Chem. Senses 27: 747–755, 2002

Demystifying Wine Expertise: Olfactory Threshold, Perceptual Skill and Semantic Memory in Expert and Novice Wine Judges

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Abstract

We investigated recognition and identification of wine-relevant odours as a function of domain-specific expertise. Eleven wine experts and 11 wine novices participated in tasks measuring olfactory threshold, odour recognition, odour identification, and consistency of odour naming. Twenty-four wine-relevant odorants were sampled orthonasally by each participant in the semantic (identification; consistency of naming) and episodic (recognition) memory tasks. Results showed superior olfactory recognition by expert wine judges, despite their olfactory sensitivity and bias measures being similar to those of novices. Contrary to predictions based on reports of an association between odour memory and semantic processing, wine experts did not perform better than novices on the verbal memory tasks. Further, ability to recognize odours and ability to name odours were not positively correlated, although the novices' data showed a trend in this direction. The results imply that the source of superior odour recognition in wine experts was not enhanced semantic memory and linguistic capabilities for wine-relevant odours. One interpretation of the data is that wine experts were less susceptible than wine novices to verbal overshadowing. When forced to identify the odorants, experts' superior perceptual skills protected them from verbal interference, whereas novices' generated verbal representations of the odours were emphasized at the expense of the odorant itself. This has implications for training in wine-evaluation skills.

Introduction

What underlies a wine lover's ability to identify a favourite vintage with their nose? Olfaction is clearly an important process when evaluating complex mixtures such as wine where much flavour is aroma (Thorngate, 1997). The orthonasally experienced, volatile component of a wine is typically perceived prior to tasting and can play a key role in affecting the judgement of quality that the wine receives. The nose provides considerable information about the type, such as cultivar or physical aspects of terroir, the wine's age, condition and overall quality. The judge may not be consciously aware of the contributions of the nose because there is no easy parallel to the shutting of eyes to exclude visual input. In some evaluative contexts, however, such as winemaking, olfaction alone may be employed as a quality control tool. For example, the nose may be relied upon for early detection of wine faults such as excess acetic acid or hydrogen sulphide. The recognition and identification of relevant odours is therefore important to fault detection and exemplifies the role of cognitive processes in wine evaluation.

Despite their obvious importance, there has been little systematic investigation of the cognitive components of olfaction in relation to wine expertise (Parr, 2000). The last decade has seen increased interest however (Morrot and Brochet, 1999), notably concerning associations between colour and odour (Morrot *et al*., 2001). The present study investigated olfactory sensitivity, odour recognition, odour identification and consistency of odour labelling in expert and novice wine judges. The questions we asked were: Are wine experts more accurate than novices at recognizing and identifying wine-relevant smells? Is the greater ability of wine experts to recognize and identify odours a result of their enhanced sensitivity or their semantic knowledge?

Fundamental psychological research on olfaction and cognition suggests that olfaction is a particularly important sense to understand in relation to wine evaluation, not least because humans are considered to have relatively impoverished language for describing odours (Engen, 1982). Odours frequently evoke idiosyncratic, autobiographical memories which are often learned in childhood (Chu and Downes, 2000), are often associated with emotion (Herz, 1997; Epple and Herz, 1999), and can be resistant to unlearning or relearning (Lawless and Engen, 1977), including in expert perfumers (Ishii *et al*., 1997).

The major theoretical basis for the present study concerns the relation between odour memory and language. Relatively poor performance by human adults when recognizing and labelling everyday odours has frequently been reported (Cain and Potts, 1996) and typically interpreted as having its source in poor semantic memory (Rabin and Cain, 1984; Lehrner *et al.*, 1999). Lehrner *et al.*, for example, investigated memory for everyday odours across several age ranges. For adults, they reported positive correlations between odour identification and odour recognition ($r = +0.69$), and between naming consistency and odour recognition ($r = +0.54$). The notion that linguistic limitations underlie poor odour recognition and identification has been adopted by many wine professionals and incorporated into their learning and teaching programmes. It is common practice when learning to assess wines that students are encouraged to engage in a matching process whereby perceived smells and tastes are matched to a linguistic tool such as the Wine Aroma Wheel (Noble *et al.*, 1984).

There is no direct evidence, however, that wine judges' semantic (verbal) memories are the source of their ability to recognize wine components such as a fault. To the contrary, emphasis on the linguistic component of olfactory cognition may come at a price, especially when emphasized early in a wine professional's development. In keeping with this notion, oenologist Emile Peynaud is reported to have said that fluency is often a screen for inaccuracy (Brochet, 1999). Olfactory perceptual ability (smelling) and language (naming an odour) may be associated, not in a facilitative way, but in an inhibitory way (Melcher and Schooler, 1996; Lorig, 1999). More specifically, verbal and perceptual processes related to olfaction may interfere with one another, the degree of interference being mediated by expertise in the particular domain such as wine. Melcher and Schooler investigated memory for wine tastes as a function of expertise. They concluded that verbalization, rather than enhancing learning of complex stimuli, may have an insidious, disruptive effect that they term 'verbal overshadowing'. Further, their data demonstrated the disruption to be a function of expertise of participants.

