



## Relaxed conditions can provide memory cues in both undergraduates and primary school children

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**Background.** Memory can be impaired by changes between the contexts of learning and retrieval (context-dependent memory, CDM). However, the reminder properties of context have usually been investigated by experimental manipulation of cues in isolation, underestimating CDM that results from interactions between cues.

**Aims.** To test whether CDM can be demonstrated using multiple contextual cues combined to create relaxing versus neutral contexts at separate learning and memory testing stages of the experiments.

**Sample.** Forty university undergraduates (in Experiment 1), and forty 9-10 year-olds (in Experiment 2).

**Methods.** All participants were given age-appropriate tasks under either relaxing or neutral conditions. The next day they were tested for retrieval or practice effects, under the same or different (relaxing versus neutral) conditions.

**Results.** For both age groups, there was a (mostly asymmetric) CDM effect with performance generally best in the relaxing – relaxing condition. There was also some overall benefit of having learned under relaxed conditions.

**Conclusion.** A relaxed learning environment can provide effective retrieval cues, as well as improve learning.

**Comment.** For both primary school children and university students, the educational implication of these findings is that learning can be improved in a relaxed state. For this benefit to be fully manifest, the assessment of learning should also take place under relaxed conditions.

Given that test anxiety can interfere with learning and memory, it would be expected that a relaxing study environment should have generally beneficial effects. However, test environments are seldom relaxing and memory can be impaired by changes in the

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context of learning and retrieval. So-called context dependent memory (CDM) is seen when material is best remembered if the circumstances of learning and retrieval are the same. Thus the presence of (at least some of) the cues that were around at encoding provides an effective reminder. This phenomenon of 'encoding specificity' (Tulving & Thomson, 1973) is a common daily occurrence for many people: for example, the recollection of past events when returning to one's home town, from hearing a particular piece of music or smelling a familiar scent. These triggers are highly idiosyncratic and so difficult to study experimentally. However, similar context-dependent effects have been studied using exposure to controlled experimental contexts, which can be external (Godden & Baddeley, 1975), or provided by internal cues like mood (Clark & Teasdale, 1981).

Experimental decreases in arousal, associated with calming effects, have received little attention as possible retrieval cues. It is known that that mood changes and increased arousal can support CDM (e.g., Clark, Milberg, & Ross, 1983) but relatively little attention has been given to the effects of low arousal or relaxation, and its influence on CDM. This despite the fact that stimuli like music and odour that could contribute to a relaxed learning environment (Hallam & Price, 1998) are known to result in CDM (see, e.g., Balch & Lewis, 1996; Schab, 1990).

We therefore selected cues both on the basis of their likely ability effectively to promote relaxation in both children and adults, and the previous evidence suggesting that they would be likely to act as effective reminders. CDM has already been found for experimentally-induced moods (Bower, Monteiro, & Gilligan, 1978; Eich & Metcalf, 1989; Kenealy, 1997) and for spontaneous variation in mood (Clark & Teasdale, 1981; Johnson & Magaro, 1987). In the present study, we used a variety of cues to produce a relaxing context.

Consistent with the well-known fact that odour and music are particularly evocative for so-called Proustian memory, under experimental conditions odour cues support robust CDM (e.g., Aggleton & Waskett, 1999; Engen & Ross, 1973; Goldman & Seamon, 1992; Rubin, Groth, & Goldsmith, 1984; Schab, 1990; Smith, Standing, & de Man, 1992). Parker, Ngu, and Cassaday (2001) found that reintroduction of the same ambient odour (lemon or lavender) improved the performance of undergraduate students some four weeks later, in this case on both free recall and recognition of a word list. Since the claims made for the effects on cognition and mood of certain odours used in aromatherapy receive some experimental support (Martin, 1996), in the present study we used lavender oil as a component of the relaxing context.

Similar CDM effects have been reported for musical contexts: for example, with instrumental music versus white noise, participants performed better if they were in the same context at retrieval as at encoding (Smith, 1985). Similar effects are produced if the music tempo is changed (Balch & Lewis, 1996). Alterations in tempo were found to influence the arousal dimension of mood and recall was also higher in a mood context consistent with a particular tempo. In the present experiments, we used classical music as a component of the relaxing context.

The effects of different contextual manipulations might be independent and additive, or interactive if they together produce some emergent effect. One such possibility is that odour, music and mood manipulations affect arousal (but see Schab, 1990). Anecdotal evidence suggests that arousal can have potent effects on memory, providing a possible account of memories retrieved under hypnosis. Experimental evidence suggests that arousal may act as a direct cue for arousal-related material in memory and second prompt mood cueing for mood-related material (see e.g., Clark *et al.*, 1983). In

the case of students, the detrimental effects of performance anxiety associated with aversive increases in arousal are well documented (e.g., Hodge, McCormick, & Elliot, 1997; Musch & Broder, 1999). Test performance could be impaired both by direct effects of raised anxiety and also because it provides a mental context incongruent with that associated with learning.

