

Context-dependent Memory: Colour versus Odour

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Abstract

An olfactory stimulus and a visual stimulus were employed in a context-dependent memory study using a prose passage as the to-be-remembered item. Ninety-five university students (aged 17–35 years) learned the passage of prose in the presence of one of the stimuli and were then asked to recall the passage with the original context either reinstated or not reinstated. The results revealed a significant context-dependent memory effect for the olfactory cue but not for the visual cue. They demonstrate support for the effectiveness of odours as context cues and it is suggested that context-dependent memory processes may underlie the formation and retrieval of odour-evoked autobiographical memories.

Introduction

The ability of odours to stimulate the recall of autobiographical events is a well established belief. While odour-evoked autobiographical memories have received scant investigative attention from psychology, anecdotal evidence is plentiful. The majority of investigations into aspects of olfactory memory accept the existence of odour-evoked autobiographical memories and draw support for its character from classical literary accounts such as Proust's (1928). Although limited in number, several studies have confirmed that odours can indeed act as effective retrieval cues for personal memories (Laird, 1935; Gilbert and Wysocki, 1987; Herz and Cupchik, 1992).

Research into odour-evoked autobiographical memories is still in its infancy and the mechanisms which subserve the formation and retrieval of such memories have yet to be identified. One plausible explanation is that context-dependent memory processes play a significant role. In keeping with the encoding specificity principle (Tulving, 1983), olfactory cues associated with the original event may trigger the recall of the autobiographical memory by reinstating the original context. While context-dependent memory effects have remained somewhat controversial, with failures to replicate supporting studies (Fernandez and Glenberg, 1985; Saufley *et al.*, 1985), a small number of studies using olfactory stimuli have shown significant support.

Significant context-dependent memory effects have been found in five studies involving a variety of learning paradigms (recall, recognition, relearning performance) and a range of odours (Smith *et al.*, 1982; Cann and Ross,

1989; Schab, 1990; Herz, 1997). The majority of the to-be-remembered items employed by the authors were simple word lists, apart from one study that used photographs of female faces (Cann and Ross, 1989). While supportive of the suggestion that odour-evoked autobiographical memory is subserved by context-dependent memory processes, the studies do not go far enough in terms of the complexity of the remembered stimuli nor do they isolate odours as solely effective environmental stimuli for such a process.

The present study was designed to investigate whether an odour can function as an effective retrieval cue for more complex stimuli such as passages of prose. The use of prose passages is more in keeping with the types of memories normally associated with odour-evoked autobiographical memory in that such memories are not usually of isolated objects or words (Laird, 1935; Gilbert and Wysocki, 1987; Herz and Cupchik, 1992). In addition, the present study attempted to compare stimuli from two modalities (olfactory and visual) to see whether the context-dependent memory effects previously identified are confined to olfactory stimuli.

Participants were exposed to an odour or colour while learning a prose passage and were later tested for recall with the original learning context either reinstated or not reinstated. The passage of prose was printed on either mildly scented paper (odour context condition) or coloured paper (colour context condition). Comparisons were undertaken on both the quality and quantity of recall for each of the two modalities.

Materials and methods

Subjects

One hundred subjects (40 males, 60 females) from the student population of The Flinders University of South Australia participated in the experiment for a small financial reward. The subjects ranged in age from 17 to 35 years. Of the 100 subjects, data from five were discarded, two subjects evidencing some colour vision deficiency and three poor olfactory acuity, resulting in a final subject pool of 95.

Materials

Prose passage

The prose passage chosen was adapted from the Rivermead Behavioural Memory Test (RBMT) Story Recall subtest (Wilson *et al.*, 1985). The passage consists of 60 'words' organized into 21 'ideas':

Two hundred men / at a shipyard / in Newcastle / went on strike / this morning. / The men / walked out / over a dispute / concerning fifty / redundancies. / The shop steward / Mr Thomas Lindsay / told reporters / 'It is outrageous! / The Company has full order books / for the next two years.' / A management spokesman said / 'We are hoping to begin / fresh negotiations / at head office / tomorrow.'

Scoring is performed by allocating one point for a word perfect recall of each idea and half a point for a close synonym. A scoring protocol for the passage was developed by the authors; in addition, an independent judge was employed to score the data. High inter-rater reliability was demonstrated with an α of 0.99.