In the present study, we investigated olfactory-guided judgements in expert and novice wine judges within a detection theory framework. Evaluations such as detecting an off-note in wine are analogous to other diagnostic problems that are intrinsically probabilistic. A fundamental characteristic of such tasks is that many variables contribute to the 'evidence' for a decision. Detection theory permits the ability to detect and recognize a smell to be measured independently from motivational factors that can influence the judging and deciding aspects of the task (MacMillan and Creelman, 1991). The present study aimed to simulate odour-discrimination tasks that occur within the typical wine-evaluation situation. Odour identification was employed as a measure of explicit, semantic memory, while odour recognition was used as a measure of explicit, episodic memory (Elsner, 2001). Semantic memory is assumed based on a person's general knowledge and experience with an odorant (Savic and Berglund, 2000). In contrast, episodic memory is not necessarily based on a verbal representation but has its basis in perceptual and possibly imaging processes (Lehrner, 1993; Herz, 2000).

In order to provide a basis for assessing accuracy in judgements of the bouquet of a wine, the stimuli employed in the present study comprised compounds typically found in wine (Lenoir, 1995; Bende and Nordin, 1997). The compounds were selected on the following basis. They were compounds that had perceived odour notes with well-established veridical names in prior published literature [e.g. the *Atlas of Odor Character Profiles* (ASTM, 1985)] and/or were included in the tool-kit of chemical compounds known as *Le nez du vin* (Lenoir, 1995) that is available for learning about wine aroma. The odorants spanned the categories of wine faults such as excess acetic acid, primary characters (those pertaining to the grape such as floral and fruity notes), secondary characters (those pertaining to fermentation and winemaking procedures), and maturation characters such as mushroom or leather.

Superior performance of expert participants was expected on the tasks involving odour naming, odour recognition, and consistent use of an odour name (Lehrner *et al.*, 1999). Such expertise was not expected in a group of novice participants. We expected, however, that experts and non-experts would not differ on ability to detect 1-butanol (Bende and Nordin, 1997; Morrot, 1999).

Materials and methods

Subjects

Twenty-two adults, 11 experts and 11 novices, classified on the basis of their experience with wines, participated in the study. The groups were matched for age, gender, dietary and smoking status. Exact matching proved difficult. There were five female novices, six male novices, four female experts, and seven male experts. Age range was 25–55 years for novices and 25–58 years for experts. There was no significant difference between the groups in terms of age. Each group contained one participant who was an occasional smoker. The remaining participants were non-smokers. Experts were defined in accordance with several previous studies (Melcher and Schooler, 1996; Bende and Nordin, 1997). 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 wine-making and/or wine evaluation;
- wine professionals (e.g. Master of Wine, wine judges, wine writers, 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).

Novices in the present study were defined as those persons who drank wine regularly but had participated in little formal wine evaluation or winemaking at the time of the study. The novice group included wine and food students who were outside the criteria for inclusion in the expert group. Relative to most studies in the sensory literature where novices and experts have been compared (Chollet and Valentin, 2000), the present group of novices could be defined as 'intermediates' rather than as novices (Melcher and Schooler, 1996). For example, the study by Chollet and Valentin compared senior wine students as experts, and senior students in other faculties as novices, when they investigated individual differences in people evaluating Burgundian red wines. The aim of comparing experts to intermediates rather than to complete novices was to provide a relatively stringent test of the issue of whether the assumed greater semantic knowledge of experts influenced their olfactory discrimination.

Materials

The stimuli employed in the olfactory-detection threshold task were prepared as described by Lehrner *et al.* (Lehrner *et al.*, 1999). Beginning with a 4% solution of 1-butanol in distilled water, serial dilution progressed in 10 steps of successive thirds (dilution factor 3). The 11 concentrations, ranging from 4% (dilution step 0) to 0.00007% (weakest concentration; dilution step 10), were stored in glass bottles with tightly fitting, plastic screw lids. Each contained ~7 ml of fluid. Four identical bottles, each containing distilled water, were also prepared.

The 28 stimuli used as odorants were chemical compounds. Due to the difficulty in assessing what it means to be 'right' when describing the bouquet of a wine, the odorants used were compounds typically found in wine (Lenoir, 1995; Bende and Nordin, 1997), rather than actual wines. They were selected to provide perceived odour notes from the categories of wine faults, primary characters, secondary characters, and aged characters (see Table 1 for a complete list). The concentration and dilution medium selected for each odorant were based on data provided in the published literature. Prior to the experiment proper, the odorants were rated by another 11 adults (drawn from the same subject pool as the novices) on a 100 mm Visual Analogue Scale (Savic and Berglund, 2000) with respect to quality and intensity of the particular odour note. Compounds that received mean ratings on the scale >80 mm or <20 mm were not included. Odorants were contained in 10 ml, amber glass bottles with polypropylene screw lids. Odorants were kept in a refrigerator when not in use and taken out to warm up to ambient room temperature (20°C) before an experimental session began.

Procedure

Participants were tested individually. Nineteen of the 22 participants were tested in a purpose-built, sensory-evaluation laboratory that was designed according to the guidelines of the American Society for Testing and Materials (ASTM, 1986). Ambient temperature of the room was maintained at 20 ± 2°C. The remaining three participants were tested at the wineries at which they were owners or employees. For two of the three people who participated off-campus, the conditions at their winery were similar to those within the Sensory Laboratory at Lincoln University. The third participant who was tested off-campus took part in an outdoor setting that was relatively free of interference in terms of noise, visual stimulation, ambient odour, and adverse weather conditions such as wind. Each participant was given a code number, seated comfortably, and general instructions were given. Novices and experts alternated in terms of participation order. Alternating category order was employed to counterbalance any effects from changes in the headspace of chemical stimuli over time. Participants were advised that the study involved naming and remembering wine-relevant smells. The participant was then seated within a booth that included a plain white table on which the stimuli were handled.