Thus not only is the manipulation of single cues in isolation somewhat artificial given that context is intrinsically multi-modal, where changes in arousal might be involved, effects are anyway typically confounded. The ecological validity of multiply determined experimental contexts is also higher in that they better simulate naturally occurring context changes. In everyday life, many factors contribute to a context change, for example from a student bedroom to the examination hall the odour, sounds, mood, lighting and social group are likely to alter. In an experimental study, Parker and Gellatly (1997) found a greater CDM effect with two cues rather than one, consistent with a gradient of effects. Similarly for mood, Eich, Macaulay, and Ryan (1994) found a change in two dimensions of mood (pleasantness and arousal) produced a greater CDM effect relative to a single change.

Thus it is likely that the entire mental context of an episode contributes to CDM. These internal cues would include a variety of representations, including mood, active memories and other incidental factors (Smith, 1995). The present experiment therefore used multiple contextual cues to induce a relaxed mental context.

## EXPERIMENT I

Experiment 1 tested learning and retrieval or practice effects using both free recall and cued recall of the same word list, then a Tower of Hanoi task (see Luger & Bauer, 1978), to see whether effects would generalise to aspects of problem-solving necessary to educational success.

## Method

### Sample

Volunteers for this experiment were 40 undergraduates from the University of Nottingham, selected by opportunity sample (26 females and 14 males, with a mean age of 20.7 years).

### Design

Four conditions were needed to demonstrate context dependency and were achieved by using a  $2 \times 2$  between-subjects design with two independent variables: Learning context and Testing context. The cross-over design generated four experimental conditions: relaxing at learning followed by relaxing at testing (R-R); neutral at learning followed by neutral at testing (N-N); relaxing at learning followed by neutral at testing (R-N); and neutral at learning followed by relaxing at testing (N-R). Task had three within-subject levels (free recall, cued recall and the Tower of Hanoi problem).

### **Test materials**

The same list of 20 words was used to test both free and cued recall. This list was made up of five categories each consisting of four nouns derived from Battig and Montague's (1969) taxonomy norms (average word length 5 letters, range 3-6). Each category list was comprised of words from the top eight examples of that category (words with strong association to avoid possible floor effects in recall). A stopwatch was used to allow one minute to memorise the word list. Participants were not required to remember the category names. A version of the Tower of Hanoi, consisting of three prongs and four disks, was used for the problem-solving task.

For the relaxing context, 0.2 ml of essential lavender oil was placed in a lit oil diffuser with 5 ml of cold water and allowed to diffuse around the room for five minutes. Relaxing music was provided by an excerpt of Mozart (Cambridge, Ronan O'Hora, 1996) from the Royal Philharmonic Collection of Sonatas in A minor (K.310 and K.331), C major (K.545) and A major (K.331) that was played for the duration.

### **Procedure**

Participants were semi-randomly assigned to one of the four conditions (up to the total of 10 per condition), counterbalancing the numbers of males and females in each group as far as possible. Apart from the intended contextual manipulations all other variables (like the room and furnishings and time of day) were kept constant.

For the relaxing context, in addition to the use of odour and music, the lights were dimmed and the experimenter also followed a more conversational protocol with additional reassurances in the task instructions: for example, for the category lists: *20% of people score less than 50% on this task, so don't worry if you can't remember them all.* The one-minute exposure to the word lists was followed by an immediate memory test to give the impression that the experiment was complete and so reduce the likelihood of further rehearsal. Participants were allowed two minutes to write down as many words as they could remember from the original word list, in any order, on a single sheet of A4 paper with the numbers 1-20 printed on the left hand side. The immediate test data were not included in the statistical analyses because (as would be expected) participants performed close to ceiling.

The Tower of Hanoi task followed. Again basic instructions were given in both relaxing and neutral conditions: *Move the four disks from pole A to pole C, moving only one disk at a time, never placing a larger disk on top of a smaller one.* In addition, further instructions and the tone of delivery were particularly reassuring for the relaxing condition: *Don't worry if you find it hard at first, as most people take practice, needing about 40 moves, but you will soon get the hang of it. Again just do your best.* In both conditions, further attempts were allowed until all participants were able to complete the problem in the minimum number of moves, so that during the learning stage all participants reached the same level (and again a sense of completion was given).

Exactly 24 hours later (to avoid the ceiling and floor effects associated with short and long delays, respectively) the students returned for the test in their assigned experimental condition that could be congruent (N-N, R-R) or incongruent (N-R, R-N). In addition to the basic task instructions, relaxing instructions at recall were the same as those used in the learning phase. Participants started with a free recall test of the original word list, as used in the immediate recall test. Second, for cued recall, the category labels were printed on the paper with the numbers 1-4 written underneath

them. Once again, two minutes were given for the student to write down as many of the words as they could remember. Third, participants were again asked to solve the same Tower of Hanoi problem. Then, on completion, they were thanked for participating in the experiment.

