Odours Cue Memory For Odour Associated Words

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Abstract

The ability of odours to cue vivid and emotionally intense memories is well known. However the majority of research has focused on the extent to which odours can act as environmental cues to memory, where odours are presented alongside the stimuli to be remembered, rather than the extent to which pre-existing associations between odour and odour related stimuli might influence memory. Here, participants (n=45 females in each experiment) were presented with words (two groups of odour associated words and one neutral) on a computer screen and randomly assigned to one of 3 conditions where they recalled the words whilst inhaling from a bottle either rosemary, jasmine or no odour (exp 1) and peppermint, bergamot or no odour (exp 2). In experiment two, participants then completed a Lexical Decision Task (LDT). Experiment one revealed that for those in the rosemary group, significantly more rosemary versus jasmine and neutral words were recalled. Experiment two replicated this effect for peppermint, though no odour congruent effects were found in the LDT. These findings demonstrate that certain odours are able to cue memory for odour associated words. Results are discussed in relation to connected odour association research and possible theoretical frameworks to account for these findings.

Keywords

Olfaction, memory, lexical decision task, odour imagery, emotion

Introduction

Olfaction is unique among the sensory modalities in its relationship to memory. Physiologically, olfaction is the closest to both the amygdala and hippocampus (Herz & Engen, 1996), which may well explain the ability of odours to induce intense emotional memories (Chu & Downes, 2000; Herz, 1997). The aim of the research here is to explore the pre-existing associations we have to odours and their ability to influence behaviour. For instance, most of us are familiar with anecdotal evidence that the smell of freshly brewed coffee from a café increases our desire for coffee and possibly related products. Hence it is the (presumably) learned association that the odour of coffee signals not simply coffee itself but additionally memories associated to that odour that is the focus of the current investigation. The experimental evidence for odours specifically cueing odour associated behaviour is still lacking. One study for example, examined whether odours found to have a greater connection to certain activities (i.e. odour of grass to gardening activity) were capable of influencing the sales of odour (thematically) congruent versus incongruent magazine titles (Schifferstein & Blok, 2002). No significant differences were found between the odour conditions, however as the study used only the sales of the magazine titles as the main measure it may be that any changes in attention were not necessarily associated with purchasing behaviour. A second study (Morrin & Ratneshwar, 2003) investigated whether recognition for brands of products was facilitated when both encoding and retrieval took place in the same scented environment with an odour associated to those brands (i.e. geranium odour to deodorant, skin lotions & laundry detergents). Results in both recall and recognition failed to show the expected effect, although overall memory recall was enhanced when the encoding environment was scented compared to a no odour condition.

In the more theoretical cognitive domain, research has examined to what extent odours can act as environmental cues to memory, also known as ‘Context Dependent Memory’(CDM). Experiments have shown that memory performance for words is increased when the odour diffused into the test environment was the same at learning and recall (Schab, 1990) . In the key experiment, from the forty words to be recalled, seven were related to the diffused odour (apple and cinnamon), including for example ‘pie’ and ‘cider’. Participants were assigned to one of 3 groups: (1) same odour at learning and test and also asked to think about and imagine the smell of that odour; (2) just given the instructions only; (3) no odour present or instructions. Results revealed that overall memory was highest for those exposed to the odour with the instructions. More interestingly, memory for the odour related words was greater in the first two groups compared to those experiencing neither odour nor imagery instructions. However, there was no difference between the first two groups, suggesting that there was no additional benefit for cueing odour associated words with the relevant odour compared to only imagining the odour. Recent work has shown that the same odour at learning and recall without imagery instructions can nevertheless yield enhanced (delayed) recall for words associated to that odour compared to a no odour control (Parker, Waterman, & Gellatly, 2000). This implies that, although semantic cues generated by imagery alone compared to odour plus imagery are just as effective at cueing odour associated words, the experience of inhaling an odour by itself (without imagery) still confers an advantage to no odour in recall. One limitation of both CDM studies (Parker et al., 2000; Schab, 1990) is that only one odour was used in each study and it is therefore uncertain if the unique relation between the odour and the associated words was responsible for the enhanced memory, or whether the same effect might occur with an alternative odour.

The majority of research to date has focused on the extent to which odours can act as environmental cues to memory, where odours are presented with the stimuli to be remembered, rather than the extent to which pre-existing associations between odour and odour related stimuli might influence memory. This latter function is particularly important if we are to understand the ability of odours to prime/cue behaviour. The present research therefore aimed to examine this using a direct method of odour inhalation whereby the odour would be inhaled explicitly by the individual, rather than using an odour diffuser to release the odour into the testing environment. Using this method ensures unambiguous attention to the odour and also permits greater control on the delivery of the odour (Ilmberger, Heuberger, Mahrhofer, Dessovic, Kowarik, & Buchbauer, 2001; Sugawara, Hino, Kawasaki, Hara, Tamura, Sugimoto et al., 1999). Additionally, previous studies have not ascertained the associations specific individuals hold with the delivered odours (Schifferstein & Blok, 2002) or response questionnaires were closed to a number of options thought to be important by the investigators (Morrin & Ratneshwar, 2003; Schifferstein & Blok, 2002). We completed a pre-study in order to select two odours with the highest degree of agreement in individual associations to that odour and produce a list of most frequently associated words for each of the two odours. Additionally the pre-study aimed to provide data on the sensory perception of the tested odours, in order that the two selected odours could be compared on the various dimensions. This was achieved using Visual Analogue Scales (VAS) as used in previous research (Ilmberger et al., 2001; Stafford & Yeomans, 2005). In the first experiment, individuals completed a free recall task using the words selected from the pre-study, whilst inhaling one of the odours, where it was predicted that recall would be enhanced when odour and odour associated words were congruent.

