

**RETROACTIVE INTERFERENCE IN VISUO-SPATIAL AND
VERBAL MEMORY**



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ABSTRACT

Two pilot studies were carried out to design a novel visuo-spatial recall task based on the 9-Box maze (Abrahams et al., 1997). Results highlight the need for such a task to take account of the probability of correct guesses in the scoring measure.

Two experiments (visuo-spatial & verbal) were designed to measure material-specific effects in a retroactive interference paradigm. Performance across interference tasks (Articulatory Suppression, Tapping, Reading & Map-search) were compared with a Minimal Interference condition shown in previous experiments (Cowan et al. 2004) to reduced RI effects. No material-specific effects were revealed in either experiment. RI effects were demonstrated in the verbal experiment, but not in the visuo-spatial.

The role of cross-modal encoding and rehearsal has been raised as a possible confounding factor. Future research might benefit from dividing participants based on preference for verbal or visuo-spatial encoding.

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1. INTRODUCTION

Memory and forgetting are everyday phenomena, and though they have been studied for over a century the processes which underlie them have not been easily understood. Early in the twentieth century it was thought that forgetting was due to decay of memory traces over time. This account of forgetting suggested that decay was perhaps a natural consequence of the passage of time. But a competing theory of memory postulated interference as the culprit of forgetting: either prior learning (proactive interference) or later learning (retroactive interference) were what caused us to forget (Wixted, 2004). So which explanation best explained forgetting, interference or decay?

Jenkins & Dallenbach (1924) found that subjects remembered more nonsense syllables after a sleep-filled delay than after an equal delay period in which subjects remained awake. Decay theory would predict no difference between the conditions, since it postulated that the passage of time was responsible for forgetting. But interference theory predicted less forgetting after sleep due to the absence of new learning. Hence decay theory was abandoned as the sole explanation of forgetting.

1.1 Interference theory

Underwood (1957) argued that prior learning was the main culprit in forgetting (proactive interference, PI), when for many studies he observed that nearly all the variability in retention of nonsense syllables after 24 hours could be explained by the variability in the number of prior lists learned. And since subjects' exposure to nonsense syllables was strictly limited to the learning of prior lists (nonsense syllables do not occur in natural speech) it seemed proactive interference was a reasonable explanation of forgetting.

However Jenkins & Dallenbach's (1924) sleep study contradicted it. If PI was responsible, why did sleep after learning new material have a positive effect on retention? Perhaps by eliminating later learning sleep produced beneficial effects on memory, by allowing recently formed memories to consolidate. Wixted (2004) explains that growing frustration with the inability of proactive interference theory to explain forgetting led to a paradigm shift. Interference was out of the explanatory picture for the time being.

Recent imaging studies on PI in healthy volunteers (Henson et al., 2002; Fletcher et al., 2000) still report significant effects of proactive interference on cued recall tasks. Henson et al. (2002) have even implicated the activation of different areas of prefrontal cortex during proactive interference. They postulate that the frontal cortex might be responsible for active inhibition of inappropriate responses during proactive interference. Ironically, Anderson (2003) outlines a detailed argument that such inhibitory control mechanisms might themselves be responsible for retroactive interference effects.

While PI could explain forgetting in the laboratory, a more ecologically valid account of forgetting was required.

1.2 Retroactive Interference

Early studies have long supported the theory that mental activity *after* learning interferes with recall (retroactive interference, RI). Skaggs (1925) demonstrated RI effects on memory for nonsense syllables after 6 minute delays, filled either with unrelated mental exertion (solving algebra problems) or mental quietude. He suggested that mental exertion after learning had a detrimental effect on the consolidation of memory traces.

Evidence from psychopharmacology has also supported the retroactive interference account. Excessive alcohol consumption is widely known to have anterograde amnesic effects, hindering the formation of new memories during intoxication. Numerous studies have reported that alcohol improves memory for material studied just before consumption (Bruce & Phil, 1997; Lamberty et al., 1990; Parker et al., 1980 & 1981). Similarly benzodiazepines, another class of amnesia-inducing drugs, have also shown beneficial effects on memory. Typically, recall is enhanced for word lists learned prior to taking the drug (Coenen & Van Luijtelaa, 1997). These findings are consistent with an account of RI which suggests that later learning disrupts the consolidation of recently formed memories.

1.3 Verbal memory & Retroactive Interference

Despite such compelling psychopharmacological evidence, surprisingly little research has been done on RI effects in humans to date. But one of the most striking recent findings in support of the RI paradigm of forgetting compared verbal recall of amnesiacs after filled and unfilled delays of either 10 minutes or 1 hour (Cowan et al., 2004). Stimuli which at first can be recalled by amnesiacs are usually forgotten within 1 minute. But Cowan et al. (2004) reported amnesiacs showed much less forgetting of stories (recall: 63%, 78% & 85%) under conditions of diminished RI (sitting in a dark quiet room) when compared with their performance (recall: 0%) after activity-filled delays (verbal and non-verbal psychometric tests). It suggests that one deficit underlying amnesia is a susceptibility to RI. Traditionally it was thought that the most recently presented stimuli inevitably fade from memory after a few seconds, but these findings suggest that they may remain accessible until additional stimuli are presented.

In a study on memory and meta-memory (subjects' predictions on their own recall performance), Eakin (2005) reported significant RI effects for cued recall of verbal stimuli. Interestingly, while recall was worse in the retroactive interference condition (consisting of interpolated study of a second set of target words related to the cue) participants' *predictions* of their subsequent performance were more positive than in the control condition, in which there was no interpolated learning. Participants demonstrated overconfidence in their ability to recall verbal stimuli under conditions of RI.

1.4 Visuo-spatial memory & Retroactive Interference

The most influential theory of hippocampal function, as a cognitive spatial map, has come from work in rats (O'Keefe & Nadel, 1978), and has since been supported in numerous studies including primates (Ono et al., 1991), food-storing birds (Shiflett et al., 2004) and humans (Parslow et al., 2005; Abrahams et al., 1997 & 1999; Baxendale et al., 1998). But is spatial memory susceptible to retroactive interference effects?

Izquierdo et al. (1999) demonstrated RI effects in rats for a one-trial step-down inhibitory avoidance task, thought to be hippocampus-dependent. Rats were given a brief shock when stepping down from a platform onto a metal grid. Latency to step down in later trials was used as a measure of learning. The interfering task saw rats placed in a novel environment (pink floor with black-lined squares) at either 1h- or 6h-intervals after the avoidance task. Memory was tested 24h after the avoidance task. Izquierdo et al. (1999) report significantly impaired learning when interference occurred 1h after the avoidance task (and much less after 6h), pointing to a temporal

gradient of retroactive interference. This finding supports the notion that memories consolidate over time.

Also, recent work (Mendl et al., 1997; Laughlin & Mendl, 2004) has shown RI effects on spatial memory in pigs. Pigs learned to find enclosed food locations within a search area. Interference conditions in the form of isolation, novel food source and novel spatial environment were administered during a 10-minute retention interval after learning. Mendl et al. (1997) reported more relocation errors following interference than on control days, when no interfering condition was administered. However, they found no significant differences in performance during relocation trials, based on the *type* of interference the pigs experienced. Exploring a novel spatial environment during the retention interval did not interfere with pigs' spatial memory for food locations any more than novel food sources or being held in isolation in a holding pen for 3 minutes. Also Laughlin & Mendl (2004) demonstrated that when pigs incurred costs (having to navigate ropes) during search trials, they were less susceptible to RI effects. This finding suggests that enhanced attention during encoding of spatial information might diminish the effects of retroactive interference.

In humans, the literature on RI effects on spatial learning is scant. Nava et al. (2004) reported a beneficial effect of mental relaxation on long-term visual memory in a recognition task. Two groups of participants, a mental relaxation group and control group (each, N=16) viewed 280 international affective picture system slides (Lang et al., 1988). Recognition for the slides was tested immediately after presentation and then again after a 12 minute interval. During the interval the mental relaxation group listened to a relaxation tape and participants in the control group pressed a button whenever a body part was mentioned. Four weeks later, another recognition test was administered to both groups. Nava et al. (2004) reported

significantly better recognition memory for the photographic slides in the relaxation group after 4 weeks, suggesting that mental relaxation has positive retrograde effects on visual memory consolidation. This finding cannot be accounted for by RI effects experienced by the control group during the 12 minute interval, since memory performance following this interval was slightly better in the control group. From this finding Nava et al. (2004) suggest that consolidation processes for short-term (after 12 minutes) and long-term memory (after 4 weeks) may be differentially affected by physiological arousal. [That these processes (STM and LTM) do not operate under the same set of rules has also been suggested by Cowan et al. (2004).]

Elmes (1988) reported RI effects for spatial memory in humans. In one experiment, blindfolded participants all learned to find 4 locations in a 12-arm radial maze by navigating it with a stylus. In the experimental condition, 12 participants then learned to find 4 different positions in an identical maze, while control participants learned to find correct positions in a rectangular maze (composed of right angles). Finally, all participants re-learned the original radial arm maze. At all times participants were blindfolded during learning and did not see the mazes. This prevented them from learning locations by associating each of the 12 arms with the hours of a clock. Elmes (1988) reported that participants who had to learn an identical maze in the interval made significantly more errors on re-learning than those who learned the rectangular maze. Elmes (1988) argues that the retroactive interference effects observed were caused by learning highly similar material in the interval.

1.5 Material-Specific effects in Retroactive Interference

General RI effects in humans have been demonstrated both in spatial (Nava et al., 2004) and verbal memory paradigms (Cowan et al., 2004). But perhaps memory for

one type of material is impaired more by intervening material of a similar type. So for example, retroactive interference effects on spatial memory may be greater after subsequent exposure to spatial material than verbal material, and vice versa. Almost no literature exists on the possibility of material-specific effects of retroactive interference in humans.

However, Wixted (2004) argues against the idea of material-specific effects in retroactive interference, suggesting that general mental exertion is responsible for RI effects. He cites the study by Weingartner et al. (1995) in which two groups of participants were asked to attend to and learn 12 words, presented to them on cards at 1 word per second. Ten minutes after the word list was presented, one group was administered with triazolam (an amnesia-inducing drug) and the other group was given a placebo. Ninety minutes after the drugs were given another (post-drug) word list (12 words, at 1 word/5s) was presented. Twenty minutes after presentation of the post-drug word list, participants' recognition memory was tested using 36 words (12 from pre-drug, 12 from post-drug and 12 novel). Weingartner et al. (1995) reported that memory for the pre-drug word list was enhanced in the triazolam group, relative to the placebo group. However, the triazolam group's memory for the post-drug word list was not significantly impaired. Wixted (2004) argues that, because participants managed to successfully encode similar material (a post-drug word list) in the interval, and this material did *not* seem to interfere with consolidation of the pre-drug word list, then one could assume that a material-specific effect was not observed. Therefore, Wixted (2004) proposes that general mental exertion is what disrupts the consolidation of recently formed memory traces, and hence is responsible for RI effects.

Three main points should be raised about this assumption. Firstly, Weingartner et al.'s (1995) study was not designed to test material-specific effects of RI, and so Wixted's (2004) interpretation of the data in that context should be more tentative.