Odour-detection threshold, odour identification and odour recognition were performed in that order, in a single session that lasted ~60 min. Specific instructions preceded each individual task. To estimate odour detection threshold, solutions of *n*-butyl alcohol in distilled water were used in a two-alternative, forced-choice procedure (Bende and Nordin, 1997; Lehrner *et al.*, 1999) involving an ascending staircase method of limits. Starting at the lowest concentration, an odorant bottle was presented to the participant in the booth, accompanied by an identical bottle that contained distilled water only. Participants were encouraged to sniff each bottle bi-rhinally. An inter-trial interval of 30 s occurred between successive trials. The distilled-water-only bottle was presented as the left or the right sample equally often. When a correct choice was made, the same concentration of odorant was presented to the participant until four consecutive correct responses were given. This concentration was taken as an estimate of the participant's detection threshold. A different bottle of distilled water was presented alongside each of the four consecutive presentations of the same concentration of odorant.

Cognitive tasks

Twenty-four odorants were selected randomly for each participant from the 28 odorants that comprised the larger sample set. Of these, 12 were selected randomly to comprise 'old' stimuli, with the remaining 12 designated as 'new' stimuli in the subsequent recognition test. Participants smelled in succession 12 odorants from the 24-item stimulus set selected for them and were asked to remember the smells. During testing, odorants other than the one being sniffed

Table 1 Details of odorants employed as materials

Veridical name(s)	Chemical name	Dilution	Source
Rancid/manure/rotting	butyric acid	10% v/v in 12% ethanol	LU Stores
Earthy/musty/mouldy	2-ethyl fenchol	neat[a]	Bedoukian 818
Cinnamon	cinnamaldehyde 97%	neat	Ajax Chemicals D3247
Pine/woody/resinous	α-pinene	neat	Aldrich P4570-2
Aniseed/liquorice	anethole	neat	BDH Chemicals
Coconut	γ-nonalactone	neat	Bedoukian 452
Fatty/oily	2,4-nonadien-1-al	neat	Bedoukian 363
Pineapple-like	Ethyl 3(2-furyl) propanoate	10% v/v in 12% ethanol	Bedoukian 852
Banana-like	amyl acetate 95%	400 p.p.m. in 12% ethanol in pilot study; 200 p.p.m. in expt 1	BDH Chemicals 27211
Buttery/malolactic	diacetyl	10% v/v in 12% ethanol	Sigma D3634
Caramel/maple	5-ethyl-4-methyl-3-hydroxy furanone	10% v/v in 12% ethanol	Bedoukian 875
Pear (Bartlett)	ethyl 2,4-decadienoate	10% v/v in 12% ethanol	Bedoukian 433
Cloves	oil of clove	10% v/v in 12% ethanol in pilot study; 5% v/v in expt 1	BDH Chemicals 36063
Ripe or rotting fruit/apple	ethanal 99.5%	100 p.p.m. in distilled water in pilot study; 400 p.p.m. in expt 1	BDH Chemicals 270034L
Coriander wood/citrus/Muscat	linalool 95–97%	10% v/v in 12% ethanol	Sigma L-5255
Floral/rose/sweet	rose oxide	neat	Bedoukian 480
Green/herbal/leafy/vegetal/apple	*trans*-2-hexenal	200 p.p.m. in 12% ethanol	Bedoukian 350
Mint/peppermint	*R*-carvone	neat	Sigma
Nutty/sweet	3-acetyl-2,5-dimethyl furan	10% v/v in 12% ethanol	Bedoukian 858
Mushroom	1-octen-3-ol	neat	Sigma
Smoky/leather/tobacco	ethyl-3-hydroxy hexanoate	neat	Bedoukian 434
Grape-like/foxy	ethyl anthranilate	neat	Bedoukian 552
Soapy/sour	capric acid	0.13 g in 12% ethanol	Bedoukian 882
Herbaceous/tobacco	γ-hexalactone	neat	Bedoukian 449
Citrus/floral	nerol BRI	neat	Bedoukian 449
Vanilla/oak	ethylvanillin prop. glycol acetate	neat	Bedoukian 831
Vinegar/sour/acetic	acetic acid 100%	5% v/v in distilled water	LU Stores
Melon	*cis*-5-octen-1-ol	neat	Bedoukian 168
Honey/rose[b]	phenylethyl 2-furoate	neat	Bedoukian 869
Woody/green-floral[b]	nerolidol	neat	Bedoukian 712

[a] Neat refers to 0.5 ml solution in the 10 ml glass bottle.

[b] Refers to odorants used in the pilot study but excluded from the subsequent stimulus set.

were kept tightly sealed and an extraction fan minimized diffusion of odours into the testing room. A stimulus presentation rate of 45 s was employed, during which time a participant sniffed the compound *ad libitum* and attempted to name the odour as specifically as possible. Participants were reminded of the wine context. An inter-trial interval of 30 s followed. Following presentation of the 12 stimuli designated as 'old', a retention interval of 10 min occurred. During the interval, the participant was invited to chat about their wine-relevant experience. Twenty-four odorants were then presented in random order. They comprised the 12 previously presented odorants (old) and 12 new. Participants judged whether each odorant was old or new, gave a confidence rating for the recognition judgement, named the odorant as specifically as possible, and finally, gave a confidence rating to reflect their certainty that the name provided was the veridical name. The confidence rating scale comprised a horizontal line scale, numbered 1–5, with the words 'extremely confident' positioned below the 5, and 'not at all confident' below the 1.