Pre-study

Participants

The fourteen participants were all female University students (as females describe more emotional and clearer memories than males (Herz & Cupchik, 1992; Laird, 1935) and have superior olfactory sensitivity (Doty, Snyder, Huggins, & Lowry, 1981) aged between 18 and 24 years (mean 20.4, sd 1.5 years) and all had English as their first language. University of Portsmouth ethics procedures were followed throughout the study.

Design

The study used a within-subjects design where participants sampled ten odours in a randomised order.

Odours

The ten odours used in this experiment were selected on the basis of providing a wide selection of contrasting essential oils and were all from Holland & Barrett (Portsmouth, U.K.): Bergamot (*Citrus bergamia*), Cedarwood (*Juniperus virginiana*), Jasmine (*Jasminum grandiflorum*), Lavender (*Lavandula officinalis*), Marjoram (*Origanum majorana*), Neroli (*Citrus aurantium*), Patchouli (*Pogostemon cablin*), Peppermint (*Mentha piperita*), Rosemary (*Rosmarinus officinalis*), Ylang ylang (*Cananga odorata*). Odours were prepared by placing a single cotton wool pad (Boots, Portsmouth, U.K.) inside a glass bottle (2.5cm diameter at the opening 13cm high) and injecting 200µl of the respective odour onto the pad and sealing the bottle with a plastic lid.

Procedure

On arrival, participants were asked if they had a cold and those who did were rescheduled for another day. They were then presented with the ten odours in a randomized order for each participant, and instructed to smell each odour in the order presented (numbers were placed in front of each bottle for clarification). For each odour, they were asked to remove the cap and inhale normally through the nose, exhale through the mouth and complete the questionnaire. The questionnaire assessed each odour using five questions. Participants rated how alerting (1), and relaxing (2) the odour made them feel or they associated with the odour, and how intense (3) and pleasant (4) was the odour. Participants made their responses on a 100mm visual analogue scale (VAS) anchored at "Not at all" and "Extremely". The final question asked "What immediate words/emotions/memories do you associate with this odour (minimum 3). Once they had completed this, they were instructed to fix the cap to the bottle, take a few breaths of fresh air before proceeding to the next odour and repeat as before. When all odours had been sampled, they were given a full debriefing.

Results

Odour Associated Words

Since the main purpose was to gather a list of words most highly associated to each odour, it was decided for each odour, to note all the words listed by at least two of the participants (this being the lowest level of common agreement). Each of the odours were then compared to see which ones yielded the most frequently associated words. This process was completed by two judges with a high level of agreement (above 80%). This analyses resulted in six odours (rosemary, jasmine, peppermint, lavender, bergamot, patchouli) that each yielded seven words mentioned by at least two participants. Patchouli was excluded since two of the words (chewing gum, mint) were likely an effect of odour order (e.g. peppermint presented before). Four odours were selected for the experiments on the basis of the highest frequency of associations and distinctiveness from each other. The most commonly associated words/themes for each of the ten odours are shown in Table 1.

Ratings

Repeated Measures ANOVA analysis of the VAS revealed a significant effect of Odour on intensity, $F(9, 117) = 5.91$, $p < .0001$, where pairwise comparisons revealed jasmine to be the least and ylang-ylang as the most intense odours (Table 2). There was also a significant effect of Odour on ratings of pleasantness $F(9, 117) = 4.04$, $p < .0001$, with mean comparisons demonstrating patchouli to be the least and peppermint the most pleasant odours (Table 2). Ratings of alertness revealed a significant effect of Odour, $F(9, 117) = 7.18$, $p < .0001$, where jasmine was the least and Ylang-ylang the most alerting odour (Table 2). Finally, in terms of relaxing ratings, a significant effect of Odour was found, $F(9, 117) = 4.16$, $p < .0001$, with mean comparisons revealing patchouli to be the least and jasmine as the most relaxing odour (Table 2).

Experiment one

The pre-study found that when presented with several different odours, the spontaneous associations female individuals made were quite varied, though some odours yielded distinctly higher rates of agreement. In particular, participant's responses to the odours of rosemary, jasmine, peppermint, lavender and bergamot clearly contained a high number of concordant words compared to the remaining odours. In terms of rosemary, the major theme related to products associated to cold remedies, e.g. “vapour rub”, “menthol”. In contrast for jasmine, the theme was mainly connected to “flowers”, “gentle”. These findings suggest that although responses to odours can be very personal and unique (e.g. “reminds me of grandmother’s house”), there is also some overlap of the same responses. In previous work, researchers have simply constructed a list of items thought to be associated to an odour and asked individuals how strongly they thought the odours were associated to such words e.g. (Schifferstein & Blok, 2002). Such approaches have the advantage of permitting inferential analysis of the data to determine significant differences, however they have less ecological validity in that items are initially proposed by the researchers themselves. The results of this pre-study are also in general support of earlier work on the durability and emotional intensity of inhaled odours (Aggleton & Waskett, 1999; Herz, 2004; Herz & Cupchik, 1992).

