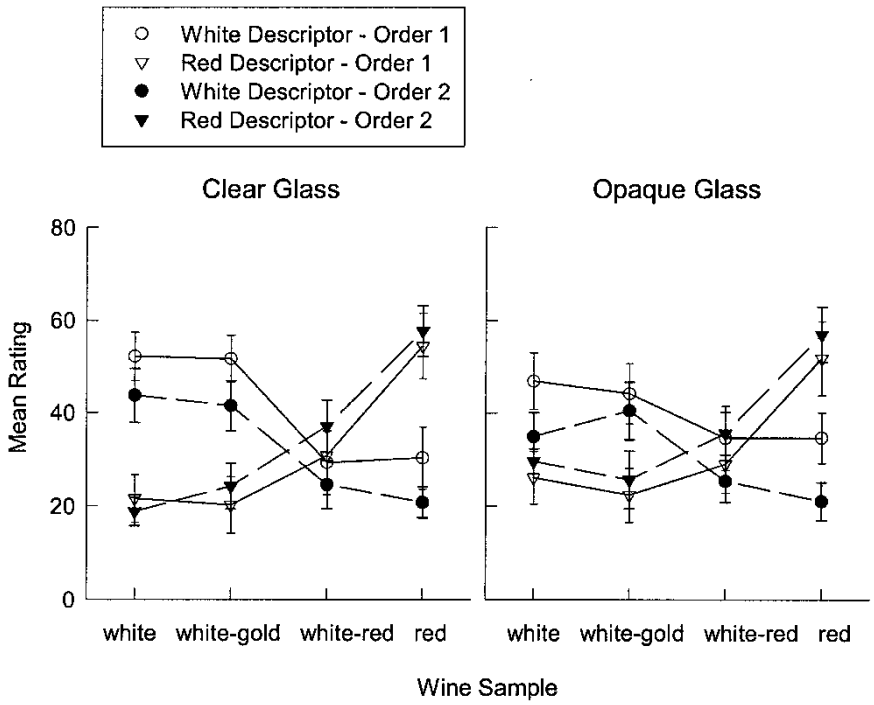

Figure 3. Mean VAS ratings as a function of descriptor, glass colour and order.

than those of the experts in the prior study, where scores of zero or 100 were not uncommon.

A threeway, repeated-measures ANOVA, where the data were collapsed over order, showed a main effect of wine sample, $F(3, 66) = 8.90$, $p = 0.0000$, and an interaction between descriptor and wine sample, $F(3, 66) = 27.35$, $p = 0.0000$. The three-way interaction among these variables and glass colour failed to reach significance in the data involving wine novices (cf. prior experiment). These data are displayed in Figure 4.

As in the previous experiment, the data were submitted to a separate, repeated-measures ANOVA on a subset of the data involving ratings to WR wine only. The ANOVA results failed to show a main effect of either descriptor, $F(1, 22) = 0.86$, $p = 0.36$, or glass colour, $F(1, 22) = 0.09$, $p = 0.77$, and no interaction between the variables, $F(1, 22) = 0.76$, $p = 0.39$. This demonstrates that wine novices' aroma judgements failed to show colour-induced olfactory bias resulting from masking a white wine with red grape anthocyanin.

One interpretation of these data is that wine novices' performance may be considered to reflect a weighting toward data-driven, or bottom-up, cognitive processes, rather than an influence from top-down processing such as expectations about the aroma of a red wine. A close inspection of Figure 4, however, suggests that wine novices were affected by the WR wine and that it did influence their overall judging behaviour. Relative to rating scores given to the other three wine samples, aroma judgements to the WR wine demonstrate indiscriminate use of descriptors, with mean ratings involving white descriptors being within 10 mm of mean ratings involving red descriptors. This observation is followed up below with a *post hoc* analysis involving data from the two experiments.