### Statistical methods

To allow statistical comparison of performance across the tasks, the dependent variable was in each case the number of errors made, i.e., the number of wrong or blank answers given in the free recall and cued recall task and, for the Tower of Hanoi, the number of moves above the optimal 15 needed to solve the task at testing. The data were entered into a  $2 \times 2 \times 3$  mixed (split plot) analysis of variance (ANOVA). Between-subjects the factors were Learning context and Testing context; the recall tests were within-subjects. Interactions between Learning and Testing arise because the effect of the (relaxed versus neutral) testing context depends on the (relaxed versus neutral) learning context. Thus it is the significance or otherwise of the interaction that tests for the presence or absence of CDM (see Abelson, 1995).

Interactions were further explored by analyses of simple main effects. For example, significant effects of Learning and Testing, at both (relaxed and neutral) levels of testing and learning respectively, would mean that the observed CDM effect was symmetric.

### Results

Table 1 shows the mean number of errors made in each of the four experimental conditions for the three task types. As would be expected, the number of errors tended to be lower for cued than for the preceding free recall task.

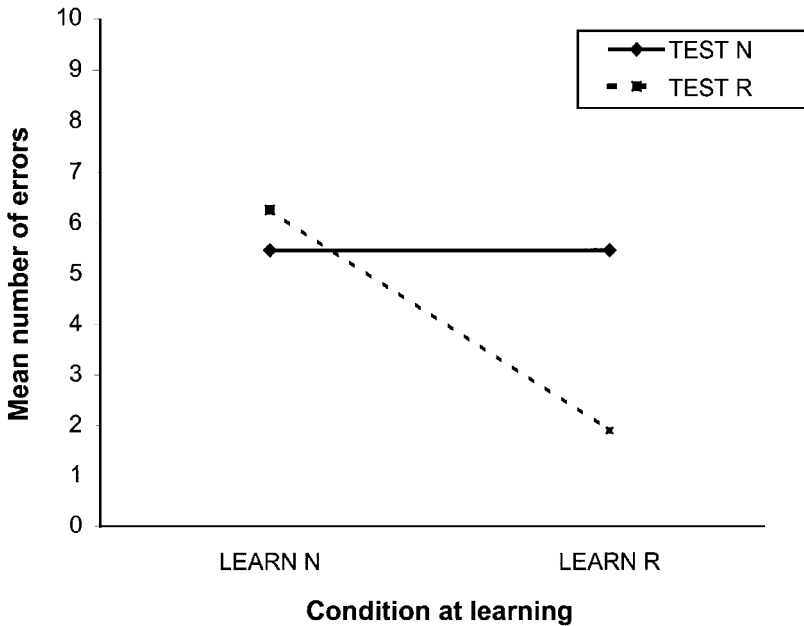
**Table 1.** Experiment 1: Effects of relaxing test conditions across a variety of tasks in undergraduate participants

CONDITION TASK	Neutral-Neutral	Neutral-Relaxing	Relaxing-Neutral	Relaxing-Relaxing
Free recall	9.1 ( $\pm$ 1.1)	6.4 ( $\pm$ 1.2)	5.4 ( $\pm$ 1.2)	1.8 ( $\pm$ 0.8)
Cued recall	5.7 ( $\pm$ 1.0)	3.5 ( $\pm$ 0.9)	3.5 ( $\pm$ 0.9)	0.9 ( $\pm$ 0.5)
Problem solving	1.6 ( $\pm$ 0.7)	8.9 ( $\pm$ 3.2)	7.5 ( $\pm$ 1.9)	3.0 ( $\pm$ 0.9)

Note. Table shows mean number of errors ( $\pm$  standard errors) for each of the congruent (neutral-neutral, relaxing-relaxing) vs. incongruent (neutral-relaxing, relaxing-neutral) recall conditions in the three tasks of learning and memory (free and cued recall and problem-solving).

Statistically, there was a significant main effect of Learning context ( $F_{1,36} = 8.57$ ,  $p < .01$ ), but not of Testing context ( $F_{1,36} = 3.44$ ). The main effect of Task was also non-significant ( $F_{2,72} = 2.87$ ), so the participants made comparable numbers of errors across the different tasks.

There was a significant two-way interaction effect between Learning and Testing ( $F_{1,72} = 8.57$ ,  $p < .01$ ), but not between Learning and Task ( $F_{2,72} = 2.13$ ) or between Testing and Task ( $F_{2,72} = 2.91$ ). The interaction between Learning and Testing most obviously arises from a reduction in the number of errors in the R-R condition (see Figure 1).



**Figure 1.** Statistical interaction between Learning and Testing context in Experiment 1, collapsed across task types to show how overall errors depend on participants' induced mental state: N = neutral conditions; R = relaxing conditions

Analysis of simple main effects of this interaction showed that there was an effect of Learning at the relaxed level of testing context ( $F_{1,36} = 17.14, p < .001$ ) and of Testing at the relaxed level of learning context ( $F_{1,36} = 11.43, p < .01$ ). This means that the overall CDM effect arose asymmetrically because of the particular effectiveness of the (reinstated) relaxing condition in reducing the number of errors.