Experiment one therefore aimed to see whether odours were capable of influencing memory to stimuli (words) associated to that odour. On the basis of the highest frequency of associations and distinctiveness from each other, rosemary and jasmine were selected for the test odours in experiment one. It was therefore hypothesised that recall would be enhanced when odour and odour associated words were congruent.

Participants

Forty-five Portsmouth university students were recruited for the study. Participants were all females aged between 18 and 24 years (mean 19, sd 1.2 years) and all had English as their first language. The participants did not differ significantly in age between the three groups: Control (18.8 ±0.3), Jasmine (19.1 ±0.3), Rosemary (19.0 ±0.4). The study was approved by the University Of Portsmouth ethics committee (BPS guidelines).

Design

Participants were randomly allocated to one of three groups: Jasmine, Rosemary, No odour and all participants completed a memory task containing three types of words. The experiment therefore used a mixed design with Group as between-subjects and Word Type as within-subjects variables.

Word Stimuli

Based on the findings of the pre-study, seven odour associated words were selected for each of the test odours (Jasmine and Rosemary) together with seven neutral words relating to motor vehicles/driving and were matched as closely as possible for word length, number of syllables, written word frequency and imageability (Francis, Kucera, & Mackie, 1982). The choice of motor vehicles/driving was random but the rationale for using such a neutral word group was to match any possible categorical priming effect that could arise for words in the jasmine and rosemary groups. The use of such categorical controls have been used in a number of previous studies, (e.g. in a modified Stroop, Green & McKenna, 1993). In total there were twenty-one words (Table 3).

Free Recall Memory Task

Participants were advised to focus on a fixation symbol '+' on the screen, followed by a briefly displayed series of words and that their task was to try and remember each word. Words were presented in lower case courier font (size 18) displayed in the centre of the screen. Each word remained on the screen for 3 seconds before being replaced by the fixation symbol and the successive trial. To minimise any categorical effects in word presentation, the words were randomised but whereby no two words of the same group could appear in succession. The memory task used here was written using E-Prime (version 1.1 SP3) and was conducted on a Gateway 2000 PC (531 MHz) running Windows XP Professional (version 2002).

Odours and administration

Two odours were selected from the pre-study: jasmine and rosemary and, due to the differences in intensity, a pilot was conducted in order to calibrate the two essential oils. Six females (who took no further part in the experiment) were asked to rate the two odours on intensity (using VAS) in a counterbalanced order. This revealed mean intensity ratings for rosemary (59.3 sd: 10.5) were higher than jasmine (45.8 sd: 21.2). On the basis of these results the volume of the two odours for the main study were adjusted whereby 200 µl of rosemary and jasmine 400 µl were used. Apart from this difference preparation was the same as for the pre-study.

Procedure

Participants were told prior to the start that the experiment would consist of a computer task and smelling a pleasant odour (if in relevant condition) and completing a questionnaire. On arrival at the laboratory participants completed an informed consent form and then undertook the computer task. When this was completed, they were then asked to count backwards in threes from 500 for three minutes as a distracter task. Following this, those in the two odour conditions were presented with a bottle containing the relevant odour and instructed to remove the cap and inhale normally through the nose, exhale through the mouth and write down one word from the previously presented list in any order. They were then asked to take a breath of fresh air and to repeat the process continuously, trying to remember a different word each time, and if they could not recall a word on a particular trial to simply keep repeating the process. Participants in the no odour condition were instructed to write down as many words as they could remember in any order. When three minutes had elapsed participants were thanked for their time and given a full debriefing. Participants were offered either course credits or monetary compensation for taking part in the study.

Data Analysis

The number of words recalled correctly for each participant was subjected to a repeated measures ANOVA using the within-subjects factor of Word (jasmine, rosemary, neutral) and the between-subjects factor of Group (jasmine, rosemary and no odour).

Results

Free Memory Recall Task

Analysis revealed a significant main effect of Word $F(2, 84) = 4.37$, $p < .05$, with mean comparisons revealing significantly higher recall for both Jasmine (3.6 ±0.2) and Rosemary associated words (3.8 ±0.2) compared to control (3.1 ±0.2, both $p<.05$), which however did not differ from each other. There was also a main effect of Group $F(2, 42) = 6.12$, $p < .01$, with post-hoc comparisons demonstrating significantly lower recall for both Jasmine (3.3 ±0.2) and Rosemary groups (3.1 ±0.2) compared to control (4.2 ±0.2, both $p < .01$), again though not differing from each other. Importantly, the Word x Group interaction was significant $F(4, 84) = 2.53$, $p < .05$, with mean comparisons revealing that, consistent with prediction, more words were recalled when Group and Word were congruent (Figure 1). Post-hoc comparisons further demonstrated that, when each group was analysed separately, there were no significant differences in words recalled in the control group. In the case of the jasmine group significantly more jasmine associated compared to neutral words were recalled ($p < .05$), but no differences were found between jasmine and rosemary associated words ($p > .1$). For the rosemary group however, significantly more rosemary associated words were recalled compared to both neutral and jasmine words (both $p < .05$).