Secondly, in Weingartner et al.'s (1995) study the post-drug word list was presented 100 minutes after the pre-drug word list. In the same review paper Wixted (2004) took great care to outline evidence for a temporal gradient of retroactive interference (pp 244-254), with RI effects decreasing as time between interpolated tasks increased. In fact, a study by Chandler (1993) supports this idea. Participants were first shown target names (e.g. Robert Harris), then in the experimental condition these names were followed by related names (e.g. Robert Knight), while in the control condition they were not. At test, participants were required to match the given names with their surnames. Chandler (1993) reported that RI effects caused by the similar names were diminished when they were presented only 30 minutes after the first list of names. Therefore one could argue that material-specific RI effects are subject to the same temporal gradient as general RI effects. Perhaps in Weingartner et al.'s (1995) study no material-specific RI effects were observed because the intervening word list was presented too long (100 minutes) after the first word list.

Thirdly, Weingartner et al.'s (1995) study tested recognition memory for the word lists, and while no material-specific effects of RI were demonstrated, perhaps these effects might manifest in a recall paradigm – in which the added process of retrieval is tested.

In fact, Skaggs (1925) has argued for an effect of similarity between original and interfering material, suggesting that it probably reflected a retrieval phenomenon – a claim which was also supported in Chandler's (1993) study. For retention intervals of 5-15 minutes, Chandler (1993) reported that name-matching was more accurate in

the control condition, suggesting that similar material presented in the interval caused RI effects. At retention intervals of 30 minutes the RI effect observed in the experimental condition diminished, but increased again when the related names were presented just before the test. In other words, related names must be *accessed* in order to interfere with retrieval of the target, which suggests that material-specific effects may manifest in retrieval processes.

Moreover, Bunt & Sanders (1972) performed an experiment which supports the idea of material-specific RI effects. Participants attended to a word or digit list and recalled it immediately afterwards. They did this for 3 different lists in succession: a PI list, TBR (to be remembered) list and an RI list. After the 3rd list was recalled, they were instructed to recall the TBR list once more. The types of list presented at each stage, whether word (W) or digit (D), were counterbalanced for order such that all combinations were produced (WWW, WDW, WWD etc). Bunt & Sanders (1972) reported that % recall of the TBR lists were lower when RI lists were of the same type as the TBR lists (independent of the type of PI list), suggesting that similar material learned afterwards caused more forgetting than material of a different type.

And more recently, Delaney et al. (2004) demonstrated material-specific effects in recall of solutions to a water jugs problem. Participants were given 3 jug sizes (e.g. 5/4/3), their initial state (e.g. 5/0/0) and a goal state (e.g. 2/3/0). They were required to figure out the moves from initial to goal state for 2 problems. A filled/unfilled interval occurred between the problems, in which they performed tasks of varying similarity to the water jugs (similarity: Water jugs>Tower of Stockholm>Reading>No task). Participants were then asked to recall the steps of the solution to the first water jugs problem. Delaney et al. (2004) found that the Water jugs group recalled fewer steps of the solution than the Tower of Stockholm group,

who in turn recalled fewer steps than the Reading group. So memory for the solution of a target problem is reduced by solving a nearly identical problem (water jugs) and by solving a moderately similar problem which shares common elements (Tower of Stockholm). Interestingly, Delaney et al. (2004) detected no forgetting caused by a very dissimilar task (Reading), suggesting that the memory for problem solutions can be maintained over a longer period of time if in the absence of similar interfering material.

1.6 The present study

Given that some studies have pointed to task-specific effects (Delaney et al., 2004) and material-specific effects (Bunt & Sanders, 1972) in RI, the following hypothesis is proposed:

Memory for a specific type of stimuli (verbal or spatial) will be worse if the interfering task requires processing of similar material.

2. PILOT 1

2.1 Aim

Pilot 1 was an exploratory experiment to design a spatial memory task based on the 9-Box maze (Abrahams et al., 1997) which would test recall (not recognition) of spatial positions. It was hoped this spatial task, hereafter called the diners test, could be compared directly with verbal recall in a healthy population.

2.2 Methods

Participants

Six participants (3male/3female) with a mean age of 39.00 (SD= 7.75) years took part in the first pilot. They were recruited without pay from the healthy volunteer list at the Department of Psychology at Edinburgh University. Of the six, five were right-handed and one (male) was left-handed. All spoke English as their first language.

Apparatus

Three white mounting boards (78cm²) were affixed with red diners (cut from A1 card) arranged in a circle (see Picture 1.). 13, 15 and 17-diners mazes were made (diner-diameters: 6cm, 5cm and 4cm respectively). Maze-diameters for the 13 & 15-diners mazes were 71cm, and for the 17-diners maze was 67cm. Blank sheets of paper (78cm²) were used as response fields on which identical diners were placed to indicate responses. The circles were arranged such that diner-positions did not map directly onto a “clock-face” arrangement. On separate clear plastic sheets (78cm²) the 13-, 15- & 17-diners maze positions were drawn, these were used to score the recalled spatial positions (see section on scoring). Three passages from *The Guinness book of*

amazing nature (1998) (Appendix 1) were used as interfering material for participants to read during the 5-minute intervals.



Picture 1. 13-diner Maze.

Design

The independent variable was the number of spatial positions to be recalled for the 13-, 15- & 17-diners mazes (5,6 & 8 respectively) and the dependent variables were mean error score for each board and % retention for each participant. A within-subjects design was used in which all participants experienced all conditions.

Procedure

Pilot 1 consisted of 3 main trials, one for each of the 3 mazes. Each trial involved immediate (IR) and delayed (DR) recall phases. A 5-minute filled delay, during which participants read from a passage aloud, separated IR and DR.

Participants were seated at one of four chairs positioned around a table. They were instructed to imagine the diner before them represented a seating plan for a dinner party of people, some of which would be vegetarians. With a pen, the

experimenter pointed out positions in a pseudo-random order, avoiding clockwise and anticlockwise presentation. For the 13-, 15- & 17-diners tests the number of vegetarian positions to be recalled were 5, 6 & 8 respectively. For IR, the presentation board was removed, participants were directed to sit in a different chair and instructed to place response counters on blank paper to indicate the vegetarians' positions. For the 5-minute delay, participants were instructed to 'read aloud from a passage at their own speed' having been informed that they would not be tested on any of the material in the passages. After the delay, participants were directed to a different chair for DR. Moving chair positions for IR and DR made it more difficult for participants to encode the positions egocentrically. Before beginning the actual trial, a practice run with 2 vegetarian positions was carried out (Appendix 2 for full instructions).

The different diners tests were counterbalanced both for order of presentation, and for pairings with the verbal material used in each delay, such that all boards occurred in every order and with each verbal stimulus once (see Appendix 3). At the end of the experiment all participants performed the National Adult Reading Test (NART, Nelson & Willison, 1991) and were asked, 'What strategy, if any, did you use to remember the positions of the vegetarians?'

Scoring: Responses were given error scores (0-4) based on their displacement (cm) away from the nearest correct diner's position, such that: 0-3cm = error 0; 4-6cm = error 1; 7-9cm = error 2; 10-12cm = error 3; +12cm = error 4. Scores with decimal places <0.5 were rounded down and those with decimal places > or = 0.5 were rounded up. A maximum error score for any single response was 4. Therefore maximum error scores for each diners test were 4x Number of positions to be recalled: Max. Errors for 13-diner=20; 15-diner=24; 17-diner=32.

Mean error scores for immediate and delayed recall were calculated for each diners test, as well as the % retention for each participant. Percentage retention = no. correct DR/no. correct IR x 100, where errors <4 were taken as “correct”.

2.3 Results

Table 1 Error score descriptives.

	13 diners		15 diners		17 diners	
	IR	DR	IR	DR	IR	DR
Mean(SD)	11.67(2.88)	11.33(2.50)	12.83(4.58)	12.83(4.45)	16 (3.63)	15 (2.90)
% error	58.35	56.66	53.46	53.46	50.00	46.88
Range	7-14	7-14	9-20	7-20	11-20	11-20

Error score means (SD) & ranges for 13-diners, 15-diners & 17-diners tests (N=6).

IR=immediate recall and DR= delayed recall. % error = mean error expressed as a percentage of the maximum possible error score for a diners test.

Table 1 summarises the results of pilot 1. Overall, mean error scores ranged between 50-58% of the maximum possible error score for each of the diners tests. Unexpectedly participants seemed to perform best when given 8 positions to recall (17-diners), less well when given 6 positions to recall (15-diners) and the worst when given 5 positions to recall (13-diners) (see Fig 1). Interestingly, mean error scores for both the 13-diners and the 17-diners tests were lower for DR than IR. Range values and standard deviations for the 15-diners test suggest less consistent performance compared to the 13- and 17-diners tests.

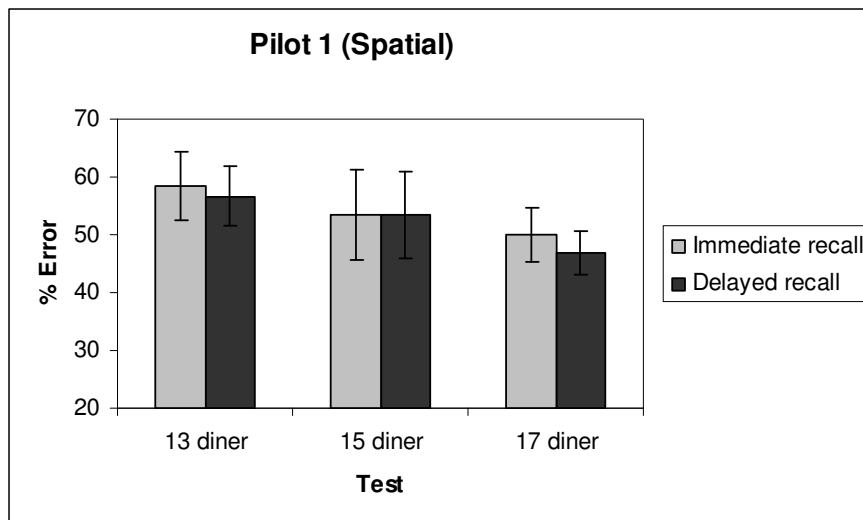


Figure 1. Performance by % error on the different diner tests.

Figure 1 illustrates how performance changed across diners tests. Mean percentage errors decreased as the number of positions to be recalled increased.

In general, percentage retention values were consistently high for the 15-diners test and 17-diners test, while only 3/6 participants scored 100% or higher in the 13-diners test (see Appendix 4).

Qualitative results:

Memory strategies

50% of participants (3/6) reported using a clock-face strategy for remembering the spatial positions, by associating them with the nearest clock position (see Elmes, 1988 for a visuo-spatial recall paradigm which eliminates this strategy). One participant used another strategy which involved mentally dividing up the diners mazes into the four quadrants of a circle and remembering how many correct positions fell within each. The remaining 2 participants attempted to recall the vegetarians' positions by joining them up to make imaginary shapes, which were then mentally rotated before recall from a different chair position around the table.