There was also a significant three-way interaction between Learning, Testing and Task ( $F_{2,72} = 5.08, p < .01$ ). Simple simple main effects for this interaction showed that, for the Tower of Hanoi task (only), there were significant effects of Learning at both levels of testing context and of Testing at both levels of learning context (minimum  $F_{1,36} = 6.07, p < .05$ ). This means that (in contrast to the overall effect that was clearly asymmetric) the CDM effect seen for the Tower of Hanoi task was symmetric. Table 1 shows that, for this task, as well as the improvement produced by reinstating relaxing conditions, fewer test errors were also made when both learning and test conditions had been neutral in the congruent (N-N) condition, than in either incongruent condition (N-R or R-N).

## Discussion

Undergraduate participants performed better when tested under relaxed conditions, provided that their initial exposure to the tasks had also been under relaxed conditions. For cued and free recall, the effect was asymmetric in that reinstating the relaxing context provided more effective reminders than those that were produced by reinstating the neutral context (i.e., CDM was seen for the congruent context R-R but not for N-N). It is possible that this asymmetry arose from additive beneficial effects

of relaxed conditions at both initial learning and the re-test (that were demonstrated by the simple main effects analyses for the Learning by Testing interaction).

However, the CDM effect for problem-solving was symmetric: on the Tower of Hanoi task, fewer errors were made in either of the congruent conditions (R-R and N-N) than in either of the incongruent conditions (R-N or N-R). This was confirmed statistically by the simple main effects analyses for the three-way interaction between Learning, Testing and Task. The fact that the neutral context also provided an effective reminder for this task suggests the possibility that it was even more susceptible to contextual cueing than the conventional tests of free and cued recall (see General Discussion, below)

## EXPERIMENT 2

Previous research examining the influence of multiple cues on memory has generally focused on undergraduate populations, as in Experiment 1 of the present study. There are known to be developmental changes in memory processes, for example, the increasing use of retrieval cues with age (Kobasigawa, 1974). In older participants, such strategies might decrease susceptibility to the disruptive effects of context change as contextual effects are easily 'outshone' by competing cues. There is also evidence that children in particular do best when retrieval cues are closely associated with the encoded information (Ackerman, 1981, 1985) and this high encoding specificity (Tulving & Thomson, 1973) might make them less sensitive to context-dependent effects. Experiment 2 therefore assessed CDM in primary school children using a similar contextual manipulation but with easier task variants, specially devised to be age appropriate. These tested memory with both visual and auditory presentation and problem-solving using a simpler version of the Tower of Hanoi task.

The basic design was as for Experiment 1, except that we also analysed performance on the immediate recall task. This was done to check how the attention of younger children might be affected by relaxing conditions at encoding and also gave a measure of how initial learning was affected by experimental manipulations.

## Method

### Sample

Participants consisted of a group of forty 9-10 year-old primary school children (20 females and 20 males with a mean age of 9.7 years). The experimental protocol was approved by the Ethics Committee, School of Psychology, University of Nottingham, and both headmistress' and parental consent were obtained by letter, including information about the tests and contact numbers for further information. The parents' letter had a tearoff reply slip to either give or withhold consent for each individual child.

### Design

Again this was a between-subjects cross-over design to generate four conditions (R-R, N-N, R-N and N-R). In this case, the dependent variables were the number of correctly

recalled items on age appropriate recall tasks (visual attention followed by auditory comprehension), and the number of moves made on an easier variant of the Tower of Hanoi problem-solving task. A measure of initial learning in each condition was also taken.

### **Test materials**

The visual attention task consisted of a scene from a kitchen, which depicted a range of hazards. The auditory comprehension task was provided by a passage of text, describing a scene from a story (that pilot tests showed was age appropriate in that it did not result ceiling or floor effects when recall was tested). The third part of this experiment tested problem-solving ability using the Tower of Hanoi. With three prongs and three disks, the optimal number of moves to reach the required solution was seven.

The neutral test environment was a large dining hall in which the child was required to sit at a desk. The room was fully illuminated and there was no experimental music or odour. For the relaxing condition, a smaller side room was used and a selection of background music from a classical compilation tape ('Classical Praise': Meditation by Massenet, Bach's 2<sup>nd</sup> Piano Concerto, Mahler's 5<sup>th</sup> Symphony) that was familiar from school assembly. In addition, cushions for seating, dimmed lighting and 0.2ml of essential lavender oil (diffused around the room for 15 minutes) were also used in the relaxing condition.

### **Procedure**

Participants were semi-randomly assigned to one of the four conditions (up to the total of 10 per condition), counterbalancing the numbers of males and females in each group, and tested in eight groups of five (counterbalanced for gender as far as possible). They were told that the experiment was about what types of activities children remember. They were presented with the auditory comprehension task first. The experimenter read the story passage aloud to the children, taking approximately five minutes. All participants were then given an A4 sheet of paper with numbers 1-10 printed down the left-hand side and verbally instructed to recall as many items as they could remember.