Discussion

The study found that consistent with prediction, participants recalled more odour associated relative to the non-odour associated and neutral words when inhaling the corresponding odour. Hence those in the jasmine and rosemary groups recalled significantly more jasmine and rosemary associated words compared to neutral words, with no differences for those in the no odour condition. However, the effect was most apparent in the rosemary odour group where recall was significantly higher for rosemary associated words compared to both jasmine and neutral words. These findings demonstrate that memory for words related to a specific odour can be enhanced when smelling the congruent odour simultaneously and are consistent with related work in context dependent memory (Parker et al., 2000; Schab, 1990), which found that memory was enhanced when the same odour was present at encoding and recall. The work here extends that research to show odours can cue odour associated words even when presented at recall only and hence are not simply an environmental cue as in CDM. Further it was unclear from the previous work whether the effects observed were due to the specific odour used or whether the same effects could be produced with another unrelated odour. It appears from the results here that this may depend on the odour used, since those in the rosemary group recalled significantly more rosemary versus jasmine related words, but no differences were found for those in the jasmine group. This could be due to the odour of rosemary being more familiar to participants compared to jasmine and thus producing a stronger connection to the related words and thereby influencing recall. It may also be due to differences in odour intensity, where although an attempt was made to match the two odours on this dimension, it could be that due to inherent differences, stronger odours such as rosemary provide a better memory cue. The main criteria for selecting the two odours here were based on distinctiveness between the two odours and strength of memory association. However, since odour intensity may not have been completely matched, together with differences in pleasantness it could be these are important features in yielding the odour congruent memory effect and is something that experiment two wished to address.

In addition, one could argue that the memory paradigm used in experiment one was not consistent with priming research in that participants were specifically asked to memorise the words. Using a more implicit or incidental learning approach would also mean that the influence of the odour may be greater since individuals would not actively be involved in word rehearsal. It was therefore decided to use an incidental learning approach, similar to that used in previous related work (Schab, 1990). Another issue with experiment one was that memory overall was poorer in the two odour groups compared to no odour, suggesting that inhaling from a bottle (perhaps unsurprisingly) acted to interfere with the memory task and impair performance. Though it is important to note that this overall impairing effect of smelling an odour was evidently not impacting on the specificity of the effects observed, hence those inhaling rosemary were uniquely better at recalling rosemary relative to jasmine and neutral words. Nevertheless in order to use a more appropriate control, participants in this condition in the follow-up experiment would inhale from a blank bottle.

Experiment two

A second experiment was completed to address the methodological limitations of Experiment 1 and additionally to examine whether effects would also be evident using an attentional task

(Lexical Decision Task, LDT). The aim was to ascertain whether individuals who had recently been exposed to an odour would be faster at recognising words associated to that odour. Related research has shown that direct inhaling of pleasant and unpleasant odours can influence reaction times in an affective priming study (Hermans, Baeyens, & Eelen, 1998). More recently it has been reported that a citrus cleaning odour diffused in the test environment led to faster responses to cleaning related compared to control words in a LDT (Holland, Hendriks, & Aarts, 2005). Therefore in this context, the LDT is a measure of the salience of words according to odour exposure, where it is assumed that faster responses to odour congruent cleaning words versus neutral words are taken to suggest attentional processes have been influenced by that odour.
In both of the above studies however, the odour was present whilst participants completed the task and it is therefore uncertain whether recent exposure to an odour can influence attention. Nevertheless, since earlier work found an effect of merely imagining an odour on memory recall (Schab, 1990), there are grounds for theorizing this may be the case. To explore this question, participants in experiment two were exposed to the relevant odour as part of the memory task per experiment one, and then completed a lexical decision task (LDT) where instead of having to smell the relevant odour, they would be asked to imagine the smell of the previously presented odour to test whether this would influence lexical decisions to odour relevant words.

It was predicted that free recall would be highest when odour condition and odour associated words were congruent. Further the effect of odour pre-exposure was explored on attention where it was theorized that responses would be fastest for those participants where odour and odour associated words were congruent.

Participants

Forty-five female Portsmouth university students were recruited for the study. Participants were aged between 18 and 24 years (mean 18.82, sd 1.3 years) and all had English as their first language. The study was approved by the University Of Portsmouth ethics committee (BPS guidelines).

Design

The study used a mixed design, where participants were randomly allocated to one of three groups (Bergamot, Peppermint, No odour) and all completed a memory task and a lexical decision task containing three and four different types of words respectively. Consequently, Group was the between-subjects factor, whereas Word Type was the within-subjects factor.

Odour Familiarity

In order to measure odour familiarity, participants were asked two questions: “How familiar was the odour you smelled to you?” and “What do you think was the odour you smelled?” Participants made their odour familiarity rating on a 100mm visual analogue scale anchored at “Not at all “ and “Extremely”, and used an open response format to provide an answer to the second question.

Odours and Administration

The two odours selected for the present study were bergamot (*Citrus bergamia*) and peppermint (*Mentha piperita)*, as they were shown in the pre-study to be similar in intensity, pleasantness, alerting and relaxing power [no significant difference on all measures, ps > .1]. The odours were administered by injecting 200µl of the respective essential oil on a cotton wool pad, placing this pad into a glass bottle and closing the bottle with a plastic lid.