Quantitative analyses

The score obtained for each participant's odour-detection threshold comprised the dilution number corresponding to the 1-butanol concentration correctly chosen over distilled water in four consecutive trials. A high number represents a low threshold.

Olfactory recognition

Based on the theory of signal detection (TSD), hit rates, false-alarm rates, and measures of discriminability and bias were calculated (MacMillan and Creelman, 1991). A 'hit' was defined as a 'yes' response to an old (previously presented) odorant, and a false alarm (FA) was defined as a 'yes' to a new odorant. The signal detection approach treats the odour recognition task in the same way as a memory recognition task, where new and old items vary along a psychological dimension of memory strength or familiarity. The groups of new and old items are represented by normal probability distributions on the familiarity dimension. A yes/no response in the recognition task is based on the assumption that the judge establishes a criterion, *C*, on the psychological dimension. If the familiarity of an odour is greater than the criterion, the judge responds 'yes', and if it is weaker than *C*, the judge responds 'no'. Discriminability is the distance between the means of the probability distributions for new and old odours. The measure of discriminability calculated was the recognition index *d′* and the measure of bias was the criterion measure, *C*. Discriminability, *d′*, is calculated from hit rates and false-alarm rates (see below). As a measure of the ability to recognize odours, it has two main advantages. First, it is not confounded with response bias (a tendency to say 'yes'), which can be measured separately in terms of the location of the criterion, *C*, on the familiarity dimension. Note that with higher values of *C* there is a tendency to say 'yes', and that *C* can vary independently of the distance, *d′*, between the probability distributions for new and old odours. Second, *d′* varies on an equal-interval scale and is not bounded in the same way as is the traditional measure of accuracy, percent correct.

$$d' = z_{\mathrm{FA}} - z_{\mathrm{hit}} \tag{1}$$

$$C = 0.5(z_{\mathrm{FA}} + z_{\mathrm{hit}}) \tag{2}$$

A correction procedure was implemented as measures of *d′* (equation 1) and bias (equation 2) are undefined for hit rates of 1.0 and false-alarm rates of zero (Snodgrass and Corwin, 1988). This involved adding 0.5 to each frequency of hits and false alarms and dividing by $N + 1$, where N is the number of old or new stimuli.

In the context of TSD, confidence judgements in the recognition task can be interpreted as the person making graded responses that reflect their degree of experience with each odorant. In detection theory, this is analogous to employing multiple criteria within a single task or situation so that the levels of confidence correspond to movements in the bias parameter (*C*) (Lawless and Heymann, 1998). Memory operating characteristic (MOC) curves for the probability of calling a previously presented odorant 'old' versus the probability of calling a previously presented odorant 'new' were constructed for the groups (Cain and Potts, 1996) by working out a mean hit and false-alarm rate for each confidence interval. The smooth curves in Figure 2 were fitted to the data points using nonlinear regression. Their equation is based on the distributions of stimulus effect assumed by TSD, with parameters for detectability, *d′*, and the ratio of the variance of the two distributions.

Semantic memory

The name(s) given for each odorant was scored for correctness (Cain, 1979; Lehrner *et al.*, 1999), and for consistency of usage. For correctness, veridical labels were scored 2 (e.g. 'pear' for pear), a near miss (e.g. 'cloves' for cinnamon) was given a score of 1, and a far miss (e.g. 'citrus' for a buttery note) was scored zero, giving a maximum of 48 points for correct identification for each participant. Consistency of naming was scored as 1 when an odorant was named with the same label at initial presentation and at recognition testing. A score of zero was given when a different label was used across the two situations (e.g. 'spicy' at presentation and 'marzipan' at testing). Proportions correct were derived for each participant from their correctness of naming score and from their consistency of naming score.

The relationships between olfactory performances were assessed using Pearson's correlations. They were performed on the individual data observed for each task.

Results and discussion

Sensitivity to 1-butanol

Estimates of the participants' detection thresholds for *n*-butyl alcohol concentrations ranged between 0.00007% (dilution step 10) and 0.016% (dilution step 5) in both groups. Consistent with previous results (Bende and Nordin, 1997), detection thresholds did not differ between groups, $t(20) = 0.31$, $P = 0.76$ (experts: mean = 8.18, SD = 1.40; novices: mean = 8.36, SD = 1.36). The means are in keeping with the reported range for olfactory threshold of 1-butanol as 2–5 p.p.m. (Moskowitz *et al.*, 1974) as dilution step 8 represents a concentration of 0.0002%. Correlation coefficients were calculated between threshold scores and the cognitive tasks. There were significant inverse correlations between estimates of experts' thresholds and odour recognition ($r = -0.82$, $P < 0.05$), and between estimates of novices' thresholds and odour identification ($r = -0.60$, $P < 0.05$). That is, for experts, higher thresholds for *n*-butyl alcohol detection (lower dilution steps) were positively associated with accuracy of odour recognition, supporting the notion that superior sensitivity in experts was not the source of any enhanced olfactory memory performance. For novices, the higher the estimated threshold for *n*-butyl alcohol detection, the greater their accuracy for identification. These associations are not easy to interpret. However, Lehrner *et al.* (Lehrner *et al.*, 1999) also reported significant negative associations between olfactory threshold and both odour memory and odour identification in their adult sample.