They were then given the visual attention task to complete. Each child was given a copy of a kitchen scene and instructed to look at the picture and find as many dangers as they could. Participants were then given a second sheet of A4 paper, again with the numbers 1-10 down the left-hand side and told to write down as many of the dangers as they could remember from the picture.

The final task was the problem-solving task using the Tower of Hanoi. The experimenter informed each child participant of the rules to the problem and demonstrated its completion in the optimal number of moves, and the children were given a practice trial. Then they were told to try and complete the task, but this time using the fewest number of moves possible. Participants were given five minutes to complete each task (but they were not informed of this time limit so there could be no time pressure). For all tasks, immediate performance was assessed in the same environment as learning (prior to testing for CDM effects).

Exactly 24 hours later (to avoid ceiling effects for shorter, and floor effects for longer intervals) the children were tested for CDM on each of the three tasks in their assigned (congruent versus incongruent) condition. They were again provided with two sheets



of A4 paper, identical to the ones they had been given on the previous day, asked to recall as many items as possible from the story passage and list them on the answer sheet provided. Next they were told to recall as many dangers from the kitchen scene as they could remember. Finally, participants were presented with the Tower of Hanoi and instructed to complete the problem, using the fewest number of moves possible. Again they had five minutes in which to complete each task. On completion of the test session, all the children were thanked for taking part in the study.

### **Statistical methods**

The effects of relaxation on immediate recall were assessed by *t*-test. Then multivariate ANOVAs were used to test for CDM on each of the three tasks separately because the dependent variable was not uniform across all of the tasks (young children show many errors of commission as well as omission, so we did not convert to number of errors to allow comparison across tasks in a mixed design, as in Experiment 1). Between-subjects factors were Learning context and Testing context. Significant interactions were explored by analysis of simple main effects.

## **Results**

### **Immediate recall**

Table 2A shows that the relaxed condition enhanced immediate recall performance on the visual attention ( $t_{38} = 2.52, p < .05$ ) and auditory comprehension ( $t_{38} = 3.24, p < .01$ ) tasks, and the problem-solving task was completed in fewer moves ( $t_{38} = 2.19, p < .05$ ) in the relaxed condition.

### **Context dependent retrieval**

Table 2B shows that the improvement seen under relaxed learning conditions was clearly seen at the retrieval tests when relaxed conditions were reinstated, reflecting CDM. For retrieval of the visual attention task, statistically, there was a significant main effect for Learning context ( $F_{1,36} = 5.20, p < .05$ ), but not for Testing context ( $F_{1,36} = 3.61$ ). The main effect Learning arose because overall children recalled more correct items after relaxed than after neutral learning conditions (so they tended to do better in incongruent condition R-N than in incongruent condition N-R). There was a significant two-way interaction between Learning and Testing ( $F_{1,36} = 7.08, p < .05$ ). Simple main effects analysis showed that there was an effect of both Learning at the relaxed level of testing ( $F_{1,36} = 12.22, p < .01$ ) and Testing ( $F_{1,36} = 10.41, p < 0.01$ ) at the relaxed level of learning. Table 2B shows the asymmetry in CDM in that children recalled more items correctly when exposed to relaxed conditions at both learning and test than in any other condition, including the congruent N-N condition.

For retrieval of the auditory comprehension task, there was also a significant effect of Learning context ( $F_{1,36} = 28.55, p < .001$ ), but not for Testing context ( $F_{1,36} = 1.44$ ). Table 2B shows that test performance was again overall better when learning had occurred under relaxing (rather than neutral) conditions (and performance was better in incongruent condition R-N than in incongruent condition N-R). As for the visual attention task, there was a significant two-way interaction between Learning and Testing ( $F_{1,36} = 28.55, p < .001$ ). Simple main effects analysis showed that, as well as

**Table 2.** Experiment 2: Effects of relaxed testing conditions across a variety of tasks in 9–10 year-old children**A Immediate recall**

CONDITION TASK	Neutral at Learning	Relaxing at Learning
Visual attention	5.95 ( $\pm$ 0.39)	7.35 ( $\pm$ 0.40)
Auditory comprehension	5.50 ( $\pm$ 0.44)	7.35 ( $\pm$ 0.36)
Problem solving	27.15 ( $\pm$ 1.67)	23.00 ( $\pm$ 0.90)

**B Delayed recall**

CONDITION TASK	Neutral-Neutral	Neutral-Relaxing	Relaxing-Neutral	Relaxing-Relaxing
Visual attention	5.70 ( $\pm$ 0.76)	5.30 ( $\pm$ 0.30)	5.50 ( $\pm$ 0.31)	7.90 ( $\pm$ 0.59)
Auditory comprehension	5.40 ( $\pm$ 0.50)	3.50 ( $\pm$ 0.52)	5.40 ( $\pm$ 0.37)	8.40 ( $\pm$ 0.43)
Problem solving	26.00 ( $\pm$ 1.09)	27.20 ( $\pm$ 1.02)	25.60 ( $\pm$ 0.64)	18.90 ( $\pm$ 0.72)

A. Encoding effects: Means ( $\pm$  standard errors) for each of the (relaxed vs. neutral) learning conditions. The dependent variables were the number of correctly recalled items for the visual attention and auditory comprehension tasks and the number of items correctly placed in the problem-solving task.