Word Stimuli

In order to ensure that the odour words used could not be mistaken for a different odour and also to obtain the most frequently associated words, a pilot study was conducted where 10 females were given a word list containing 30 words and were asked to rate on a visual analogue scale how much they associate each of the 30 words with one of the two test odours they were inhaling continuously. After a short break the same 30 words had to be rated while smelling the other odour. Participants also stated how familiar the two odours were to them using a 100mm visual analogue scale. The 30 words were taken from the pre-study. Based on the results of the pilot here, the seven most highly associated words were used in the memory task; bergamot (citrus, zesty, clean, fresh, comfort, baths, cough) and peppermint (mints, menthol, gum, toothpaste, spearmint, mouthwash, vapourrub) together with seven neutral (wheels, driver, garage, brake, journey, wiper, traffic) words belonging to the category driving. There were no differences in familiarity between bergamot (63.2 ±5.3) and peppermint (63.0 ±10.9), $t(9) = 0.16$, $p > .9$. For the LDT, rather than use the same set of words for the memory task which would have obviously affected performance in the LDT (and not the aim here) the next most highly associated words, seven for each category were selected from the pilot; bergamot (chemicals, disinfectant, relaxation, nostalgic, home, massage, drowsy), peppermint (sweets, unpleasantness, dentist, winter, laboratory, dizziness, old), neutral (sharpener, marker, paper, rubber, sellotape, glue, pencil) together with twenty-one non words (e.g. pramdin). The word groups were matched as closely as possible for word length, number of syllables, written word frequency and imageability (Francis et al., 1982).

Free Recall Memory task

This task was identical to experiment one. However since we were interested in using an incidental learning approach, here participants were instructed that words would be briefly displayed on the screen. Further, for each word presented, they had to decide whether it was pleasant or unpleasant by pressing the 'Y' or 'N' key respectively. So, although there was no specific instruction to memorise the words, the act of making a decision would require at least some form of deeper processing and is similar to previous work e.g. (Schab, 1990)

Lexical Decision Task

Participants were instructed to focus on a fixation symbol (+), which appeared in the middle of the screen for 1000ms before being replaced by a word or a pseudo word. Participants were advised to decide as quickly and as accurately as possible whether the presented word was a real or pseudo word by pressing the "Y" labelled key when it was a real word and the "N" labelled key when the word was a pseudo word. The words were presented in random order, courier new font size 20 and remained on the screen until the participants responded. Importantly, participants were furthermore instructed to imagine the odour they had smelled in the previous task. This was done by presenting the reminder "Imagine that smell from the bottle" before each single trial for 1500 ms in the middle of the screen. As in the memory task, to minimise any categorical effects in word presentation, the words were randomised but whereby no two words of the same group could appear in succession.

Procedure

On arrival, participants were seated in front of a computer screen and read the instructions for the memory task and instructed to start when they were ready. Once this task had finished they were instructed to count backwards in fives from 500 for 30 seconds as a distraction. Participants were then given a glass bottle, which contained either a wool pad with bergamot, peppermint or a plain wool pad with no odour, depending on the participant's group. The instructions were then identical to experiment one. When 5 minutes had elapsed the free recall task was finished and participants completed the LDT. Participants then filled in an odour familiarity rating questionnaire. In order to minimise any lingering odours that remained, two identical cubicles (these dimensions of these testing rooms were 3.68m(length) x 1.72m(width) x 2.60m (height), each containing a desk, 2 chairs and a computer) were used in this experiment; one for the two odour groups and one for the no-odour group. Finally participants were then given a full debriefing.

Data Analysis

For the memory task, a repeated measures ANOVA was conducted with each participant's number of correctly recalled words, using Word (bergamot, peppermint, neutral) as the within-subjects factor and Group (bergamot, peppermint, no odour) as the between-subjects factor.

Data for the LDT was checked for outliers, where RTs for incorrect responses (i.e. defining a real word as a non word), those for non words and RTs less than 200ms and more than 2500ms were removed from the data set, as in previous work (Carreiras & Perea, 2002). The remaining latencies were averaged for each participant, separately for bergamot, peppermint and neutral words. Scores being more than 2 *SD* away from the mean were regarded as outliers and were therefore omitted from any further analysis. On the whole, there were four outliers (one from the bergamot group, three from the peppermint group). For the main analysis, the mean RTs for each participant were subjected to a repeated measures ANOVA, using the within-subjects factor of Word (bergamot, peppermint, neutral) and the between-subjects factor of Group (bergamot, peppermint, no odour).

For the questionnaire data, a correlational analysis was conducted with the familiarity scores and the number of recalled words in the memory task and separately with the familiarity scores and the RTs in the LDT, using Pearson product-moment correlation coefficients.

Results

Free Memory Recall Task

Analysis revealed a significant main effect of Word, $F(2, 84) = 16.89$, $p < .0001$, where more peppermint (4.5 ±0.2) associated words were recalled compared to both neutral (3.6 ±0.1) ($p < .0001$) and bergamot (3.1 ±0.2), that also differed from one another ($p < .05$). Importantly there was a significant Group x Word interaction, $F(4, 84) = 2.46$, $p = .05$, where mean comparisons revealed those individuals in the peppermint group recalled more peppermint compared to bergamot and neutral words (Figure 2). Separate ANOVAs of each group demonstrated significant effects of Word, in the no odour, $F(2, 28) = 5.61$, $p < .01$, and peppermint, $F(2, 28) = 12.98$, $p < .0001$, groups only, where although those in the no odour group recalled significantly more peppermint compared to bergamot words ($p < .05$), only in the peppermint group was there also significantly more peppermint versus neutral words recalled (both $p < .01$).