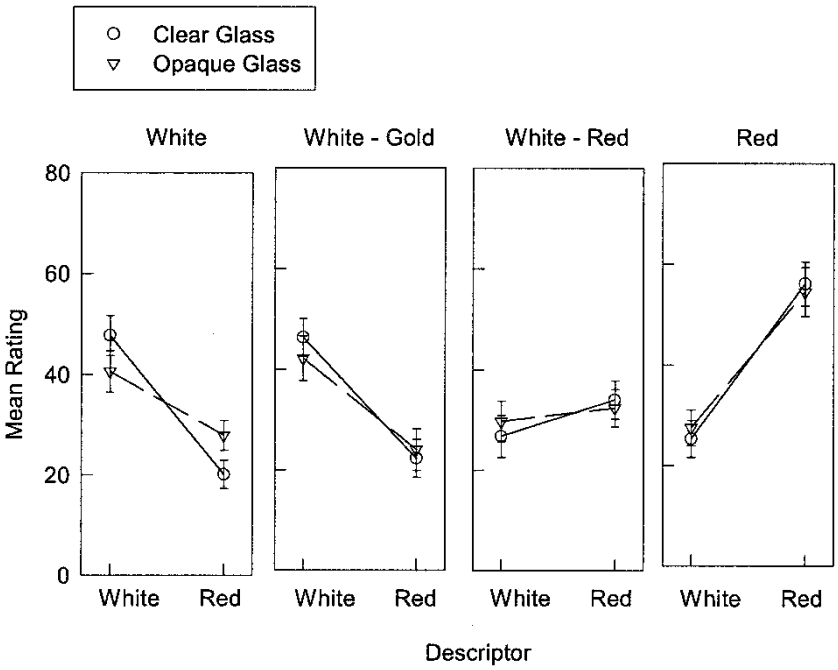

Figure 4. Mean VAS ratings as function of descriptor, wine sample and glass colour.

Wine Descriptors

The two descriptors provided by each participant to the Chardonnay and Pinot Noir wines were collated and are reported in Table 5. As occurred across the wine experts in the previous experiment, the 23 participants produced a large number of different descriptors. It was apparent to the experimenter who conducted both experiments that the social drinkers typically found it a much more difficult task than the wine experts to provide two descriptors that reflected the most salient aspects of the aroma of each wine.

Post hoc Analysis: Comparison of Data from Experiments 1 and 2

Observation of the respective data sets from the two experiments suggests that some useful information may be gathered by submitting the data to a combined analysis. The data from Experiment 2 suggest that failure to demonstrate colour-induced olfactory bias in wine novices may not have its source in data-driven judging. Rather, the result may have its source, at least in part, from the highly variable and non-discriminating behaviour of the wine novices that in turn has its locus in the inherent difficulty of the task for this group of participants.

A $2 \times 2 \times 2 \times 4$ mixed-model ANOVA was conducted on the combined data from Experiments 1 and 2. The data were collapsed over glass order (clear first, opaque first), as the effects of this variable were minimal in previous analyses. There were two levels of expertise (expert, novice), two levels of glass (clear, opaque), two levels of descriptor (white, red) and four wine samples (W, WG, WR, R).

There was no main effect of expertise, $F(1, 50) = 0.09$, $p > 0.05$, but this is qualified below in the light of interactions with other variables. Glass colour failed to reach

Table 5. Descriptors provided by the 23 novice participants to the white (Chardonnay) and red (Pinot Noir) wines; two descriptors were provided per participant to each wine

Chardonnay		Pinot Noir	
Descriptor	Frequency	Descriptor	Frequency
Grass	1	Earthy	3
Woody	2	Plums, plummy	2
Citrus/citrusy	2	Oak/oaky	5
Herbaceous	1	Musty	2
Gooseberry hedge	1	Toffee	1
Sharp/sour	1	Alcohol	1
Vanilla	2	Thin	1
Whisky/aromatic	1	Sawdusty	1
Zingy/alcohol	1	Fruity	3
Woody/musty	1	Mellow	1
Prunes	1	Blackberries	1
Peachy	1	Burnt	1
Damp/musty	1	Mouldy	1
Oak/oaky	4	Berry, berry-like	3
Buttery	1	Sweet	1
Sweet	1	Subtle	1
Fresh	2	Warm	1
Honey	1	Cherry	1
Yeasty	2	Woody	4
Yellow passionfruit	1	Mild wood	1
Crisp	2	Dry/chemical	1
Fruity	3	Blackcurrant	4
Creamy	1	Tangy	1
Aromatic	1	Elderberry	1
Lemon	1	Soft	1
Apple	2	Rich	1
Musty/chemical	1	Full	1
Flat	1	Tingly	1
Chemical/solvent	1		
Green fruit	1		
Acid	2		
Musty	1		
Clean	1		

significance, $F\ (1,\ 50) = 1.11,\ p > 0.05$, but a triple interaction of this variable with descriptor and wine sample, $F(3,\ 150) = 7.07,\ p = 0.0002$, is discussed below. There were main effects of descriptor, $F(1,\ 50) = 13.12,\ p = 0.0007$, and of wine sample, $F(1,\ 50) = 30.20,\ p = 0.0000$. These effects must be qualified in the light of their own interaction, $F(3,\ 150) = 98.20,\ p = 0.000$, and an interaction between expertise and descriptor, $F(1,\ 50) = 7.23,\ p = 0.0097$.