B. Retrieval effects: Means ( $\pm$  standard errors) for each of the congruent (neutral-neutral, relaxing-relaxing) vs. incongruent (neutral-relaxing, relaxing-neutral) recall conditions in the three tasks of learning and memory (free and cued recall and problem-solving). The dependent variables were the number of correctly recalled items for the visual attention and auditory comprehension tasks, and the number of moves made in the problem-solving task (in the latter task, low scores reflect better performance).

an effect of both Learning at the relaxed level of testing ( $F_{1,36} = 57.09, p < .001$ ) and of Testing at the relaxed level of learning ( $F_{1,36} = 21.40, p < .001$ ), there was in this case also an effect of Testing at the neutral level of learning ( $F_{1,36} = 8.58, p < .01$ ). Since there was no significant effect of Learning at the neutral level of testing, this pattern of effects means that the CDM effect was still asymmetric. Table 2B shows this asymmetry in that contextual reinstatement was of most benefit in the R-R condition, though in this case performance in the N-N condition was somewhat improved relative to the incongruent N-R condition.

For the problem-solving task, there was a significant main effect for Learning context ( $F_{1,36} = 24.08, p < .001$ ), and also for Testing context ( $F_{1,36} = 9.62, p < .01$ ). The main effect of Learning arose because children again did better if their first exposure to the task was under relaxed conditions, especially so when they were also tested under relaxed conditions (see Table 2B). This was confirmed by a significant two-way interaction between Learning and Testing ( $F_{1,36} = 19.85, p < .001$ ). Simple main effects analysis showed that there was an effect of both Learning at the relaxed level of testing ( $F_{1,36} = 43.83, p < .001$ ) and Testing at the relaxed level of learning ( $F_{1,36} = 28.56, p < .001$ ). Table 2B shows the asymmetry in CDM in that children showed more positive transfer (from their initial exposure to the tasks to the re-test) under relaxed conditions at both learning and test than in any other condition, including the congruent N-N condition.

## Discussion

The results with the 9-10 year-olds tested in Experiment 2 confirm and extend those seen in Experiment 1 with older participants. Immediate recall (still in the initial environmental context) was introduced as a methodological refinement for testing younger children (to check for any initial differences in attending to or learning the tasks). Then, as in Experiment 1, the cross-over design was applied to retrieval testing that could be under congruent or incongruent conditions.

For all the tasks, relaxing conditions improved performance on the initial task and reinstating relaxing conditions on the retest was particularly effective in facilitating recall. However, in contrast to the results obtained in Experiment 1, the CDM effect observed for problem-solving was asymmetric in that reinstating the relaxed context more effectively facilitated test performance than did reinstating the neutral context.

## GENERAL DISCUSSION

This study used a range of age appropriate tasks to assess the effects of experimentally-induced relaxation on the retrieval of a variety of learning abilities necessary to education. In general, performance was most improved by reinstating the relaxed condition (i.e., in the R-R condition compared with performance in the congruent N-N condition). This shows that the relaxed conditions in use were sufficiently distinctive to act as retrieval cues and so support CDM.

### *Asymmetry in CDM*

The benefits of contextual reminders were mostly asymmetric in that reinstating relaxed conditions led to better performance than reinstating neutral conditions. This was true for two of the three tasks used with the undergraduate sample and for the 9-10 year-olds across all tasks. Thus reinstating the neutral condition was not as beneficial as a cue to recall.

Previous studies with environmental context have tended to find symmetrical CDM. For example, Godden and Baddeley (1975) found that divers produced greatest levels of recall in congruent conditions: whether under water or on land, it was congruence that mattered. However, whilst effects of auditory context can be demonstrated, and Smith (1985) found symmetrical CDM for instrumental versus white noise conditions, a 'no noise' condition did not provide an effective reminder cue. This finding is similar to that of the present study in that the neutral environmental context represents the absence of any salient environmental intervention that would produce distinctive contextual cues. Similarly, studies with odour-based CDM have found that this effect is greater when the odours in use are novel and therefore distinctive (Herz, 1997). Furthermore, the neutral environments used were also typical and familiar learning environments to which participants would most likely be habituated.