Olfactory recognition and semantic memory

There was a significant difference in odour recognition, as measured by the discriminability index *d′*, as a function of wine-relevant expertise, $t(20) = 2.13$, $P < 0.05$. Experts showed superior recognition of olfactory stimuli (mean = 2.26, SD = 0.49) when compared with novices (mean = 1.63, SD = 0.85). Figure 1 and Table 2 show detection thresholds and recognition results. Not only was episodic memory enhanced in experts as shown by their enhanced recognition ability, but experts also demonstrated less within-group variability as reflected in the standard deviation measures. There was no difference between groups in the bias measure,

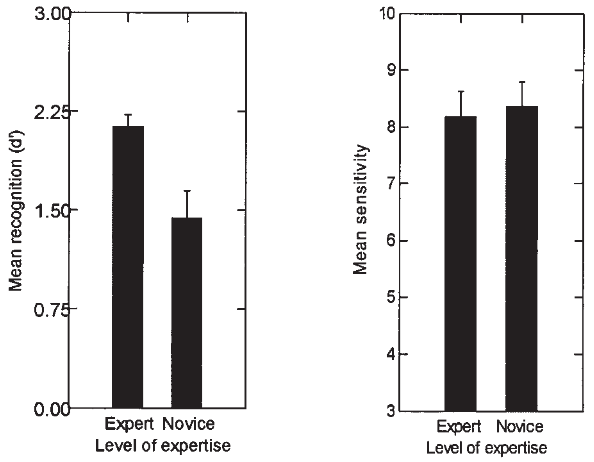

Figure 1 Mean sensitivity to 1-butanol (in dilution steps, where a higher number represents a lower threshold) and mean recognition (*d′*) as a function of expertise.

Table 2 Summary of olfactory performance as a function of expertise. Identification of odorants and consistency of naming are reported as proportions correct. Sensitivity to 1-butanol is reported in dilution steps, where a higher number represents a lower threshold

Olfactory performance	Wine experts		Wine novices	
	Mean	SD	Mean	SD
Odour memory (*d′*)	2.26	0.49	1.63	0.85[a]
Hit rate	0.86	0.10	0.77	0.17[a]
False-alarm rate	0.17	0.10	0.24	0.10[a]
Response criterion (*C*)	0.08	0.42	0.05	0.35
Identification of odorants	0.51	0.12	0.45	0.10
Consistency of naming	0.55	0.14	0.53	0.22
Sensitivity to 1-butanol (threshold)	8.18	1.40	8.36	1.36

[a] Denotes a significant difference between groups ($P < 0.05$).

$t(20) = 0.184$, $P > 0.05$. Therefore the difference between the groups reflected a true difference in recognition ability and not a difference in tendency to report having experienced the odorant before.

A two-way ANOVA on the hit rate versus false-alarm rate data for experts versus novices produced a significant interaction between these two variables, $F(1,20) = 6.10$, $P < 0.05$. Table 2 shows the 'mirror effect' where experts' hit rates were overall higher and their false-alarm rates were overall lower compared to those of novices. This result is similar to that found in both human and non-human memory studies where increasing the difficulty of a discrimination task results in an increased false-alarm rate (Wixted, 1992). It is also consistent with the conclusion that novices found the task overall more difficult than experts. The symmetrical change in hit and false-alarm rates is consistent with no difference in response bias (at least as defined by the measure, *C*), $F(1,20) = 0.034$. The greater difficulty in discrimination for novices was reflected in a lower d' than for experts, $F(1,20) = 4.55$, $P < 0.05$.

Memory operating characteristic (MOC) curves for the recognition data as a function of expertise are shown in Figure 2. The values of the d' parameter for the fitted functions were 3.35 and 2.55, respectively, for the experts and novices. The values of r were 1.0 in both cases, showing that the variances of the distributions for old and new odorants were equal and symmetrical.

Table 2 reports proportions correct for the semantic memory tasks, namely identification and consistency of labelling an odorant, as a function of expertise. Each group's mean identification performance was similar to, or slightly better than, that reported in the literature concerning humans' identification of everyday odorants (Cain and Potts, 1996). However, contrary to experimental hypotheses, there was no evidence of superior olfactory identification by experts, $t(20) = 1.31$, $P > 0.05$ (expert mean = 0.51, SD = 0.12; novice mean = 0.45, SD = 0.10). Nor was there an effect of expertise on consistency of labelling the wine-relevant odorants, $t(20) = 0.30$, $P > 0.05$ (expert mean = 0.55, SD = 0.14; novice mean = 0.53, SD = 0.22). To investigate the relationship between measures of semantic memory (identification and naming consistency) and episodic memory (recognition), Pearson's correlations were performed. The results are reported in Table 3.