2.4 Discussion

The aim of pilot 1 was to assess the suitability of the new diner tasks as tests of spatial recall memory in a healthy population. The main finding of this pilot was that participants seemed to perform better (lower % error) when required to recall more spatial positions. This finding was unexpected. However when the probability of scoring a correct response by chance is considered these findings are easily explained. With 8 positions to be recalled the probability of “hitting” a correct position by chance (landing anywhere within 12cm of one), is higher than with only 5 positions to be recalled. And since the overall area of the presentation boards were constant at 78 cm² then the probability of correct guesses increases with the number of positions to be recalled.

There appeared to be no interesting differences between IR and DR in any of the diner tests. One possible explanation for this might be that reading verbal material during the delay period does not interfere with processes of consolidation for spatial material, and this explanation is consistent with the idea that dissimilar material may not interfere with memory consolidation (Delaney et al., 2004).

In the 13-diners test, % retention scores across participants were generally lower than in the 15- and 17-diners tests. This disparity most likely reflects the difficulties of applying a % retention measure (well-established in verbal paradigms) to a novel spatial recall paradigm.

Since the probability of guessing correctly increases as the number of positions to be recalled increases, then using smaller numbers of diners in the test would minimise the incidence of correct guesses and therefore improve our measure of spatial recall.

3. PILOT 2

3.1 Aim

The purpose of this pilot was to compare performance on a 9-diners test (4 positions to recall) and the 17-diners test (8 positions to recall). If, as in pilot 1, there was no difference in performance then the 9-diners test would be used for the main study, owing to its previous success as a allocentric spatial memory paradigm (Abrahams et al., 1997).

3.2 Methods

Participants

Five of the six participants from pilot 1 were also recruited for the second pilot. A female, right-handed student (23years) was recruited from the University to make up six participants in the second pilot. Mean age in years was 37.17 (SD= 10.11)

Apparatus

The 17-diners test from pilot 1 was used again, along with the 3 verbal passages and the blank response fields and counters. A new 9-diners test was also constructed (diner-diameter: 9cm, maze-diameter: 54.6cm) and a fourth verbal passage introduced (see Appendix 1).

Design

As in pilot 1, the independent variable was the number of spatial positions to be recalled for the 9- & 17-diners tests (4 & 8 respectively) and the dependent variables were mean error score for each board and % retention for each participant. A within-subjects design was used in which all participants experienced all conditions.

Procedure

There were 4 main trials, two tests for each of the mazes (9-diners & 17-diners). For procedure see Pilot 1, tests were counterbalanced for order of presentation and pairing with verbal material (Appendix 3).

3.3 Results

Table 2 Error score descriptives.

Test	9-diners				17-diners			
	1	2	1	2	1	2	1	2
	IR	DR	IR	DR	IR	DR	IR	DR
Mean	7.00	7.67	7.83	9.50	14.50	14.67	14.17	19.67
(SD)	3.35	4.68	5.12	4.42	3.56	3.61	3.87	3.44
%Error	43.75	47.92	48.96	59.38	45.32	45.84	44.27	61.46
Range	2-12	2-13	2-16	2-15	11-19	11-21	9-19	15-23

Error score means (SD) & ranges for 9-diners & 17-diners tests (N=6). IR=immediate recall and DR= delayed recall. % error = mean error expressed as a percentage of the maximum possible error score for a diner (max error: 9-diners= 16 & 17-diners= 32).

Table 2 summarises the results of pilot 2. Overall, mean error scores for DR were higher than for IR, but these differences were small. Mean % errors for IR and DR remained consistent (43-49%) regardless of the number of positions to be recalled. However, despite tests being counterbalanced for order, in test 2 DR in both diners tests was unexpectedly high. SD and range values demonstrate a larger variability in performance in the 9-diners relative to the 17-diners test.

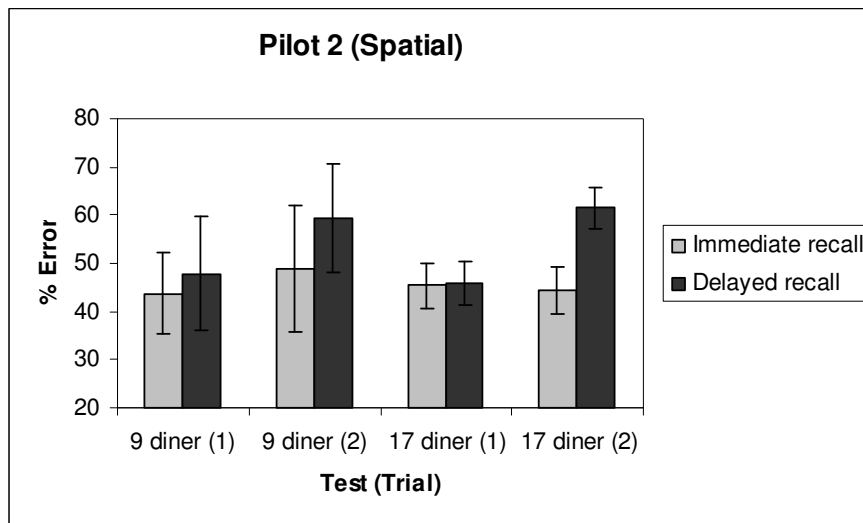


Figure 2. Performance by % error on 9- & 17-diners tests. () represents test number.

Figure 2 represents performance in the 9-diners and 17-diners tests. Percent error for DR is larger in test 2. SE bars indicate the greater variability in performance in the 9-diners test.

Percentage retention values for test 1 were consistently high for both diners tests, while in test 2 fewer participants scored 100% or more (see Appendix 4).

Qualitative results:

Memory strategies

50% of participants (3/6) used a clock face strategy for recalling the positions. And 50% recalled the vegetarians' positions by joining them up to make imaginary shapes, which were then mentally rotated before recall from a different chair position around the table.

3.4 Discussion

The aim of this pilot was to compare performance of healthy participants on the 9-diners and 17-diners test of spatial recall. Overall, there appeared to be no difference in performance with regard to the number of diners used in the test. Performance, whether measured by % error or percent retention, was equally as good for both tests.

Unexpectedly, DR performance in test 2 for both diners tests was worse than in test 1. Because all 4 trials were counterbalanced for order of presentation, neither effects of order nor a build up of proactive interference over the experiment may be appealed to as an explanation of this finding.

Because there appeared to be little difference in performance between the tests, the 9-diners test was favoured for the main study. Also, its previous success as a paradigm sensitive to allocentric spatial processing (Abrahams et al., 1997) made it a better choice.

4. METHODS (MAIN STUDY)

4.1 Participants

Fourteen participants (3male/11female) with a mean age in years of 34.29 (S.D. 9.04, range 23-50) took part in the experiment. They were recruited without pay, 9 from the healthy volunteer list and 5 from the student body at the Department of Psychology at Edinburgh University. Of the fourteen, 13 were right-handed and 1 was left-handed. All participants spoke English as their first language.

4.2 Apparatus

The 9-diners test, based on the 9-box maze (Abrahams et al., 1997), consisted of nine identical circular ‘penny washers’ 5cm in diameter, with a central hole, 2cm in diameter. These were fixed to a white laminated hardwood board of area 78cm² in a circular formation at a distance of 19cm along the chord of the circle (see Picture 2). Identical washers served as response counters, using double-sided sticky tape. Ten identical 78cm² hardwood boards were used as response fields upon which the counters were placed to indicate a recalled position. A clear plastic sheet 78cm² with the nine-box diner positions drawn on it was used to mark the recalled spatial positions. 5 Word lists, of 15 words each were recorded on a laptop Windows Media Player and presented through portable speakers. Two typed, double-spaced passages from *The Guinness book of amazing nature* (1998) were used in the Reading interference tasks (checked for content against the wordlists). Two fictitious maps, with numerous symbols and containing no verbal material, were created on Word for the Map-search interference task (actual size A3), these were based on the map-search test from the Test of Everyday Attention (Robertson et al., 1994) and were designed to be non-verbal. Articulatory suppression and the Tapping task (metronome: 1

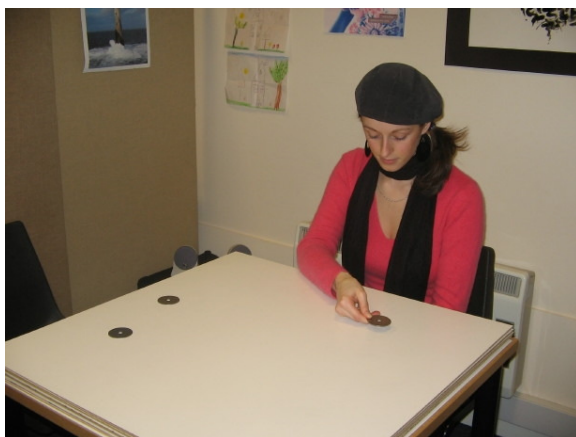
beat/second) were recorded on e-prime and presented through speakers (see Appendix 1, for all materials).



Picture 2. 9-diners test - presentation.



Picture 3. Changing chair position for IR.



Picture 4. IR of spatial positions.

4.3 Design

A within-subjects design was used with all subjects tested in two main tasks – visuo-spatial and verbal, each consisting of immediate and delayed recall. The spatial task contained 5 interference levels: Minimal Interference 1 (MI1), Minimal Interference 2 (MI2), Tapping, Reading and Map-search. The independent variable was interference task while the dependent variables were spatial displacement, spatial error score and percent retention. The verbal task also contained the same 5 interference levels, except the Tapping task was replaced by Articulatory Suppression (AS). The independent variable was interference task, and the dependent variables were number of words recalled and percent retention score.

4.4 Procedure

Spatial Experiment

There were 3 main stages: Minimal Interference 1, Interference Conditions & Minimal Interference 2. All trials consisted of presentation, IR, 5-minute delay and DR.

Stage 1 (MI 1): Participants were instructed to imagine that the presentation board represented a seating plan for a dinner party of nine people, four of which would be vegetarians. With a pen, the experimenter pointed out four positions in a pseudo-random order, avoiding clockwise and anticlockwise presentation. For IR, the board was removed, participants were directed to sit in a different chair and instructed to place metal counters on a blank board to indicate the 4 vegetarians' positions (see Pictures 2-4). Before beginning the actual experiment, a practice run with 2 vegetarian positions was carried out. In the first trial participants were *not* told there would be a DR stage. After IR they were instructed to relax in the cubicle while the experimenter

dimmed the lights and 'set up the next part of the experiment'. After the 5-minute delay, time by stopwatch, participants were directed to a different chair for DR.

Stage 2 (Interference Conditions): Trials 2-4 consisted of identical spatial tasks, but contained *Tapping, Reading* and *Map-searching* interference tasks. Before each trial, participants were given specific instructions on how to perform the relevant interference task.

Interference tasks: The Tapping task required participants to shadow a recording of a tapping sound by tapping three points fixed to a mounting board placed before them on the table (see Picture 5). Participants kept time for a 20-second period followed by 40 seconds of silence during which they rested. This task was designed as a spatial analogue to the AS task, and was administered only in spatial trials (AS task only in verbal trials). In the reading task participants read aloud from a passage at their own speed, and were made aware they would not be tested on the passages later. In the map-search task participants searched for and circled a geometric shape hidden amongst many others in fictitious map. If the participant finished a search within the time allotted, fresh copies of the map were provided, each with a different shape to search for, until the allotted time was filled. Interference tasks were counterbalanced to avoid any effects of order.