Thus one possible explanation for the generally greater effectiveness of R-R over N-N as a congruent state is that the context provided in the neutral condition is impoverished compared with that seen in the relaxing condition. A similar pattern of effects was found by Smith (1985) who found that whilst a CDM effect could be demonstrated for instrumental versus white noise, there was no such effect against a 'no noise' condition. Thus the distinct manipulation of noise did show an effect, but 'no

noise' was not a beneficial reminder and this may be analogous to the relative lack of effect of the neutral condition (that was not particularly distinctive) in the present study. By contrast, whilst (in the neutral condition) the room in itself was unremarkable, in the relaxing condition, the playing of music, the lavender odour and the relaxing manner of the experimenter would all be relatively novel in the context of an experiment or classroom (cf. Herz, 1997).

Fernandez and Glenberg (1985) offer a similar explanation of their failure to find a CDM effect for location. On this account, our observed effects would tend to be asymmetric because the manipulation of environmental context was inherently asymmetric, with neutral baseline conditions insufficiently salient to provide effective retrieval cues. By contrast, the relaxing environment would have provided participants with a range of salient contextual cues to be encoded in memory alongside the to-be-remembered task items. The notion that neutral versus relaxing contexts are differentially effective in terms of the cues to recall provided fits the idea that cues can compete in encoding specificity (Tulving & Thomson, 1973) so that more obvious cues are more likely to provide better reminders through 'outshining' (Smith, 1988, p. 19).

However, there was a discrepancy in the findings of Experiments 1 and 2 in that the CDM effect for problem-solving was symmetric for older and asymmetric for younger participants. This could mean that, for the undergraduates, the harder Tower of Hanoi problem in use was even more susceptible to contextual cueing (because, in contrast to the CDM observed with conventional tests of free and cued recall, the neutral context also provided an effective reminder). Alternatively, this difference might arise because of some difference in the relative salience of the context designated neutral to the different age groups (given that it was effective as a reminder only for the undergraduates), or some age-related change in the strategies adopted and so the psychological demands imposed by what was notionally the same task.

### **CDM for problem-solving**

The effects of contextual reminders for problem-solving extend the findings obtained with standard memory tests. The CDM effect, seen in both the undergraduate and the 9-10 year-old sample, contrasts with a previous study using a Tower of Hanoi variant in which a lavender cue in isolation was not an effective cue to retrieval (Parker *et al.*, 2001). This difference in sensitivity is consistent with the view that single cue studies can seriously underestimate the size of CDM effects, or alternatively could be attributable to differences in the task variants in use.

The problem-solving task made different psychological demands (to the more conventional tests of free and cued recall) and (as such) was intended to test the generality of the observed effects. However, as posed here it was likely to provide participants with cues as the variants in use provide a strong external representation for the problem's current state and the rules to be applied (Kotovsky, Hayes, & Simon, 1985). This externalising of the representation should reduce the need for an internal representation and so facilitate memory, providing some analogy with more conventional tests of cued recall, which similarly provide external memory cues. To the extent that this analysis of the demands imposed by the task holds true, the CDM result obtained would be surprising, as tests of CDM where salient external cues are available tend to yield negative results (see Eich, 1980; Smith, 1988). However, for the Tower of Hanoi task, the moves necessary to its solution must be executed in a specific

order, and this results in a substantial increase in the memory load imposed. Thus in this respect the task provides a better analogy with conventional tests of free recall and the requirement to retrieve order information may well account for the improvement produced by further contextual reminders.

In general, performance in problem-solving tasks is significantly influenced by prior experience, the effects of which can be measured in transfer tests (see, e.g., Luger & Bauer, 1978; Parker *et al.*, 2001; Richardson & Webster, 1996). Transfer effects operate between tasks that are similarly structured with similar rules, and context extrinsic to the task can operate as a further cue in promoting the transfer of cognitive reasoning. The present study provides evidence that contextual reinstatement aids the recall of task specific strategies. Only further research will tell us how far contextual reminders may generalise across isomorphic tasks to improve reasoning across whole categories of problem.

### **Relaxed learning**

The design used to test for CDM is not ideal for examining the effects of arousal on memory and performance as the tasks in use are very varied and (on the Yerkes Dodson law) we would expect an interaction between arousal and task difficulty. However, in both experiments, the significant main effects of (prior) learning context (on re-test performance) reflected an overall benefit of being in the relaxing context at the first exposure to the tasks. And where we tested immediate recall in Experiment 2, this was improved in the relaxing condition for all the task variants.

Over and above, its clear effect as a contextual reminder, how might relaxing learners contribute to improved test performance? Lavender oil is used in aromatherapy as a relaxant and its sedative effects on inhalation have been experimentally confirmed (Buchbauer, Jirovetz, Jager, Dietrich, & Plank, 1991; Lis-Balchin & Hart, 1999). We have previously found that lavender improved performance in a Tower of Hanoi task, though here the effect was significant only at the second 'retrieval' performance (Parker *et al.*, 2001). The beneficial effect in the present study at learning may have been manifest at this earlier stage because of the additive effects of multiple components to the soothed mental context. Alternatively, the participants' soothed state at encoding may have carried over to their test condition without the need for further reinstatement. On this account, relaxing learners at the beginning of the study would to some extent reduce their apprehensions about the second phase of the experiment, irrespective of the test condition.