The correlation coefficients show no significant relation between odour recognition and odour identification or between odour recognition and consistency of naming for either experts or novices. However, there is a trend in these directions for novices that may have reached significance were a larger sample size employed in the study. There is no such trend for odour recognition and identification in the expert data. There is also a trend toward a positive association between odour recognition and consistency of naming for experts. This suggests that, for experts, consistent use of a name is more important than its 'objective' or veridical name in advantaging odour recognition. Lehrner *et al.* reported a similar result (Lehrner *et al.*, 1999).

Olfactory performance by odorant

Descriptive statistics were gathered on the odorants used in the experiment. Each odorant could be employed a maximum of 22 times (i.e. once per subject) as the 24 odorants used for any particular subject were selected at random from the larger stimulus set of 28 odorants. Presentation frequencies over the duration of the study ranged from 9 (cloves) to 19 (vinegar; pine), with a median of 15.5. Table 4 shows mean recognition accuracy and mean identification score as a function of odorant. Proportions correct for recognition ranged from 1.0 for anise and nutty/sweet to 0.63 for green/vegetal. Proportions correct for identification ranged from 0.63 for caramel to 0.23 for cloves. When odorants were sorted to provide an order of recognizability and an order of identifiability, there was no particularly salient outlier in either list. No relation was found between an odorant's recognizability and its identifiability, Pearson's $r = -0.08$. For example, vanilla was recognized with 95% accuracy but identified less frequently than the mean identifiability score.

The major finding of the present study is the demonstration of superior explicit recognition by wine experts for wine-relevant odorants. This superiority did not have its source in bias (criterion), sensitivity (detection threshold), or semantic memory as measured by odour identification and naming consistency. This implies that the locus of superior recognition of wine-relevant odours in the present study appears to be perceptual, or sensory-based memory (e.g. olfactory imaging).

There are several differences between the present study and most published research concerning odour recognition and identification (Lehrner *et al.*, 1999). First, the present study involved a contextualized situation where domain-specific olfactory expertise was investigated, rather than olfactory expertise in general. Second, the present study's sample size was relatively small. The aim of employing a small N was to demonstrate any effects that were sufficiently robust to be detectable with small groups of participants. This resulted in the performance of participants on odour recognition and identification tasks being dissociated by the variable of wine expertise.

Finally, the present study involved experts and novices who presumably differed more with respect to experientially gained knowledge than semantic knowledge (e.g. wine theory). The present novices were intermediates in relation to wine education and it is conceivable that perceptual skill opportunities separated the novices from experts more than linguistic skills or semantic knowledge. The specific style of wine-evaluation experience encountered by many in the

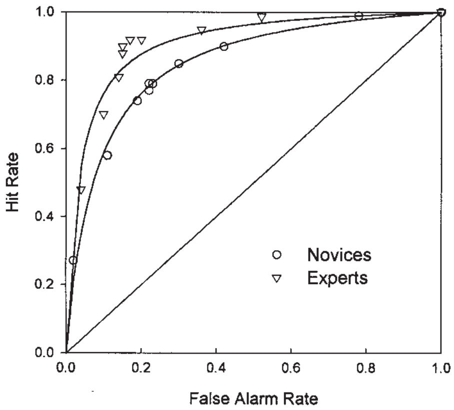

Figure 2 Group memory operating characteristic (MOC) curves for wine experts and novices for the probability of calling an old odour 'old' (hit rate) versus probability of calling an old odour 'new' (false-alarm rate) for each confidence interval.

Table 3 Correlations of olfactory threshold, odour recognition, odour naming and consistency of odour naming in expert and novice wine judges

Variables	1	2	3	4	5	6
(A) Whole sample (n = 22)						
1 Threshold						
2 Odour recognition	–0.40					
3 Hit rate	–0.23	+0.78[a]				
4 False-alarm rate	+0.16	–0.57[a]	+0.01			
5 Odour identification	–0.40	+0.30	+0.16	–0.35		
6 Consistency of naming	–0.31	+0.32	+0.56[a]	+0.13	+0.28	
(B) Experts (n = 11)						
1 Threshold						
2 Odour recognition	–0.82[a]					
3 Hit rate	–0.24	+0.41				
4 False-alarm rate	+0.42	–0.44	+0.59[a]			
5 Odour identification	–0.24	–0.09	+0.36	–0.49		
6 Consistency of naming	–0.41	+0.30	–0.54	–0.01	+0.17	
(C) Novices (n = 11)						
1 Threshold						
2 Odour recognition	–0.21					
3 Hit rate	–0.23	+0.86[a]				
4 False-alarm rate	–0.15	–0.55	–0.11			
5 Odour identification	–0.60[a]	+0.43	+0.53	–0.04		
6 Consistency of naming	–0.26	+0.33	+0.65[a]	+0.27	+0.38	

[a] Denotes a significant relation between variables ($P < 0.05$).