Stage 3 (MI 2): This stage of the experiment (trial 5) was identical to the Stage 1. It was included to determine whether there would be a build up of proactive interference throughout the trials.

Means of displacement and error scores for each participant were calculated, as well as % retention (see Pilot 1 for calculation).



Picture 5. Tapping task.

Verbal experiment

The stages of this experiment were identical to those in the spatial experiment.

Stage 1 (MI 1): In the first trial participants were instructed to listen to a recorded wordlist and then recall, in any order, as many of the words as they could remember immediately afterwards. Participants were not informed there would be a DR stage (see Appendix 5).

Stage 2 (Interference Conditions): Trials 2-4 consisted of identical verbal tasks, with the same interference tasks as in the spatial experiment, except the Tapping task was replaced by an AS task, which required participants to “shadow” a recorded voice repeating the sound “duh” for 20-second periods followed by 40 seconds of silence in which the participant rested.

Stage 3 (MI 2): This stage was identical to Stage 1 above.

Verbal and spatial experiments were carried out in a single session, with their trials interposed throughout, to minimise proactive interference (see Appendix 6 for counterbalancing). 50% of participants began the experiment with a verbal trial and 50% began with a spatial trial. At the end of the experiment all participants performed the National Adult Reading Test (NART) (Nelson & Willison, 1991) and a short

interview was carried out to determine what memory strategies were used (see Appendix 5).

Mean number of words recalled and % retention were calculated for each participant.

4.5 Statistical design

Spatial experiment: The two within-subjects factors were: *Condition* (4 levels: MI1, Tapping, Reading & Map-search) and *Recall* (2 levels: IR & DR)). Repeated measures ANOVAs were carried out separately for both experiments.

Verbal experiment: There were two within-subjects factors: *Condition* (4 levels: MI1, AS, Reading & Map-search) and *Recall* (2 levels: IR & DR).

Further ANOVAs were carried out to rule out effects of Trial Order.

5. RESULTS

5.1 Spatial Experiment

Displacement measure

a) MI1 vs MI2:

To determine whether there was any build up of proactive interference over the experiment, a repeated measures ANOVA with two within-subjects factors: Condition (MI1 vs MI2) and Recall (IR & DR) was carried out. Significant main effects of Condition [$F= 5.24$, $d.f.= 1,13$, $P<0.05$] and Recall [$F= 5.87$, $d.f.= 1,13$, $P<0.05$] were revealed. There was no significant interaction between Recall and Condition [$F= 1.61$, $d.f.= 1,13$, $P=0.23$]. Mean displacement values for MI1 and MI2 (see Table 3) confirm that performance in MI2 was worse than in MI1. Also, performance in DR was worse than in IR for both conditions. Figure 3 shows IR & DR performance on the 9-diners test in conditions MI1 and MI2.

Table 3 Descriptives for displacement (cm) in the 9-diners test.

	MI1		MI2		Tapping		Reading		Map search	
	IR	DR	IR	DR	IR	DR	IR	DR	IR	DR
Mean	25.06	28.61	32.69	44.02	24.66	35.60	32.75	33.90	33.70	34.97
(SD)	10.82	10.40	17.72	25.38	9.95	21.39	19.20	25.00	22.82	16.19
Range	8.20- 46.20	13.00- 44.70	15.20- 77.70	16.20- 110.20	13.20- 47.30	15.40- 74.30	17.30- 83.90	9.80- 89.30	13.10- 81.50	14.30- 63.00

Means (SD) & Ranges for displacement scores (cm) across all interference conditions. MI1= minimal interference 1, MI2= minimal interference 2. IR= immediate recall & DR= delayed recall.

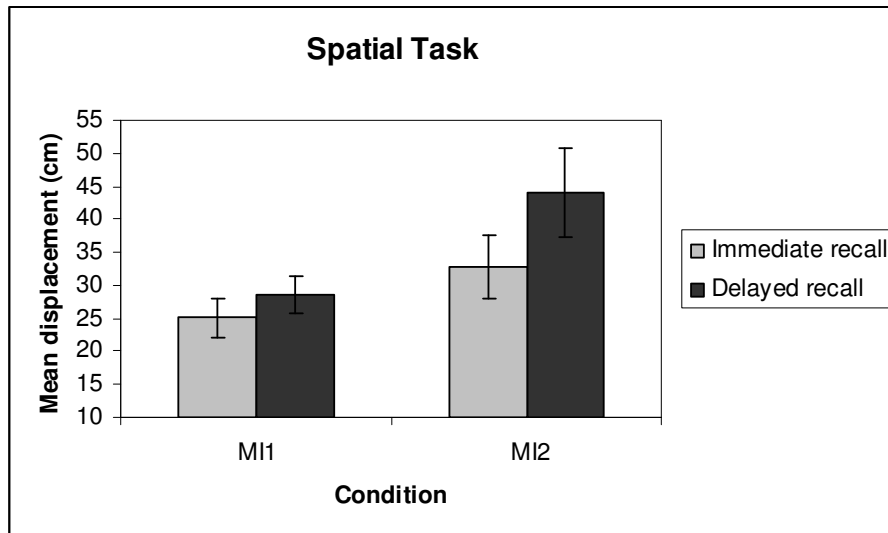


Figure 3. Nine-diners test: mean displacement scores (cm) for IR & DR across MI1 & MI2.

b) Comparing conditions:

To determine whether there were any effects of type of interference condition a repeated measures ANOVA with two within-subjects factors: Condition (MI1 vs Tapping vs Reading vs Map-search) and Recall (IR vs DR) was carried out. No significant main effects of Condition [$F= 1.30$, $d.f.= 3,39$, $P=0.29$] or Recall [$F= 2.22$, $d.f.= 1,13$, $P=0.16$] were revealed. And there was no interaction between Condition and Recall [$F= 0.68$, $d.f.= 3,39$, $P=0.57$]. Though no main effects were found, mean displacement values across all conditions appear to suggest that IR performance was worse in the Reading and Map search conditions compared to the MI1 and Tapping conditions (see Table 3). The Tapping condition appeared to have the largest drop in performance (increase in mean displacement) across IR and DR. A post hoc ANOVA revealed that the difference approached significance, [$F= 3.90$, $d.f.= 1,13$, $P= 0.07$]. Figure 4 shows IR & DR performance across MI1 and the 3 interference conditions.

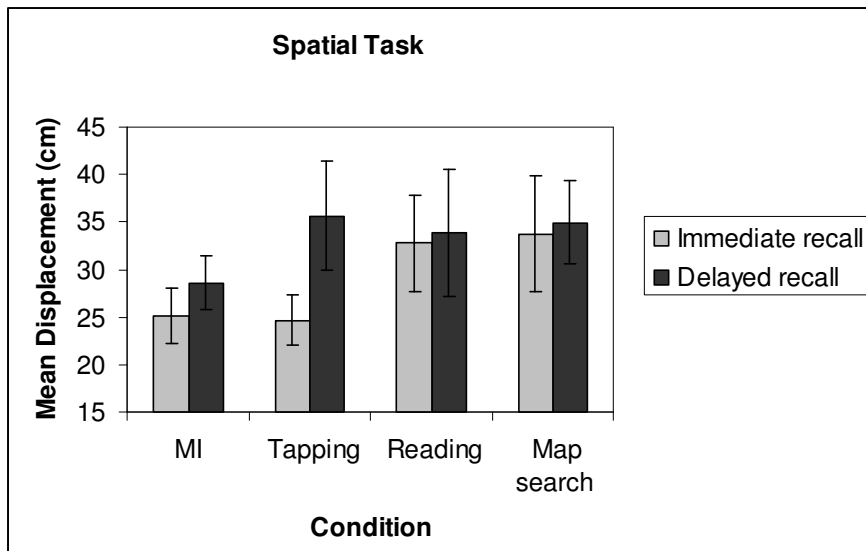


Figure 4. Nine-diners test: mean displacement scores for IR & DR across conditions.

c) Comparing trials 2-4:

To determine whether there was any effect of trial order, a repeated measures ANOVA with two within-subjects factors: Order (2 vs 3 vs 4) and Recall (IR & DR) was carried out. No significant main effects of Order [$F= 2.05$, $d.f.= 2,26$, $P=0.15$] or Recall [$F= 1.59$, $d.f.= 1,13$, $P=0.23$] were found. Also no interaction between Order and Recall was revealed [$F= 0.23$, $d.f.= 2,26$, $P=0.80$]. From inspection of the mean displacement values, performance in trial 2 appeared to be worse (IR= 34.47, DR= 38.63) than in trial 3 (IR= 24.49, DR= 32.19) and trial 4 (IR= 32.15, DR= 33.64). Figure 5 shows IR & DR performance for trials 2-4, irrespective of condition.

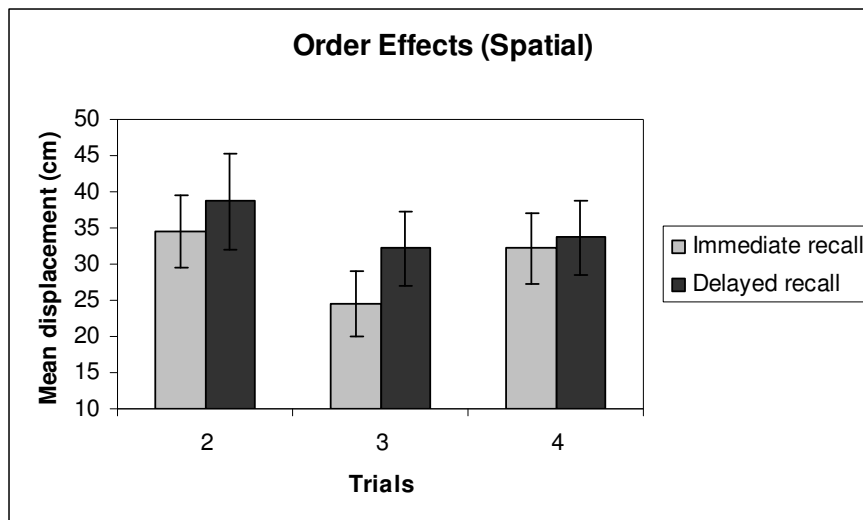


Figure 5. Mean displacement scores for IR & DR arranged by trial order.

Error measure

a) MI1 vs MI2:

A repeated measures ANOVA with two within-subjects factors: Condition (MI1 vs MI2) and Recall (IR & DR) was carried out. No significant main effect of Condition [$F= 1.98$, $d.f.= 1,13$, $P=0.18$] was found, but a significant effect of Recall [$F= 10.30$, $d.f.= 1,13$, $P<0.01$] was revealed. There was no significant interaction between Recall and Condition [$F= 0.21$, $d.f.= 1,13$, $P=0.65$]. Mean error values for MI1 and MI2 (see Table 4) confirm that performance in MI2 was worse than in MI1. Also, DR performance was worse than IR in both conditions. Figure 6 shows IR & DR performance on the 9-diners test in conditions MI1 and MI2.