The interaction of major interest is that among expertise, descriptor and wine sample, $F(3,\ 150) = 8.49,\ p = 0.0000$. Figure 5 graphically demonstrates the effects of interest. First, the mean ratings demonstrate that experts were indeed more discriminating than novices in rating the wine samples. Experts' ratings of the white wine samples (W, WG, WR) with white descriptors and their ratings of the red wine (R) with red descriptors were always higher than the ratings given by novices. Conversely, ratings of

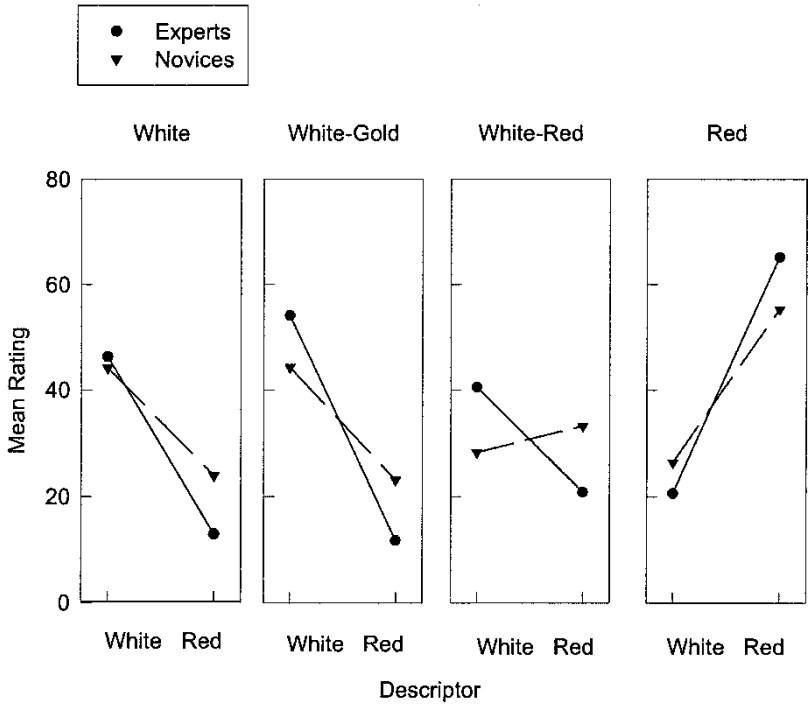

Figure 5. Mean VAS ratings for experts (Experiment 1) and novices (Experiment 2) as a function of descriptor and wine sample.

red descriptors to white wine samples and ratings of white descriptors to the red wine sample were always lower than ratings given by novice participants.

Results from the combined analysis make explicit the relation between expertise and discrimination in the wine aroma rating task employed. When the white wine was coloured red (wine WR), novices demonstrated relatively indiscriminate behaviour with their aroma ratings. The key interaction is graphically displayed in the third and fourth panels of Figure 5. While novices gave lower white descriptor ratings than red descriptor ratings to wine WR, experts gave more appropriate ratings, despite their demonstration of colour-induced bias. In other words, novices were not data-driven but were influenced by the red colouring of wine WR, demonstrating top-down cognitive influences. Novices did rate the red wine (R) correctly, but still gave higher white descriptor ratings to the red wine than the experts did (fourth panel of the figure), along with lower red descriptor ratings to the red wine.

Conclusion

The study investigated colour-induced olfactory bias in novice wine judges. We argued that social drinkers' relative inexperience with wine styles would protect them from the knowledge-driven olfactory bias demonstrated by wine experts in the prior study. In other words, we predicted that novices were less likely than experts to 'perceive' characters that were not present in the wine sample.

At face value, the data appeared to support this argument. However, *post hoc* analysis, in which the novices' data were compared with those of the wine experts described in

Experiment 1, showed that wine novices were influenced by masking a white wine with red colouring, but not in the same way as the wine experts. Novices' aroma judgements to the WR wine demonstrated indiscriminate use of descriptors, relative to rating scores given to the other three wine samples, with mean ratings to white and red descriptors being within 10 mm of each other. This could be interpreted as wine novices being influenced by the WR wine due to top-down processing, but not having sufficient knowledge or confidence to know how to deal with the ambiguity. Contrary to the competence of wine experts when judging wine aroma in opaque glasses, wine novices displayed a trend toward poorer performance without visual cues than with visual cues. This indeed suggests that contrary to our hypothesis, wine experts were more data-driven than wine novices, their judgements generally reflecting the actual volatile components available in the sample.

General Discussion

Two experiments investigated perceptual bias, a term used to reflect erroneous judgements that have their source in a person's domain-specific prior experience and knowledge. Perceptual bias is exemplified in the situation where a wine judge 'smells' or 'tastes' something that is not objectively present, presumably due to expectations which can be initiated by cues such as the label on a bottle, or by the colour of a wine.