Table 4 Mean olfactory performance as a function of compound, and as a function of the number of participants to whom each odorant was presented (max. = 22). Recognition and identification by odorant are reported as proportions correct

Odorant descriptor(s)	Recognition	Identification	Participant no.
Earthy/musty/mouldy	0.83	0.47	18
Cinnamon	0.86	0.25	14
Pine/woody/resinous	0.84	0.40	19
Anise/liquorice	1.00	0.47	18
Coconut	0.88	0.38	16
Fatty/oily	0.94	0.56	18
Melon/tropical fruit	0.65	0.35	17
Caramel/maple	0.75	0.63	16
Nutty/sweet	1.00	0.53	18
Pears	0.75	0.34	12
Pineapple-like	0.85	0.43	17
Grape-like	0.94	0.30	16
Herbaceous/tobacco	0.69	0.25	11
Vanilla/oak	0.95	0.37	18
Buttery	0.94	0.61	17
Coriander wood/citrus/muscat	0.79	0.32	15
Mushroom	0.75	0.35	15
Green/leafy/vegetal/herbal	0.63	0.55	12
Citrus/floral	0.81	0.25	13
Mint/peppermint	0.73	0.37	11
Smoky/leather/dried	0.80	0.50	12
Floral/rose	0.65	0.79	11
Cloves	0.82	0.23	9
Banana-like	0.94	0.34	15
Rancid/manure/rotting	0.65	0.65	11
Ripe/rotting fruit	0.90	0.53	17
Soapy	0.94	0.53	15
Vinegar/sour/acetic	0.95	0.50	19
	mean = 0.829	mean = 0.436	median = 15.5

novice group largely involved analytical techniques with a strong linguistic base. That is, students are encouraged to deconstruct a wine into its particular characters (e.g. odours, tastes and mouth-feel components), identifying and verbally labelling each individual character that has been detected. This approach contrasts with more synthetic wine-evaluation approaches where a wine may be considered as a whole or Gestalt. It is conceivable that evaluation of a wine as a whole, rather than deconstructing it, places greater emphasis on perceptual skill than on linguistic skill.

One possible interpretation of the present data involves Melcher and Schooler's concept of verbal overshadowing (Melcher and Schooler, 1996). Verbal overshadowing is a form of memory illusion that is assumed to occur when people are forced to name complex stimuli (i.e. those that are difficult to capture in words, such as tastes and smells), particularly when the relevant perceptual and linguistic skills are not equally developed. An example of verbal overshadowing is where a verbal representation of a stimulus (e.g. the word 'aniseed') is remembered at the expense of the actual stimulus itself (e.g. the odour of aniseed). When a person has both perceptual and verbal expertise in a domain (as could be expected from the experts in the current study), their susceptibility to verbal overshadowing is assumed reduced because experts can shift between reliance on verbal or perceptual expertise without consequence. Such a notion could account for the present data from the expert group. To date, verbal overshadowing has been examined in situations where it has been argued that perceptual expertise exceeded verbal expertise (Melcher and Schooler, 1996; Schooler and Engster-Schooler, 1990). The present study, to our knowledge, is the first to demonstrate attenuated episodic (recognition) memory for odorants in a situation where verbal expertise was similar across groups. The notion that information processing of odours can be interfered with by concurrent use of language has been argued on the basis of electrophysiological as well as behavioural data. Lorig hypothesizes that language perception and odour information processing share a similar neural substrate so that when we are called upon to simultaneously process odour and language information, interference occurs (Lorig, 1999).

Although language serves memory well under many situations, language may also be an insidious source of memory disruption in situations for which it is not well suited, such as when remembering smells. The type and degree of disruption appear dependent on an individual's domain-specific expertise. It is conceivable that in some areas of expertise, semantic memory plays a large role in the early stages of skill development, but that qualitatively different processes are involved subsequently as expertise advances. There is a precedent in the literature for arguing for such a qualitative change in processing with increasing expertise. For example, in the specific area of cognitive research involved with problem solving, work with expert systems (i.e. artificial intelligence simulations of human performance) has been used to argue for qualitatively different processes underlying medical diagnoses by experts and novices. It has been argued that inexperienced physicians follow rules (e.g. 'if three out of five symptoms are present, diagnose as X'), whereas senior medical specialists may operate at a more global or 'intuitive' level (Reisberg, 1997).

In conclusion, an accumulating body of evidence suggests that verbal codes are not essential, or even necessarily activated (Herz, 2000), for successful odour-guided cognition. In keeping with this notion, our data suggest that perceptual skill, at least in relation to olfaction, is critical to wine expertise. Further, emphasizing verbal skill (e.g. forced naming of a perceived odour and/or matching to a linguistic tool) may interfere with olfactory performance in some situations (e.g. in the absence of well-developed perceptual expertise). From an applied perspective, some things may be better left unsaid (Schooler and Engstler-Schooler, 1990): that is, current training methods in wine evaluation would be unwise to emphasize linguistic skills in the absence of well-developed, relevant perceptual skill.

Acknowledgements

The work was funded by a Lincoln University Doctoral Scholarship, a Lincoln University Fund for Excellence award, and a Claude McCarthy Fellowship awarded by the New Zealand Vice-Chancellors' Committee (2001) to Wendy Parr. We would like to thank Bedoukian Research Inc. for generously donating many of the odorants, and Dr Rob Sherlock, Graeme Steans and Janette Busch for assistance with development of materials.

References

ASTM (1985) Atlas of Odor Character Profiles. ASTM Publications, Philadelphia.

ASTM (1986) Physical Requirement Guidelines for Sensory Evaluation Laboratories. ASTM STP 913. ASTM Publications, Philadelphia.

Bende, M. and **Nordin, S.** (1997) *Perceptual learning in olfaction: professional wine tasters versus controls*. Physiol. Behav., 62, 1065–1070.

Brochet, F. (1999) *The taste of wine in consciousness*. Journal International des Sciences de la Vigne et du Vin: Special Issue: Wine Tasting, 19–22.

Cain, W.S. (1979) *To know with the nose: keys to odor identification*. Science, 203, 467–470.