Table 4. Descriptives for error score in the 9-diners test.

	MI1		MI2		Tapping		Reading		Map search	
	IR	DR	IR	DR	IR	DR	IR	DR	IR	DR
Mean	5.21	6.57	6.36	8.29	5.43	6.43	6.07	6.00	6.43	6.79
(SD)	2.58	2.95	2.56	3.69	2.38	2.77	3.10	3.82	3.52	3.47
Range	1-10	1-10	2-11	3-16	2-10	2-11	2-11	1-13	2-13	2-15

Means (SD) & Ranges for error scores across all interference conditions. MI1= minimal interference 1, MI2= minimal interference 2. IR= immediate recall & DR= delayed recall.

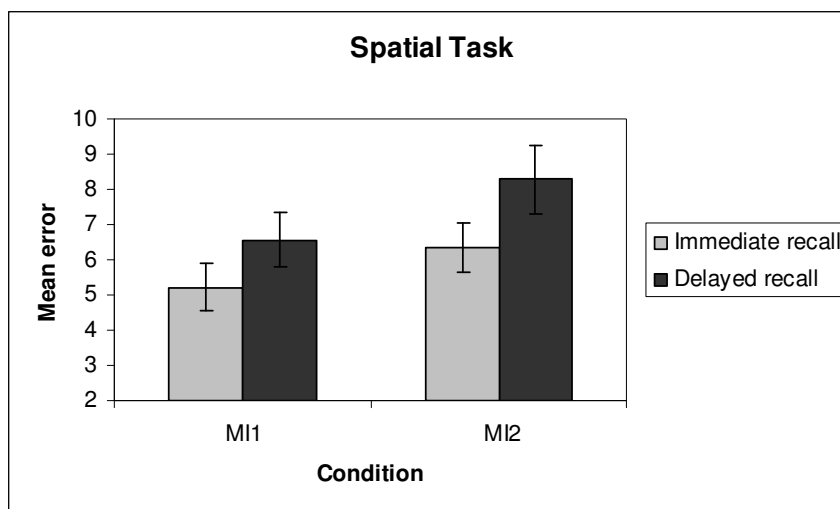


Figure 6. Nine-diners test: mean error scores for IR & DR across MI1 & MI2.

b) Comparing conditions:

A repeated measures ANOVA with two within-subjects factors: Condition (MI1 vs Tapping vs Reading vs Map-search) and Recall (IR vs DR) was carried out. No significant main effects of Condition [$F= 0.35$, $d.f.= 3,39$, $P=0.79$] or Recall [$F= 2.37$, $d.f.= 1,13$, $P=0.15$] were revealed. And there was no interaction between Condition and Recall [$F= 0.60$, $d.f.= 3,39$, $P=0.62$]. Mean error values (see Table 4) appear to

suggest that performance was fairly consistent across all conditions. DR performance was worse than IR performance in all conditions, except the Reading condition.

Figure 7 shows IR & DR performance across MI1 and the 3 interference conditions.

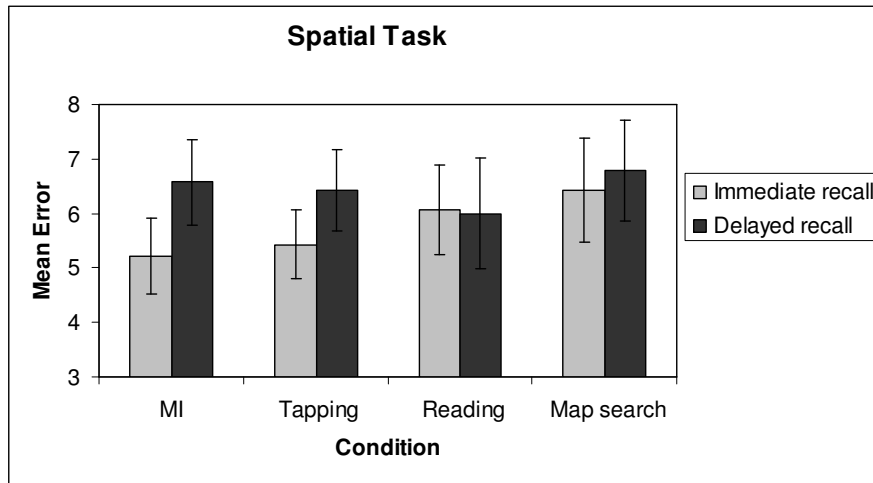


Figure 7. Nine-diners test. Mean error scores for IR & DR across conditions.

c) Comparing trials 2-4:

A repeated measures ANOVA with two within-subjects factors: Order (2 vs 3 vs 4) and Recall (IR & DR) was carried out. No significant main effect of Recall [$F= 0.61$, $d.f.= 1,13$, $P=0.45$] was found, but a 6% trend was observed for Order [$F= 3.192$, $d.f.= 2,26$, $P=0.058$]. However, inspection of mean errors for trials 2-4 suggest that performance in trial 3 (IR= 4.86, DR= 5.71) was worse than in trial 2 (IR= 7.07, DR= 7.14) and trial 4 (IR= 6.00, DR= 6.36). Also no interaction between Order and Recall was revealed [$F= 0.21$, $d.f.= 2,26$, $P=0.82$]. Figure 8 shows IR & DR performance for trials 2-4. Figure 8 shows IR & DR performance for trials 2-4, irrespective of condition

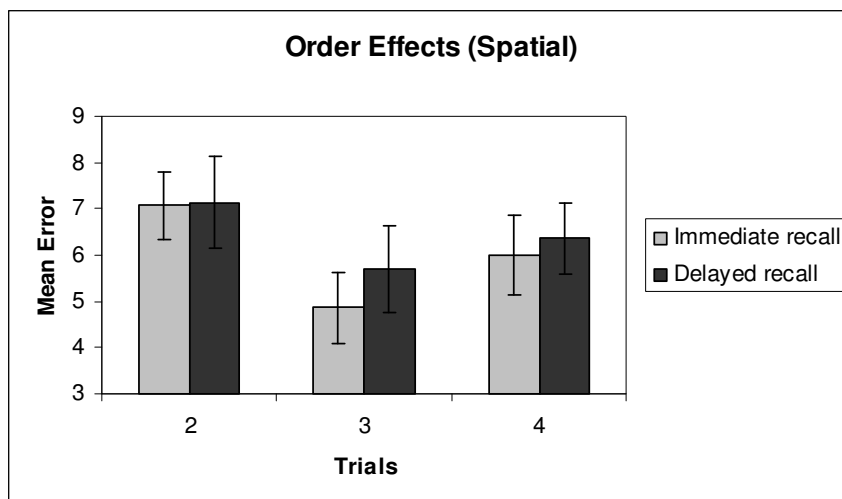


Figure 8. Nine-diners test: mean error scores for IR & DR arranged by trial order.

Percent retention measure

a) MI1 vs MI2:

A repeated measures ANOVA with the within-subject factor: Condition (MI1 vs MI2) revealed no significant main effect of Condition [$F= 0.003$, $d.f.= 1,13$, $P= 0.96$]. Table 5 shows performance as a measure of percent retention (see Pilot 1 Methods for calculation) between IR and DR for all conditions. Mean percent retentions remained fairly consistent throughout. The MI2 condition showed the most variability in performance, as indicated by SD and range values. Figure 9 shows performance in percent retention for MI1 and MI2 conditions.

Table 5. Nine-diners test: percent retention across IR & DR (all conditions).

	MI1	MI2	Tapping	Reading	Mapsearch
Mean (SD)	86.90 (19.53)	87.50 (29.00)	89.88 (17.35)	86.31 (23.93)	87.50 (19.00)
Range	50-100	0-100	50-100	33-100	50-100

% retention= number of correct responses DR as a percentage of correct responses IR, where an error score < 4 is taken as correct.

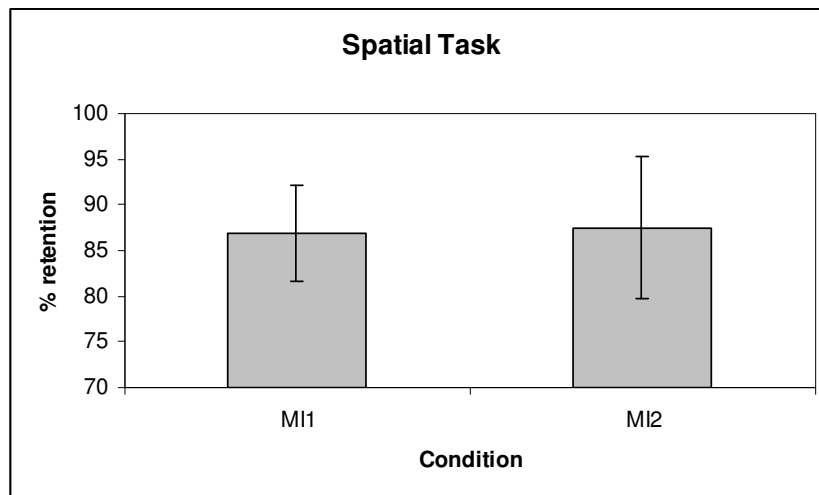


Figure 9. Nine-diners test: percent retention for MI1 & MI2 conditions.

b) Comparing conditions:

A repeated measures ANOVA with the within-subjects factor: Condition was carried out. No significant main effect of Condition [$F= 0.23$, $d.f.= 3,39$, $P= 0.87$] was revealed. Inspection of mean percent retentions suggested fairly consistent performance for all conditions (Table 5). Figure 10 shows performance in percent retention for MI1 and the 3 interference conditions.

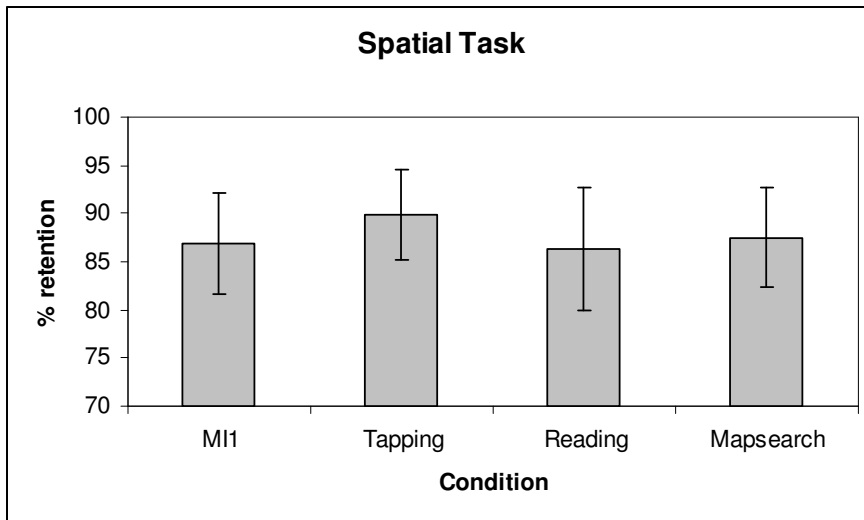


Figure 10. Nine-diners test: percent retention across conditions.

c) Comparing trials 2-4:

A repeated measures ANOVA with the within-subjects factor: Trial Order (2 vs 3 vs 4) revealed no significant main effect of Order [$F= 2.93$, $d.f.= 2,26$, $P= 0.09$]. Figure 11 shows performance in percent retention for trials 2-4, irrespective of condition. Performance appears to improve as the trials progress.