Olfactory context cue

The odour of peppermint was selected to serve as the olfactory context cue for several reasons. Firstly, in terms of practicality, peppermint essence (the odour source) is a readily available substance requiring no special preparation in order to be impregnated into the paper containing the prose passage. Secondly, the odour was previously judged to be highly familiar and neutral in pleasantness, two characteristics which may counter any potential novelty effects resulting from the presence of the odour during the experimental sessions.

The RBMT passages for the odour context condition were prepared by impregnating 10 ml of peppermint essence into white A4 sheets of paper. Impregnation was achieved by applying the essence across the top of the page containing the prose passage using a standard 300 ml disposable syringe. Prior testing with a similar subject pool revealed that this amount of essence produced an odour which was noticeable but not overpowering; in addition, no visual evidence of the application was apparent to the

subjects. Each impregnated page was prepared and stored in sealed A4 plastic bags half an hour prior to presentation to maintain the desired level of intensity.

Colour context cue

Kaskad canary yellow was chosen as the colour context cue. Canary yellow was selected to allow clear discrimination of the prose passage without changing the colour of the text (black) from that used in the olfactory context cue condition. In order to maintain the similarities between the conditions the colour context cue pages were also stored in sealed A4 plastic bags.

Distracter task

A word finder puzzle was employed as the distracter task. The subjects were instructed to find and circle as many words as they could in a matrix of letters.

Screening tests

Subjects were screened to assess colour vision using the Ishihara Test for Colour Blindness 6 Plate Short Form (Ishihara, 1968). Olfactory acuity was assessed using an eight-item questionnaire. The first two items referred to the subject's age and gender. The other six items related specifically to medical conditions (e.g. sinusitis and rhinitis), use of medication and smoking habits, all of which may influence a subject's ability to perceive olfactory stimuli (Schiffman, 1992). Subjects were also asked to provide information about their past and present medical and personal history in relation to each of the items.

Experimental environment

The experiment was conducted in a suite of eight cubicles. The cubicles were identical in both size (width 1750 mm; length 2750 mm; height 2710 mm) and decor (each cubicle contained a chair, desk and computer workstation). Four of the cubicles were designated as the learning environment and the remainder as the recall environment.

Procedure

The subjects were tested in groups of four, with each subject commencing the study in one of the learning environment cubicles. Once seated, the subjects were asked to read an instruction sheet which briefly outlined the procedures involved. Each subject was then asked to remove the prose passage from the sealed plastic bag. Depending on which condition the subject had been randomly allocated to, the bag would have contained the prose passage printed on either a yellow page or a white page impregnated with the odour. Two minutes were allowed for the subjects to learn the passage before beginning the distracter task. At no time was the subject's attention intentionally drawn to the environmental manipulations, and post-experimental debriefing revealed that the subjects had not associated the olfactory or visual stimuli with the passage of prose.

After 5 min of working on the distracter task the subjects were escorted to the adjacent cubicle where they were asked

to remove a recall sheet from the plastic bag. Subjects in the olfactory context condition received a plastic bag containing either a blank impregnated sheet of white A4 paper (odour odour) or an unscented white A4 sheet of paper (odour no-odour). Subjects in the colour context condition received a plastic bag containing either a blank sheet of canary yellow A4 paper (colour colour) or a white A4 sheet of paper (colour no-colour). The subjects were instructed to write down as much of the prose passage, word for word, as they could recall. Once the experiment had been completed the subjects were asked to fill out the olfactory acuity questionnaire followed by the administration of the Ishihara Colour Blindness Test.

Results

Raw scores were calculated by summing the ratings ($\frac{1}{2}$ or 1 point) for each idea recalled, resulting in a maximum score of 21. Table 1 presents the raw scores for each of the conditions along with the norms for the RBMT Story Recall subtest. The range of scores obtained in the present study is comparable to the norms reported from the standardization sample. In order to compare the effects of context dependency on the subjects' recall, the raw scores were transformed into quantity of recall (total percentage of ideas recalled) and quality of recall (percentage of word perfect ideas recalled). The descriptive statistics for these variables can be found in Table 2.

Within the colour context condition, reinstatement of the original learning environment had no effect on either the quantity or quality of recall as confirmed using independent samples *t*-tests [$t(46) = 0.14$, $P = 0.89$ and $t(46) = 0.10$, $P = 0.92$ respectively]. A strong context-dependent learning factor was evident in the olfactory context condition for quantity of recall [$t(45) = 2.95$, $P = 0.01$]. In real terms, subjects who had the original learning environment reinstated recalled 12% more of the story than subjects whose recall environment differed from the learning environment. An increase in quality of recall approaching significance was also identified [$t(45) = 1.87$, $P = 0.07$].