Lexical Decision Task (LDT)

Analysis revealed a significant main effect of Word, $F(2, 74) = 16.47$, $p < .0001$, where responses were faster for neutral compared to both peppermint and bergamot words (both $p < .001$) which also differed from each other ($p < .01$). The main effect of group failed to reach statistical significance, $F(2, 37) = 2.68$, $p = .08$, though overall RTs were clearly faster for the no odour (697.03 ±39.76) compared to peppermint (758.47 ±42.95) and bergamot (827.33 ±39.76) groups. Against prediction, the Group x Word interaction was not significant, $F(4, 74) = 1.01$, $p > .1$, with mean comparisons revealing RTs were no faster when previously experienced odour and word type were congruent (Table 5).

Familiarity

The analysis of odour familiarity revealed no differences between those in the peppermint (71.3 ±4.4) and bergamot (78.4 ±4.4) groups, $t(28) = 1.07$, $p > .2$.

Correlations

To explore whether memory and attention were associated with differences in familiarity, correlations were conducted on the data for the two odour groups separately. This revealed no significant relationships.

Discussion

Consistent with prediction, participants in the peppermint condition recalled significantly more words associated to peppermint compared to bergamot or control words. This pattern was not found with either the no odour or bergamot groups. The fact that in both experiment one and two only one of the odours yielded a clear effect of priming implies that the relationship between the odour and associated words is critical in producing this effect. One possibility is that since the words related to peppermint contained more functional words (e.g. toothpaste, gum) compared to a higher number of adjectives for bergamot (e.g. zesty, fresh), it may be the effects of odours are strongest for odour plus functional words. This gains some support from experiment one where both odour related words contained more functional words compared to adjectives, and although the effects were clearest for those exposed to rosemary, even for those in the jasmine group, more jasmine versus neutral words were recalled which was not seen for bergamot in the experiment here. It is also worth noting that the earlier CDM study (Schab, 1990) appeared to use more functional type words (though only 3 out of 7 listed: pie, cider, spice for words related to apple and cinnamon odour), suggesting further that memory for odour associated words are stronger when words are more functional which possibly also helps strengthen the categorical priming effect.

We can be more confident in stating that in the present experiment, the observed differences in memory recall cannot be explained by differences in intensity, pleasantness and familiarity since the two odours were matched on these dimensions. These results confirm and extend the findings of experiment one by demonstrating that odours can prime memory for words associated to that odour, even when intensity is controlled. Further by using an incidental memory task, they show the effect is not simply limited to explicit memory tasks. The observation that overall memory did not differ between the three groups make it quite probable that the poorer performance of the two odour versus no odour groups in experiment one was due to a general distraction of the task of holding a bottle, rather than any specific odour impairing effect. This finding is in agreement with research that found no differences in word recognition when an encoding session was accompanied by either constant rose odour or room odour (control) using an olfactometer (Walla, Hufhagl, Lehrner, Mayer, Lindinger, Imhof et al., 2003).

The results in the LDT were that previous exposure to an odour did not influence responses to words associated to that odour which was against prediction and previous work (Hermans et al., 1998; Holland et al., 2005). In both of these studies, the odour was either directly inhaled or diffused in the test environment whilst participants completed the relevant tasks and hence may well account for the divergent findings. It could therefore be inferred that merely imagining a recently inhaled odour is an insufficient cue to affect cognition, at least as measured by the LDT. Interestingly however, research has shown that previous exposure to an odour can influence behaviour associated to that odour (Holland et al., 2005). In the final, unusual experiment in the series, that study found that individuals who recently experienced the citrus cleaning odour in one test room compared to those who had not, were more likely to remove crumbs away when eating biscuits in an odour free environment. This suggests (perhaps) that the action of cleaning was stronger for those who had recently smelled the cleaning associated odour which thereby acted to increase cleaning (crumb removal) behaviour in the subsequent task (Holland et al., 2005). However, further work needs to be completed to compare performance on other (more easily interpretable) tasks and using at least two contrasting odours to check for specificity of any effects.

In considering the limitations of the experiment, one might contend that the use of the pleasant/unpleasant categorization of words in the memory task introduced an affective component to the task, possibly introducing unwanted effects. The reason for using such a task was simply to induce a greater/deeper level of processing and has been used in previous studies involving odours (Schab, exp 3 1990; Walla et al 2003). Nevertheless future work should use a more affective-neutral method such as asking participants to write down the word.
For the LDT, it could be the case that the words used lacked the association strength to the odour (unlike the memory task) and contributed to the null effect. The rationale for using a different set of words to the memory task was in order to avoid any obvious carry-over effects from that task, i.e. to rule out the possibility that enhanced lexical decision was due to previous word rather than odour exposure. It may also be the case that task order could have influenced LDT findings, since LDT always followed the memory task. Hence it would be interesting to see if contrasting findings would result in a replication of the LDT but using the words from the memory task. Lastly, the LDT as used here may have lacked the necessary sensitivity to detect any odour association effects, especially if one considers the rather unnatural instruction to "imagine that smell from the bottle" combined with a lexical task. It could be that participants did not engage in the imagination part fully and this influenced the findings. On reflection, the mental act of imagining an odour may work better with a task not necessarily using response times as its main measure (e.g. instead use accuracy), else a task that requires individuals to imagine once only for

the duration of the task, as the several imagination instructions here may well have been overly demanding.