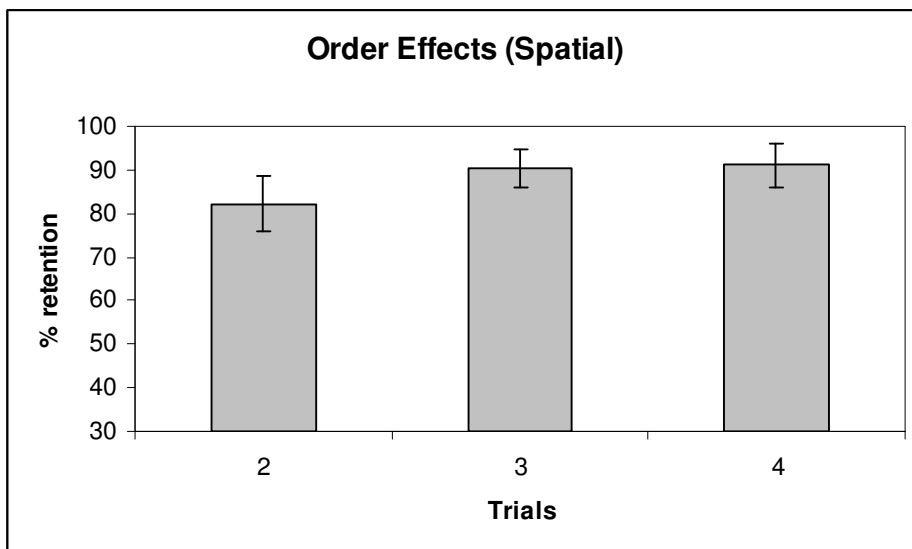


Figure 11. Nine-diners test: percent retention across trials 2-4.

Qualitative results:

Memory strategies

50% of participants (7/14) reported using a strategy which involved visualizing imaginary shapes made by joining up the spatial positions to be recalled. When they were able to rehearse, all of these participants did so by continuing to picture the shapes as they would appear on the response field, and mentally rotating the image before recall from a different chair position.

Over 28% of participants (4/14) reported using a clock face strategy for remembering the spatial positions. All 4 participants engaged in sub-vocal rehearsal of the clock positions.

One participant reported dividing the 9-diners maze into four quadrants, and remembering the spatial positions according to how many fell into each quadrant. Another participant used three diners' positions on the board to form an imaginary triangle which divided up the board equally. Rehearsal involved visualizing the positions which fell on, to the left of, and to the right of the triangle. Yet another participant gave each of the 9 possible diners the name of someone personally relevant to her. She engaged in sub-vocal rehearsal of the named diners.

Rehearsal

Over 50% of the participants (4/7) who began the experiment with a spatial trial reported having rehearsed the spatial material in the first unfilled delay, despite not having been informed that there would be a delayed recall phase. Over 64% of participants (9/14) reported rehearsing the material in the last unfilled delay (MI2). Interestingly, performance across IR and DR in this condition was the worst (see Appendix 7 for Rehearsal summary).

5.2 Verbal experiment

Recall measure

a) MI1 vs MI2:

A repeated measures ANOVA with within-subject factors: Condition (MI1 vs MI2) and Recall (IR vs DR) revealed significant main effects of Condition [$F= 10.47$, $d.f.= 1,13$, $P<0.01$] and Recall [$F= 13.16$, $d.f.= 1,13$, $P<0.01$]. There was no significant interaction between Condition and Recall [$F= 2.52$, $d.f.= 1,13$, $P=0.14$]. Inspection of mean recall values (Table 6) indicates that performance was better in the MI2 condition than in the MI1 condition. Also, DR performance was worse than IR performance in both conditions. Figure 12 shows performance in MI1 and MI2 conditions for IR and DR.

Table 6. Descriptives for verbal recall.

	MI1		MI2		AS		Reading		Map search	
	IR	DR	IR	DR	IR	DR	IR	DR	IR	DR
Mean	6.86	5.57	7.64	7.07	6.57	5.07	6.93	5.07	6.57	4.50
(SD)	1.88	1.95	1.55	1.54	1.91	2.13	1.69	1.59	2.62	2.74
Range	3-9	3-10	5-10	5-10	3-10	1-9	4-10	2-8	3-11	1-10

Means (SD) & Ranges for number of words recalled across all interference conditions. MI1= minimal interference 1, MI2= minimal interference 2 & AS= articulatory suppression. IR= immediate recall & DR= delayed recall.

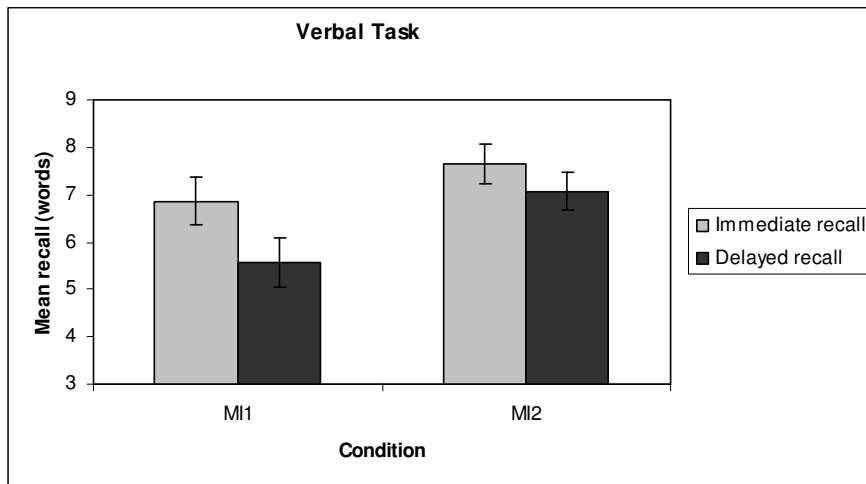


Figure 12. Mean scores for IR & DR across MI1 and MI2.

b) Comparing conditions:

A repeated measures ANOVA with the within-subjects factors: Condition (MI1 vs AS vs Reading vs Map search) and Recall (IR vs DR) was carried out. No significant main effect of Condition [$F= 0.83$, $d.f.= 3,39$, $P=0.49$] was found, but a significant effect of Recall [$F= 49.77$, $d.f.= 1,13$, $P<0.001$] was revealed. Differences between IR and DR were significant in all conditions: MI1 condition [$F= 12.10$, $d.f.= 1,13$, $P<0.005$], AS condition [$F= 8.27$, $d.f.= 1,13$, $P<0.05$], Reading condition [$F= 31.84$, $d.f.= 1,13$, $P<0.001$] and Map search condition [$F= 29.00$, $d.f.= 1,13$, $P<0.001$]. There was no interaction between Condition and Recall [$F= 0.85$, $d.f.= 3,39$, $P=0.48$]. From mean recall values (Table 6) it appears that DR performance was worse than IR performance in all conditions. Although no main effect of Condition was found, mean recall values suggest a stepwise decrease in DR from the MI1 to Map search conditions. Figure 13 shows IR & DR performance across MI1 and the 3 interference conditions

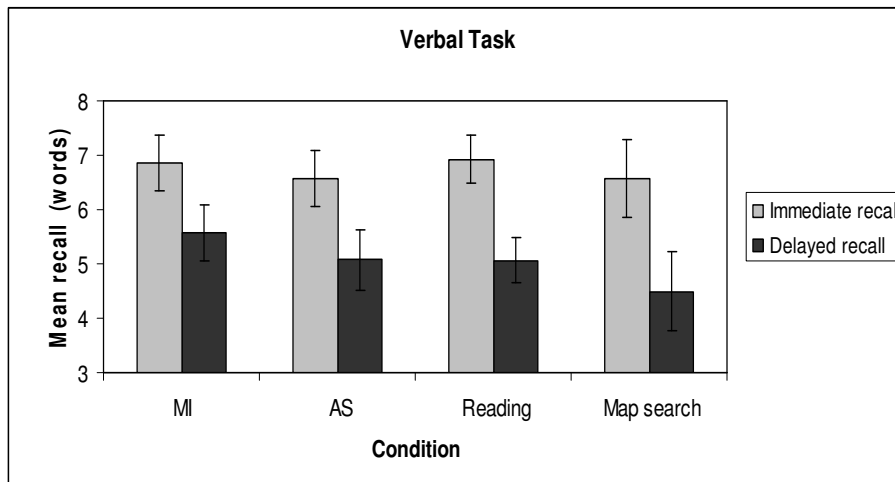


Figure 13. Mean verbal scores for IR & DR across conditions.

c) Comparing trials 2-4:

A repeated measures ANOVA with the within-subjects factors: Order (2 vs 3 vs 4) and Recall (IR vs DR) was carried out. No significant main effect of Order [$F= 0.70$, $d.f.= 2,26$, $P=0.51$] was found, but a significant main effect of Recall [$F= 47.29$, $d.f.= 1,13$, $P<0.001$] was revealed. There was no interaction between Trial Order and Recall [$F= 0.86$, $d.f.= 2,26$, $P=0.44$]. From inspection of mean recall values performance in trial 2 (IR= 6.86, DR= 5.36) appeared better than in trial 3 (IR= 6.64, DR= 4.43) and trial 4 (IR= 6.57, DR= 4.86). Figure 14 shows performance in mean recall across trials 2-4 of the verbal task.

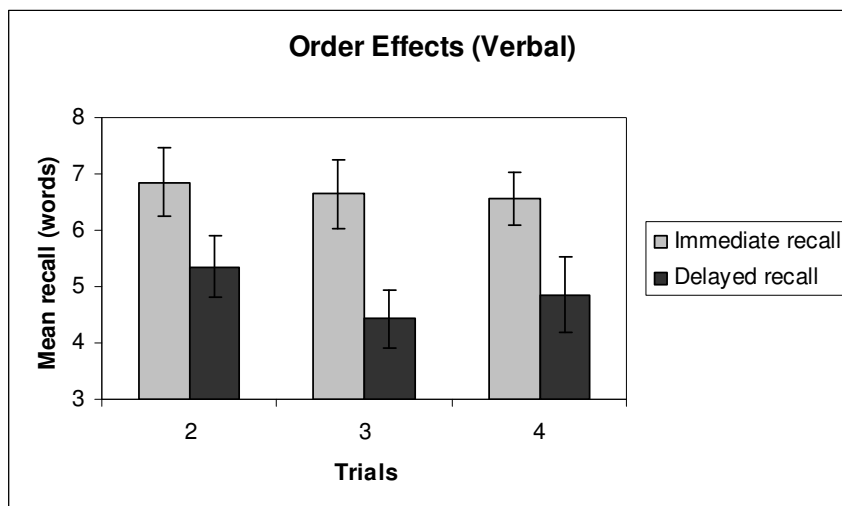


Figure 14. Mean verbal scores for IR & DR arranged by trial order.