Whilst strong sedative actions would most likely impair rather than improve cognitive functioning, moderate levels of relaxation are likely to lower levels of apprehension and anxiety with beneficial effects. Such arousal-mediated effects are consistent with the hypothesis proposed by Easterbrook (1959), which examined the relationship between arousal level and task variables. On this hypothesis, increases in arousal restrict the range of environmental cues utilised by the organism, and such an effect could explain why HTA children use fewer task-relevant cues and may instead focus on negative self-deprecatory thoughts, which ultimately impair their performance on tasks (Prins & Hanewald, 1997; Zatz & Chassin, 1985). Conversely, providing HTA adults with a reassuring, task-orientated atmosphere reduced the performance deficits experienced by these individuals (see, e.g., Sarason, 1980). Similarly, for younger children, in informal classroom environments, background music has already been found to improve academic performance and this has been attributed to its calming

effects (e.g., Hallam & Price, 1998).

In the present study, decreased arousal under relaxed conditions could enable the subject to focus and encode a wider range of contextual cues alongside the task material. Thus increased processing at encoding may have enhanced recall performance, particularly when participants were provided with the same additional experimental reminders at test.

### ***Significance for context dependent memory literature***

What this study adds to the literature on context-dependent memory is an examination of the cueing effectiveness of a naturalistic multi-modal context in young children as well as adults. Many studies of context-dependent retrieval may have underestimated the effect because they have typically only manipulated a single unimodal aspect of the context. With respect to age, whilst there has been work on how children's memory is helped by specific cues (e.g., props like toys or photographs), context-dependent retrieval has rarely been investigated in young children (see review by Salmon, 2001). What studies there are suggest that contextual reinstatement is only effective as a cue to retrieval under limited conditions. It has even been suggested that children are only helped by stimuli specifically associated with the encoded material (Ackerman 1981, 1985; Tulving & Thomson, 1973).

With the use of a multi-modal context (likely to promote CDM) we cannot be certain which of the factors manipulated was critical in mediating the observed effects. In Experiment 1, other (physical) contextual factors like the room and its contents were held constant. In Experiment 2, the relaxed and neutral environments were set up in physically different rooms. In both experiments, participants learned and recalled the test materials at the same time of day. Thus the results find likely interpretation in the overall effect of the mental context produced by relaxing environmental conditions, experimentally manipulated with, for example, odour and music. We did not test the effectiveness of these manipulations in inducing relaxation directly and (even if we had) it would still not follow that a calmed state had necessarily mediated the observed effects. However, that relaxation was induced, particularly given the use of music and odour cues, seems likely (cf. Hallam & Price, 1998).

### ***Applications to education***

This study suggests that relaxed learning conditions can improve performance, especially when later test conditions are similarly relaxed. In the primary school children, we found that relaxing conditions also improved immediate recall. Furthermore, in both experiments, the prior learning context had carry-over effects on re-test performance, showing an overall benefit of being in the informal (relaxing) learning context at the first exposure to the tasks. This suggests that the benefit of a relaxed learning environment can prevail, even when it is necessary that students be tested under more normal conditions. These findings have clear educational implications, particularly where the emphasis on examination-based assessment is at issue. For example, in the UK, at primary school level, pupils are under increased pressure because of the use of national tests; by contrast, at an undergraduate level, there are now relatively fewer examination-based assessments and a greater emphasis on course work. Individual pressures to perform in examination tests, further exaggerated by the pressure to raise rankings at the institutional level, will undermine

the relaxed environment conducive to improving learning and test performance. As well as providing evidence pertinent to future changes in educational systems, the present study also suggests some practical solutions to the problem of underachievement in examination-style tests.

Previous research has shown the importance of the physical environment as a retrieval cue that demonstrably affects students' performance (Abernethy, 1940; Metzger, Boschee, Haugen, & Schnobrich, 1979). Thus we already know that there is an advantage in testing students in the same environment in which they learned, where possible. However, there is always the question of how effects of changed context are mediated and, in the case of different learning and examination environments, one plausible explanation is that the students feel more relaxed in their own classroom. Experiment 2 did involve a change of room. However, in Experiment 1, we showed an effect (over and above that produced by reinstating the room context) of portable cues, some of which could be adapted for use in an educational setting. For example, for younger children, classroom music can be entirely appropriate (see Hallam & Price, 1998). Whilst complete elimination of examination anxiety is likely to be impossible, our study also suggests that the manner of delivery of test instructions and invigilation style could, in conjunction with improvements in aspects of the physical environment, make for a significant difference in student performance. Moreover, we are likely to have underestimated the potential gains to be had since there was an advantage in relaxing learners under conditions unlikely to be particularly stressful to begin with. Finally, the fact that these effects are present in young adults and children alike shows that the potential for educational improvement could be considerable, from the early schooling.

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