Conclusion

The two experiments demonstrate that the explicit inhalation of odours can act to influence recall of stimuli associated to that odour. Both experiments showed that the effect was stronger for certain odours which cannot be explained by differences in odour intensity and pleasantness and hence may be due to the strength of the relationship between word and odour. Relevant here are the findings of a study (Dematte, Sanabria, & Spence, 2006) examining the association between certain odours and colours which showed that relatively few odours yielded a consistent choice of colours, with the most highly associated odour/colour to be spearmint (turquoise). Hence the observed effect for peppermint but not bergamot in experiment two suggests that as with odour/colour associations, some odour/word associations are simply stronger than other combinations.

More generally, the findings here could be seen to provide further experimental evidence of the Proustian effect, i.e. the ability of odours to induce vivid emotional memories (Chu & Downes, 2000). The pre-study showed that individuals had relatively intense emotional memories to some of the odours presented. By distilling this into a list of most frequent associations, experiments one and two demonstrated that odours can act as a potent cue to memory for associated words. It therefore appears that individuals' pre-existing associations with the relevant odour here were strong enough to cue memory recall. The findings may also be explained by the encoding specificity principle (Tulving & Thomson, 1973), where recall is enhanced to the extent that the cues available at recall match those at encoding. So, recall for the peppermint words was facilitated as these words became associated to the odour of peppermint on a previous occasion. However, this theory seems more appropriate to CDM e.g. (Parker, Ngu H., & Cassaday, 2001; Schab, 1990) where odours are simply an environmental cue to neutral words. Alternatively the effects could be more related to Mood Congruent Memory theories e.g. (Bower, 1981) where the odour activates a network of nodes and emotions connected to the odour related words. Though such theories are generally applied to actual changes in mood and its congruence to the stimuli recalled (e.g. induction into a happy mood state enhances recall for happy words), hence some modification of the theory would be necessary to accommodate the findings here. This could be achieved if we theorise that smelling a particular odour alters some broader aspect of mood/behaviour not solely related to positive/negative emotion but is nevertheless congruent with memories linked to that odour which thereby provide preferential access to words related to the odour.

In summary, the research here demonstrated that odours are able to cue memory to odour associated words (relative to non-associated and neutral words), without the odour being present when the words were originally presented. The finding that some odours had stronger effects than others is interesting and worthy of future research which could also examine participants' cultural origins, eating and cosmetic practices, as these factors may well influence the degree to which associations are attached to certain odours. Connected to this, work has demonstrated that the area an individual resides (city/surburbia/country) can predict the vividness of memories associated to popcorn (higher for city dewellers) and fresh-cut grass (higher for country residents)

(Herz, 2004). It would therefore be fruitful for additional work to examine more specifically how these factors help predict the influence of odour on odour associated behaviour.

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Table 1. Most Commonly Associated Words/Themes For The Ten Odours (Pre-study)

	Word/Theme	Frequency	Example of Personal memory
Bergamot	Lemony/Citrus/Zesty	5	Drinking coca-cola
Cedarwood	Wood/Chopping logs/Building work	6	Church at easter
Jasmine	Flowers	3	Nana's house
Lavender	Lavender	4	Long baths
Marjoram	Coughs/Colds	6	Bedroom when younger
Neroli	Plants/Crushed plants	3	Quietus mind
Patchouli	Herbs/Forest/Green/Fairgrounds	5	Being sick
Peppermint	Mint	8	Christmas
Rosemary	Vapour rub	6	Being cared for
Ylang Ylang	Disinfectant/Chemicals	5	Hospitals

Table 2. Mean (SEM) Pre-Study Ratings For Intensity, Pleasantness, Alerting and Relaxing

	Intensity	Pleasantness	Alerting	Relaxing
Bergamot	60.2 ±6.5	53.0 ±7.3	51.4 ±6.0	42.1 ±7.8
Cedarwood	53.2 ±6.4	27.4 ±6.0	41.4 ±4.5	31.0 ±6.0
Jasmine	33.4 ±5.3	50.3 ±6.6	33.9 ±5.6	60.5 ±5.5
Lavender	61.1 ±5.2	36.0 ±9.8	50.6 ±5.3	38.3 ±8.5
Marjoram	65.7 ±5.5	42.8 ±5.5	58.9 ±3.7	44.8 ±6.7
Neroli	37.4 ±4.5	44.1 ±6.2	35.9 ±5.3	47.5 ±6.2
Patchouli	52.8 ±6.9	20.9 ±5.8	39.1 ±5.3	23.0 ±4.5
Peppermint	60.9 ±5.5	63.7 ±5.5	58.5 ±5.5	43.3 ±7.5
Rosemary	63.0 ±7.4	41.2 ±5.3	63.4 ±5.7	38.1 ±6.3
Ylang Ylang	72.6 ±5.2	32.5 ±5.7	67.6 ±3.2	25.0 ±6.1

Table 3. Word stimuli used in the Memory Task (experiment one).