Percent retention measure

a) MI1 vs MI2:

A repeated measures ANOVA with the within-subject factor: Condition (MI1 vs MI2) revealed no significant main effect of Condition [$F= 1.63$, $d.f.= 1,13$, $P= 0.22$]. Table 7 shows performance as a measure of percent retention in delayed recall. Mean percent retention appeared higher in the MI2 than in MI1 condition. Figure 15 shows performance in percent retention for MI1 and MI2 conditions in the verbal task.

Table 7. Percent retention across IR & DR (all conditions).

	MI1	MI2	AS	Reading	Mapsearch
Mean (SD)	75.47 (18.30)	82.70 (12.86)	67.98 (21.94)	71.54 (17.13)	63.77 (21.38)
Range	50-100	67-100	33-100	40-100	20-100

Specific % retention= no. of words in DR (which had also been recalled in IR) expressed as a % of no. of words in IR.

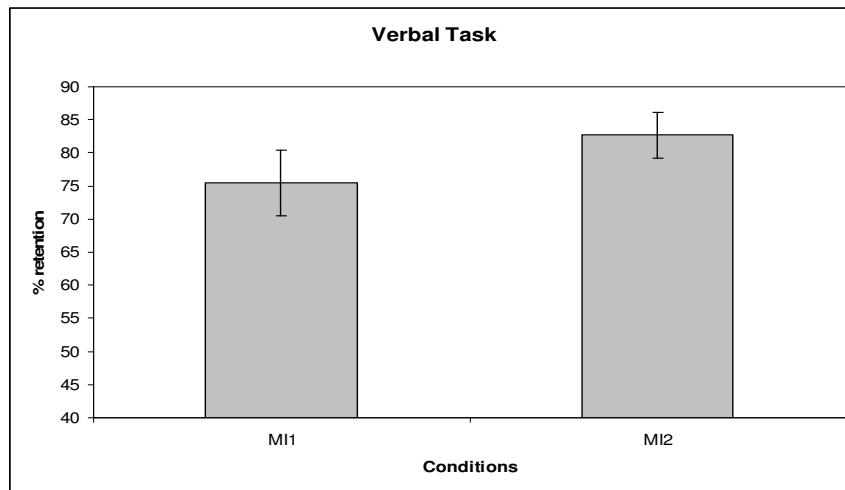


Figure 15. Mean percent retention in MI1 & MI2 conditions.

b) Comparing conditions:

A repeated measures ANOVA with the within-subjects factor: Condition was carried out. No significant main effect of Condition [$F= 1.32$, $d.f.= 3,39$, $P= 0.28$] was revealed. However, mean % retentions were lower for the interference conditions than for MI1 (see Table 7). Also, mean % retention for the Reading condition was higher than % retention for both the AS and Map search conditions. Figure 16 shows performance in percent retention across MI1 and the 3 interference conditions.

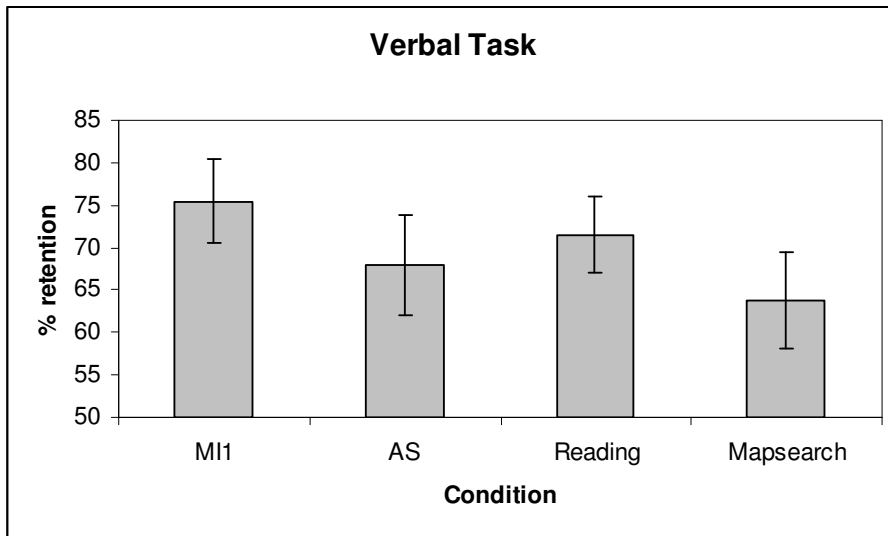


Figure 16. Mean percent retention across interference conditions.

c) Comparing trials:

A repeated measures ANOVA with the within-subjects factor: Trial Order (2 vs 3 vs 4) was carried out. No significant main effect of Order [$F= 1.42$, $d.f.= 2,26$, $P=0.26$] was revealed. Mean % retention for trial 2 ($M= 73.71$) was higher than % retentions for trial 3 ($M= 64.50$) and trial 4 ($M= 65.29$). Figure 17 shows performance in percent retention across trials 2-4 of the verbal task.

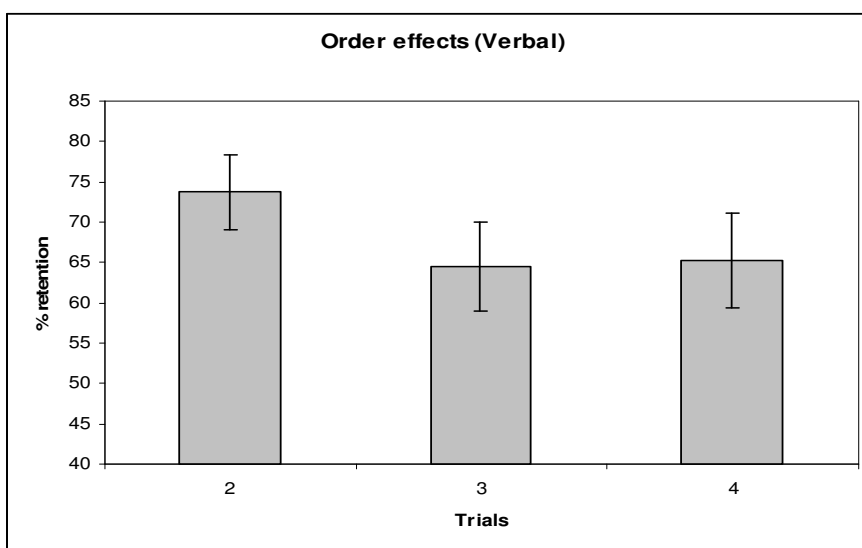


Figure 17. Mean percent retention for trials 2-4.

Qualitative results:

Memory strategies

57% of participants (8/14) reported composing a scenario out of mental images which represent the words to be recalled. Rehearsal involved visualizing these scenarios during the delays. 50% (7/14) reported using semantic associations between words on the same list to aid recall. And 50% reported using sub-vocal rehearsal of the words to aid recall.

One participant reported chunking words on the same list according to the sound-similarity of their endings (e.g. 'Edition' & 'Junction'). Another participant drew upon emotional memories of a personal nature which might be associated with the words on the lists. And one participant formed associations between several words and the characteristics of specific persons in her life.

Finally, 50% of participants reported using a combination of 2 (or more) of the above strategies to boost recall and rehearsal.

Rehearsal

71% of the participants (5/7) who began the experiment with a verbal trial reported having rehearsed in the first unfilled delay, despite not having been informed that there would be a delayed recall phase. Over 85% of participants (12/14) reported rehearsing the verbal material in the last unfilled delay (MI2), while 50% of participants (7/14) reported rehearsing during the articulatory suppression task. Interestingly, 42% of participants (6/14) reported rehearsing words during the Map search task, but performance across this delay was poorest (see Appendix 7).

6. DISCUSSION

6.1 Results summary

Analyses of visuo-spatial data found no effect of type of interference. Performance in the MI1 condition was significantly better than the MI2 condition, with IR significantly better than DR. Analysis of the error measure revealed a significant effect of Recall only, and a 6% trend for Trial Order.

In the verbal experiment, no significant effect of type of interference was observed, but DR was significantly worse than IR. Means for DR show a stepwise reduction across conditions, in the direction MI1>AS>Reading>Map search. Mean recall analysis revealed significantly better performance in MI2 relative to MI1, which is the opposite finding for the spatial data. No significant effects of Trial Order were revealed, but a significant effect of recall was found.

6.2 Material-specificity and Retroactive Interference

Visuo-spatial Experiment

The present study found no evidence of retroactive interference in visuo-spatial memory, despite evidence to the contrary in studies on human long-term visual memory (Nava et al., 2004) and spatial memory (Elmes, 1988). While results show that recall was consistently poorer after the delays, no significant effect of type of interference was observed.

There were no significant differences in performance across all conditions, though it has been shown that under conditions of mental relaxation RI effects on visual long-term memory are diminished (Nava et al., 2004). The largest drop in performance between IR and DR occurred in the Tapping condition, though this was not borne out in either the error or the percent retention measures. Possibly, the

Tapping task disrupted visuo-spatial encoding and rehearsal more than the other tasks. In fact, working memory paradigms have demonstrated significant RI effect of finger tapping on a Corsi type task (Zimmer et al., 2003), using a response field of similar size (72 cm² projection screen) to that used in the present study (78 cm²). In their Corsi task, participants used a computer mouse to indicate their responses. A 10 s interval followed presentation of the Corsi task, during which participants tapped on a 12-button key board. Even after separating out spatial performance from temporal performance on the Corsi task, Zimmer et al. (2003) reported small (non-significant) RI effects of tapping on memory for spatial locations only. They concluded that the large RI effect of tapping on the Corsi task as a whole (i.e. spatio-temporal performance) is due to the need for serial rehearsal of the spatial positions. Perhaps tapping disrupted recall in the present study because participants were encoding the positions in the order of presentation. Future studies could examine serial order effects in the 9-diners test to determine if serial encoding is differentially affected by tapping.

However, 50% of participants reported picturing and mentally rotating the imaginary shapes (formed by the spatial positions) before recall, which seems to suggest non-sequential encoding. It is unlikely that choice of hand in the tapping condition could explain the observed decrease in performance. In a dual-task paradigm Yeary et al. (2002) demonstrated that right hand tapping interfered with mental rotation of 3D objects more than left hand tapping (all right-handed participants). And in the present study 13/14 participants used their right (preferred) hand for tapping (Right handed= 13, Left handed= 1). But since chair positions were only changed *after* the tapping task was completed, when mental rotation became necessary, it is unlikely that the incidence of right-hand tapping was a factor.

It is also possible that the Reading task did not interfere with rehearsal of spatial material. It has been shown that verbal and visuo-spatial working memory use separate cognitive resource pools (Shah & Miyake, 1996). Performance on a verbal reading span task correlated with Verbal SAT scores but not with performance on a spatial span task, and vice versa (Shah & Miyake, 1996). Therefore rehearsal of spatial positions may have been possible during the Reading task. However, participants' choice of strategy may have confounded the results. Since 28% of them reported using a clock face strategy for sub-vocal rehearsal of the spatial positions, perhaps these participants were unable to rehearse during the Reading task.