In a comparison between modalities, subjects recalled 6.46% more information and were 4.50% more accurate when an olfactory cue was employed. However, independent samples *t*-tests failed to achieve statistical significance between quantity and quality of recall [$t(45) = 1.25$, $P = 0.22$ and $t(45) = 0.78$, $P = 0.44$ respectively].

Discussion

Context-dependent memory effects were found for the quantity of material remembered when an olfactory stimulus was employed but not when a visual cue was used. While the quality of the material remembered approached significance in the olfactory condition no such trend was identified in the visual condition. The present study has replicated the findings of previous studies of olfactory

Table 1 Raw recall scores for each of the conditions and the normal scores from the RBMT standardization sample

	Mean	SD	<i>n</i>	Range
RBMT	8.60	4.06	118	NA
Colour no-colour	9.76	3.73	25	2.50–16.50
Colour colour	9.61	4.04	23	3.50–16.50
Odour no-odour	8.50	2.60	23	3.50–13.50
Odour odour	10.90	2.94	24	4.50–16.00

Table 2 Comparison of the percentage of quality and quantity of recall for the colour and olfactory context conditions

	Mean	SD
<i>Colour context condition</i>		
Quality of recall		
Colour no-colour	33.00	18.54
Colour colour	32.40	22.30
Quantity of recall		
Colour no-colour	48.80	18.63
Colour colour	48.04	20.18
<i>Olfactory context condition</i>		
Quality of recall*		
Odour no-odour	28.70	12.90
Odour odour	36.90	16.80
Quantity of recall**		
Odour no-odour	42.50	13.01
Odour odour	54.50	14.71

* $P = 0.07$; ** $P = 0.01$.

context-dependent memory processes, adding weight to the robustness of the phenomenon (Smith *et al.*, 1982; Cann and Ross, 1989; Schab, 1990). Furthermore, the results extend such findings by demonstrating that the effect holds for more complex to-be-remembered material.

While the effects of the olfactory cue are most salient, the lack of effect of the visual cue is intriguing. Why would an olfactory cue become associated in a contextual manner with the passage of prose but not a visual cue? Investigations of context-dependent memory processes have concentrated on the type of learning paradigm employed and the to-be-remembered stimuli but have not addressed the issue of what aspects of the context are important in the formation of context-dependent memory.

Due to the inherent difficulties in equating two stimuli from different modalities, it is possible that the reason for the differences between the two conditions lies in the complexity or novelty of the stimuli. Whether the odour of peppermint essence constitutes a more novel or complex cue than a bright yellow sheet of paper is difficult to evaluate. Post-experimental debriefings indicated that neither stimulus was particularly salient for the subjects; however, it is

possible that differences between the two stimuli were processed at a subconscious or incidental level.

Another possible explanation for the differences stems from the suggestion that olfactory memory involves fundamentally different processes to the memory for stimuli from other modalities (Engen *et al.*, 1973; Lawless and Cain, 1975; Engen, 1982). Certainly the physiology of the olfactory system is much different to the physiology of the verbal and visual systems, with very close associations between the hippocampus (implicated in the formation and storage of memories) and the olfactory bulb (Gervais *et al.*, 1988; Dodd and Castellucci, 1991; Engen, 1991; McLean and Shipley, 1992; Reid and Morris, 1993). How such a physiological difference would contribute to performance in various memory tasks has yet to be elucidated or consistently proven to exist (Annett, 1996).

Regardless of the differences between odours and colours in the current study, the present findings offer a new direction for the investigation of odour-evoked autobiographical memory. The effectiveness with which olfactory stimuli can be associated with prose passages provides support for the suggestion that context-dependent memory processes may underlie odour-evoked autobiographical memory. Ambient odours present at the time of the autobiographical event may be encoded as a part of the context and, at some later date, can trigger recall of that event by reinstating the original encoding environment.

The context-dependent memory paradigm will, potentially, allow researchers to operationalize characteristics of odour-evoked autobiographical memories and provide a means for experimental manipulation. By employing different olfactory stimuli with characteristics known to influence the elicitation of autobiographical memories (e.g. familiarity, pleasantness) a more complete understanding of the relationship between odours and memory may be forthcoming. Similarly, experimental manipulation of the to-be-remembered material would provide the same opportunity to examine which characteristics of the autobiographical memories are important in odour-evoked autobiographical memory formation and retrieval.

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