Neutral	Jasmine	Rosemary
wheel	flower	clear
drive	gentle	colds
garage	grassy	fresh
brake	herbs	menthol
journey	pollen	nose
wiper	spring	olbas
traffic	summer	vapourrub

Table 4. Mean (SEM) Group Characteristics Experiment Two

Group	Age	Odour familiarity[1]
No odour	18.3 ±0.2	31.1 ±7.7
Bergamot	19.2 ±0.4	71.3 ±5.1
Peppermint	18.9 ±0.4	78.5 ±4.3

[1] Higher scores suggest greater familiarity

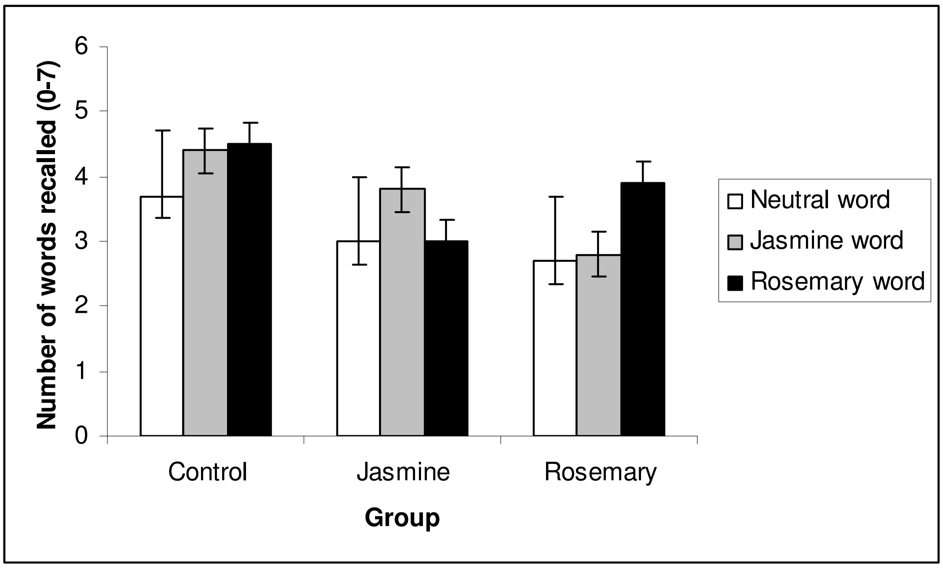
Table 5. Mean (SEM) LDT Reaction Times By Group And Word Type

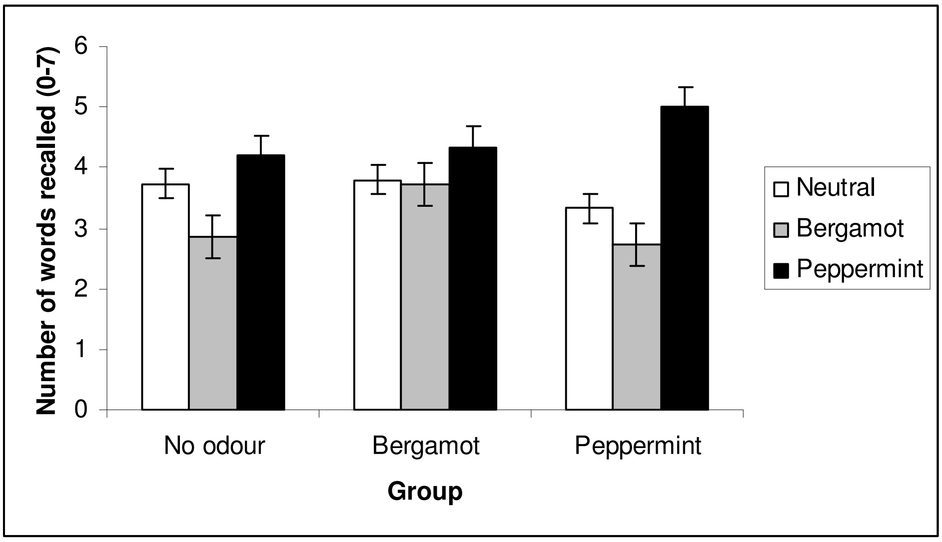
	Word Type		
Group	Bergamot	Neutral	Peppermint
No odour	756.00 ±52.80	660.68 ±30.64	674.42 ±46.94
Bergamot	869.72 ±57.03	759.55 ±33.10	852.73 ±50.71
Peppermint	826.53 ±52.80	680.76 ±30.64	768.13 ±46.94

Legends for figures:

Figure 1 Mean (±SEM) number of words recalled depending on word type and odour condition in experiment one.

Figure 2 Mean (±SEM) number of words recalled depending on word type and odour condition in experiment two.


Number of words recalled (0-7)
6
5
4
3
2
1
0
Control
Jasmine
Rosemary
Group
Neutral word
Jasmine word
Rosemary word


Number of words recalled (0-7)
6
5
4
3
2
1
0
No odour
Bergamot
Peppermint
Group
Neutral
Bergamot
Peppermint