Experiment 1 demonstrated that colour served as a visual misinformation cue, biasing wine experts' judgements. Experiment 2 demonstrated that the lesser skills of social drinkers in judging wine aroma protected them from clearly demonstrating colour-induced olfactory bias; that is, the combined effects of the difficulty of the task for novices, and the ambiguity of the stimulus (a white wine coloured red), resulted in novices resorting to indiscriminate judging. A *post hoc* analysis involving data from both experiments showed that novices, despite not demonstrating colour-induced bias at a statistically significant level, were in fact less data-driven than experts. Wine experts, on the other hand, despite demonstrating a degree of colour-induced bias, showed a high level of competency in terms of both accuracy and consistency in their aroma judgements. Experts continued to rate the wines appropriately under all conditions in that they always gave higher ratings to white descriptors than to red descriptors when rating white samples (including WR) and gave higher ratings to red descriptors than to white descriptors when rating red samples.

There are several theories concerning how a person may react when their expectations of a food or beverage are not met (Deliza and MacFie, 1996). Expectations generated via visual perception that a judge finds inconsistent with their olfactory data-driven input may result in a form of cognitive dissonance (Festinger, 1957). That is, seeing the colour 'red' and subsequently smelling characters in a wine sample that do not typically correlate with a red wine may lead to a situation where the mind or brain tries to remedy the ambiguous nature of the situation. Inherent in this theoretical analysis is a general awareness by the participant of the aroma characters or notes that would be expected to be present in a red wine and those that are more likely to be present in a white wine.

Participants in the present study were not given any information that could have alerted them to the notion that colour may not be correlated with expected aroma profiles in the wines. Psychological research has frequently demonstrated the importance of considering the information given to a participant when interpreting data. Engen (1972) commented that colour-induced olfactory bias could be reduced by alerting a participant to the idea that odour may not be correlated with visual information. In the

present experiment, to simulate real-life situations for most wine professionals, such feedback was considered not likely to contribute to ecological validity. Further, Stillman (1993), in a study involving artificially flavoured beverages, demonstrated that tasters who were alerted to the fact that colour might not be indicative of the actual flavour were still significantly influenced by colour when making flavour judgements.

The wide range of descriptors provided by the participants to the two wines may seem surprising, particularly in the group of wine experts (Experiment 1). However, it could be expected that individual differences would be exacerbated in a situation where participants were asked to provide only the two most salient aspects of the complex aroma of each wine. This is in keeping with results reported by Jinks and Laing, (2001), who reported that even expert perfumers, who use their olfactory abilities to make professional judgements, are able to identify no more than three or four components in complex odour mixtures (Livermore and Laing, 1996).

Overall Conclusion

The present studies, along with recent work by Hughson and Boakes (2002), Gawel (1997), Morrot *et al.* (2001) and Solomon (1988), are beginning to paint a picture of the nature of wine expertise. Previous research has demonstrated that conceptual knowledge, such as knowing the typical features that go together in a specific wine style, appears more structured in wine experts than in novices. Further, data reported to date suggest that such categorical structure assists wine experts to recall (Hughson and Boakes, 2002) and match (Solomon, 1988) wine descriptions. The theory drawn upon to interpret these results includes top-down cognitive processes of semantic memory and language, including a wine-appropriate vocabulary, and a conceptual system that includes prototypes of wine types or styles.

The present studies not only extend the current state of knowledge about wine expertise by moving the information-processing emphasis from conceptual and language aspects to focus on perceptual processes, but also demonstrate the relation between perceptual mechanisms and top-down processes of semantic memory and language. Wine experts, as well as having superior knowledge (Hughson and Boakes, 2002) and superior olfactory recognition memory skills (Parr *et al.*, 2002), have been shown in the present experiments to have superior blind-sniffing ability relative to their judgements of the same wines when colour was a cue.

Finally, the present data have potential application for wine industry professionals in their demonstration of the fallibility of humans as judges (Kahneman *et al.*, 1982) within the world of wine. Top-down cognitive processes can interfere with, or overshadow, perception of the phenomenological properties of a wine sample. For example, expectations that a deep-coloured white wine sample may be older than a pale sample have their source in knowledge of wine maturation. The present work has potential to help raise awareness of winemakers and wine judges concerning the systematic cognitive biases that have been demonstrated when people make probabilistic judgements across a range of fields such as medicine, economics and political decision making (Kahneman *et al.*, 1982). Wine evaluations are analogous to other diagnostic problems that are intrinsically probabilistic, such as detecting a spot on the lung via radiography (Parr, 2002). The present work clearly demonstrates that such probabilistic judgement errors can occur in wine-evaluation situations. Perceptual bias is of major significance in that misidentification of odorants in wine samples could result in a wine being inappropriately categorised in a formal judging. Further, perceptual bias is particularly dangerous in that

it is apparently accompanied by marked confidence that the erroneous judgement is in fact correct (e.g. Cain and Potts, 1996).

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Note

1. The concept of 'information' refers to a stimulated receptor *informing* the organism, via encoding processes, about characteristics of a wine sample (Norwich, 1991).

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