Cain, W.S. and **Potts, B.C.** (1996) *Switch and bait: Probing the discriminative basis of odor identification via recognition memory*. Chem. Senses, 21, 35–44.

Chollet, S. and **Valentin, D.** (2000) *Le degré d'expertise a-t-il une influence sur la perception olfactive? Quelques éléments de réponse dans le domaine du vin*. L'Anne psychologique, 100, 11–36.

Chu, S. and **Downes, J.** (2000) *Odour-evoked autobiographical memories: psychological investigations of Proustian phenomena*. Chem. Senses, 25, 111–116.

Elsner, R.J.F. (2001) *Odor memory and aging*. Aging Neuropsychol. Cogn., 8, 270–284.

Engen, T. (1982) The Perception of Odors. Academic Press, New York.

Epple, G. and **Herz, R.S.** (1999) *Ambient odors associated to failure influence cognitive performance in children*. Dev. Psychobiol., 35, 103–107.

Herz, R.S. (1997) *Emotion experienced during encoding enhances odor retrieval cue effectiveness*. Am. J. Psychol., 110, 489–506.

Herz, R.S. (2000) *Verbal coding in olfactory versus nonolfactory cognition*. Mem. Cognit., 28, 957–964.

Herz, R.S. and **Engen, T.** (1996) *Odor memory: review and analysis*. Psychon. Bull. Rev., 3, 300–313.

Ishii, R., Kemp, S., Gilbert, A. and **O'Mahony, M.** (1997) *Variation in sensory conceptual structure: an investigation involving the sorting of odor stimuli*. J. Sens. Stud., 12, 195–214.

Lawless, H.T. and **Engen, T.** (1977) *Associations to odors: interference, mnemonics and verbal labeling*. J. Exp. Psychol. Hum. Learn. Mem., 3, 52–59.

Lawless, H.T. and **Heymann, H.** (1998) Sensory Evaluation of Food: Principles and Practices. Chapman & Hall, New York.

Lehrner, J. (1993) *Gender differences in long-term odor recognition memory: verbal versus sensory influences and consistency of label use*. Chem. Senses, 18, 17–26.

Lehrner, J., Gluck, J. and **Laska, M.** (1999) *Odor identification, consistency of label use, olfactory threshold and their relationships to odor memory over the human lifespan*. Chem. Senses, 24, 337–346.

Lenoir, J (1995) Le nez du vin. Éditions Jean Lenoir, France.

Lorig, T.S. (1999) *On the similarity of odor and language perception*. Neurosci. Biobehav. Rev., 23, 391–398.

Macmillan, N. and **Creelman, C.D.** (1991) Detection Theory: a User's Guide. Cambridge University Press, Cambridge.

Melcher, J. and **Schooler, J.** (1996) *The misremembrance of wines past: verbal and perceptual expertise differentially mediate verbal overshadowing of taste memory*. J. Mem. Lang., 35, 231–245.

Morrot, G. (1999) *Can we improve taster performance?* Journal International des Sciences de la Vigne et du Vin: Special Issue: Wine Tasting, 29–35.

Morrot, G. and **Brochet, F.** (1999) *What our nose can tell us*. Journal International des Sciences de la Vigne et du Vin: Special Issue: Wine Tasting, 15–17.

Morrot, G., Brochet, F. and **Dubourdieu, D.** (2001) *The color of odors*. Brain Lang., 79, 309–320.

Moskowitz, H.R., Dravnieks, A., Cain, W. and **Turk, A.** (1974) Standardized procedure for expressing odor intensity. *Chem. Senses Flavor*, 1, 235–237.

Noble, A., Arnold, R., Masuda, B., Pecore, S., Schmidt, J. and **Stern, P.** (1984) *Progress towards a standardized system of wine aroma terminology*. Am. J. Enol. Viticulture, 35, 107–109.

Parr, W.V. (2000) *Sensory evaluation of wine: a psychological perspective*. Proceedings of Lincoln University Annual Grape and Wine School, Canterbury, NZ. Lincoln University, pp. 91–99.

Rabin, M.D. and **Cain, W.S.** (1984) *Odor recognition: familiarity, identifiability, and encoding consistency*. J. Exp. Psychol. Learn. Mem. Cogn., 10, 316–325.

Rapp, A. and **Mandery, A.** (1985) *Wine aroma*. Experientia, 42, 873–884.

Reisberg, D. (1997) Cognition: Exploring the Science of the Mind. W.W. Norton, New York.

Savic, I. and **Berglund, H.** (2000) *Right-nostril dominance in discrimination of unfamiliar, but not familiar, odours*. Chem. Senses, 25, 517–523.

Schooler, J.W. and **Engstler-Schooler, T.Y.** (1990) *Verbal overshadowing of visual memories: some things are better left unsaid*. Cognit. Psychol., 22, 36–71.

Snodgrass, J. and **Corwin, J.** (1988) *Pragmatics of measuring recognition memory: applications to dementia and amnesia*. J. Exp. Psychol. Gen., 117, 34–50.

Thorngate, J.H. (1997) *The physiology of human sensory response to wine*. Am. J. Enol. Viticulture, 48, 271–279.

Wixted, J.T. (1992) *Subjective memorability and the mirror effect*. J. Exp. Psychol. Learn. Mem. Cogn., 18, 681–690.

Accepted July 30, 2002