The map search task also did not produce significant RI effects on spatial recall, seemingly suggesting that material-specific effects were not demonstrated. One explanation could be that the map search task was not attention-demanding enough to interfere with rehearsal. Indeed, Bruyer & Scailquin (1998) have shown that attention-demanding tasks, such as random-generation, interfere with maintenance and rotation of mental images, more so than articulatory or spatial suppression. [In their study, spatial suppression was achieved by playing tones either to the right or left of participants every 2 seconds; participants were required to respond by saying, "right" or "left" while performing the generation and rotation tasks.] Participants were shown a lower case letter (e.g. 'r') on a computer screen. They were required to generate a mental image of the upper case version of the same letter. When a probe (X) appeared, participants decided whether the probe would be "on" or "near" the imagined upper case letter. The results showed that random-generation of numbers caused more interference than either the AS or the spatial suppression tasks. And since 50% of participants in this study used a mental shape strategy, a low attention-

demanding task such as the map search task, might not have interfered with the maintenance of such a simple mental image.

Other studies, which have reported material-specific RI effects, have used interfering tasks with memory loads. For instance Elmes' (1988) study involved an interfering condition requiring participants to learn a new maze, either of same (radial) or different (rectangular) orientation. In the present study, no memory load was imposed upon the participants in the interference tasks. Perhaps material-specific RI effects occur when the interference tasks carry a memory load.

However, serious limitations in the present study prevent any firm conclusions about the nature of material-specific RI being reached (see Limitations).

Verbal Experiment

The main significant finding from this experiment was an effect of recall, with DR worse than IR in all conditions. This seems to suggest that RI effects were demonstrated. Although no main effect of condition was shown DR means showed a stepwise reduction, in the direction MII>AS>Reading>Map search. This observation is difficult to explain in terms of a material-specific account of RI, since it would suggest that DR performance for word lists should have been worst after the Reading task. But 57% of participants reported generating scenarios of mental images formed from the wordlists, and this form of encoding might be less susceptible to the verbal interference from a Reading task. In fact, Zimmer et al. (2003) have argued that memory traces for object locations in a scene may not require rehearsal for their persistence in memory. This cross-modality in encoding the wordlists might also explain the poorer performance in the Map search condition with respect to a material-specific account. Perhaps the maintenance of complex mental images is

disrupted by such a task. A compelling argument, if only a similar disruption of the mental shape strategy was observed in the visuo-spatial task – but this was not the case.

Interference tasks in previous verbal paradigms which have supported material-specific RI effects have also involved a memory load. For example, Bunt & Sanders (1972) demonstrated material-specific RI effects on memory for word and digit lists, in a procedure which required the learning of three consecutive lists. Perhaps material-specific RI effects on verbal memory occur when the interfering material carries a memory load.

6.3 Order effects and Proactive Interference

Visuo-spatial Experiment

The MI2 condition was included in the present study to determine whether any build up of proactive interference had occurred throughout trials. Roitblat & Harley (1988) have reported PI effects on spatial memory in rats. They trained rats to enter baited arms of a starburst (3-arm) maze. The rats learned to enter a baited arm in a forced-choice trial, and then their memory for the correct arm was tested. The inter-trial interval (ITI) was varied to make short (10.2 s) and long (2 minutes) ITI's. Roitblat & Harley (1988) report that as ITI's were increased the mean percentage of correct choices increased. This indicates that the longer ago the rats experienced the previous trial, the better their performance on the next trial – even in successive trials which were mismatched for baited arms (i.e. baited arm in trial 2 different in trial 1). These findings support the idea of PI in rat spatial memory.

Analysis of the displacement data in the present study revealed a significantly better performance in the MI1 condition relative to MI2. Interestingly, 50% of

participants reported rehearsing the spatial information in MI1, but 64% reported rehearsing in MI2, suggesting that perhaps rehearsal of spatial information does not improve performance in the same way that rehearsal of verbal information might. Since MI1 always occurred first in the order of trials and MI2 last, it seemed possible that worse performance in MI2 pointed to a build up of PI. Analysis of error performance with respect to trial order (trials 2-4) revealed a 6% trend in performance. However the pattern of results obtained are not consistent with a PI explanation. Performance decreased from trials 1-3, and this was followed by an improvement in performance in trial 4, followed by a decrease in trial 5. Proactive interference on spatial memory was not demonstrated in this experiment.

Verbal Experiment

Proactive interference effects have been demonstrated in verbal paradigms (Underwood, 1957), and its effect on forgetting is still used in studies on human memory (Henson et al., 2002). But in this experiment, performance was significantly better in MI2 compared with MI1, which clearly opposes the possibility of a build up of PI. Analysis of trial order revealed no significant effect of order. Performance decreased from trials 1-3 and then improved in trials 4 and 5. These findings do not demonstrate a build up of proactive interference across the verbal trials.

However perhaps a practice effect was observed, which could explain the improved performance in trials 4 and 5. Or the incidence of rehearsal in both MI1 and MI2 could explain performance in these trials. Over 70% of participants reported rehearsing in the interval of the MI1 condition, while over 85% reported rehearsing in the MI2 condition. Since performance in MI2 was significantly better than in MI1, this explanation seemingly fits the results.

6.4 Limitations of the present study

One of the major limitations of this study involved the displacement measure in the spatial experiment. Responses were scored as the distance (cm) away from the nearest correct position to be recalled. But this often created a skew in the data which did not reflect participants' true performances. For example, if a participant placed 3 spatial responses near 3 correct positions and placed 1 response quite far away from the last correct position, then this last response increased the total displacement score for that recall stage. Such a displacement score would suggest moderate performance instead of perhaps a very good performance. Because of this displacement skew, interpretation of the visuo-spatial results is tentative. The error score measure, however, was designed to overcome the displacement skew problem by limiting those responses with large displacements to a maximum error score (4).

The spatial percent retention measure was developed to compare the verbal and visuo-spatial data. A response was deemed "correct" if it landed within 12cm of any correct co-ordinate. A participant who placed a counter within 12cm of the same co-ordinate in IR and DR was considered to have retained that position in memory. But the probability of correct guesses (see Pilot 1 discussion) confounds this measure. Zimmer et al. (2003) used a threshold displacement of 8cm to distinguish between "correct" and "incorrect" responses in their object-location task, but they did not explain how they arrived at this value, or indeed if they had corrected for the probability of correct guesses. In the end due to the disparate natures of spatial and verbal data, direct statistical comparisons of the two may prove intractable.

Also, the 9-diners test was designed to test allocentric spatial processing, but many of the participants reported using a clock face strategy for remembering the

spatial positions. And while this strategy is not especially egocentric, it is probably limited to within-maze processing. Furthermore, the 9-diners maze consisted of a circular array of positions on a square board. This arrangement made it easier for participants to recall positions which coincided with the four corners of the board.

Another point of concern involved the presentation of the AS and Tapping tasks. Designed to prevent rehearsal during the interval, they were perhaps not as effective as hoped. The tasks were carried out on e-prime, participants shadowed recordings of an AS task or a tapping noise for a 20s period at the start of each minute of the 5 minute interval. Obviously this does not prevent rehearsal in the 40 s period of rest during each minute. [However, making participants perform both AS and table-tapping continuously for 5 minutes carries some ethical concern.] Perhaps more importantly was the need to prevent rehearsal directly after IR, which these tasks probably failed to do. A delay of 6-10 s was necessary in order to set up and run e-prime for each task, which probably provided a window in which participants could begin rehearsal.

6.5 Future research

Future studies on material-specificity in RI may overcome the problems with the error score and percent retention measures mentioned above by building up a normative dataset on recall of spatial positions. This could be used to determine a threshold displacement for “correct” recall of a spatial position. Furthermore, this threshold value could be used to calculate the total “correct” area surrounding the 4 positions to be recalled in the 9-diners test. Dividing this area by the total area of the presentation board (78cm^2), would give a measure of the probability of correct guesses, which

could then be used to adjust participants' error data to make the measure a truer reflection of spatial recall performance.

In the spatial experiment, 28% participants reported using a clock face strategy for remembering the spatial positions. Perhaps testing participants' recall on non-circular arrays might eliminate the use of this strategy, which may have confounded the visuo-spatial results.

One interesting finding from the present study was the opposite effects rehearsal seemed to have in verbal and spatial minimal interference trials. More rehearsal of spatial material seemed to result in poorer performance, and the reverse was the case in the verbal trials. Future studies could compare rehearsal and non-rehearsal groups for verbal and spatial recall to determine whether this effect is of genuine interest. Alternatively, training participants in mental quietude and cutting down the delay before presentation of the AS and Tapping tasks might improve the current design.

Because cross-modality of encoding and rehearsal strategies was a factor in this experiment, it might be of interest to separate participants according to preferred strategy choice (verbal or spatial). Indeed, Noordzij et al. (2004) did this by examining reaction times to picture-picture and sentence-picture verification tasks. They demonstrated a differential effect of finger-tapping on the two groups' ability to process simple spatial relations. Perhaps material-specific effects of RI may manifest differently in the performance of two such groups.

Finally, because material-specific effects were not demonstrated in this experiment (the above limitations notwithstanding) where the interference tasks carried no memory load, it might be useful to repeat the experiment with interference tasks which do carry a memory load. It remains to be seen whether a spatial

interference task (with memory load) causes *more* RI in a spatial task, than a verbal interference task with a memory load. In other words, material-specific RI may still be revealed in instances where the intervening interference tasks all carry memory loads.

6.6 Conclusion

The limitations of the present study made interpretation of the results problematic. And although no material-specific RI effects were demonstrated on either verbal or visuo-spatial memory in this experiment, the results point to a few interesting avenues which could be explored in future research.

From the qualitative data obtained choice of encoding and rehearsal strategies emerge as important factors to consider in the design of future experiments. Also, the possibility of material-specific RI effects for interference tasks which carry a memory load has been raised. Fundamental problems in trying to make statistical comparisons between verbal and visuo-spatial data have been revealed, while PI effects appeared to have been adequately controlled for in the current design.

This experiment, above all, has been an exploratory study, and it is hoped that future research on the nature of Retroactive Interference may draw momentum from it.

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APPENDIX 1 (Materials)

Complete list of cubicle decorations:

Two 60x80cm colour posters ('Turkish Café' by August Macke, & 'Violin & Guitar' by Pablo Picasso, both published by Icon Art, England), two coloured child's drawings (researcher's nephew: male, 5years), a black and white painting (researcher), a large glass-fronted bookcase, a broom standing in one corner, a tape-recorder, plastic bottle of water, plastic Tupperware container of biscuits (participants were unaware of contents during testing), researcher's black scarf and ¾ length coat (hung at one corner of the cubicle) and a table with pens, stopwatch and a folder at the entrance to the cubicle.

Wordlists:

The words used in these lists were taken from the 'MRC Psycholinguistic Database Interface' (http://www.psych.rl.ac.uk/MRC_Psych_Db.html). Criteria used during word selection were:

- syllables: 2-4
- familiarity (300 < x < 700)
- concreteness (300 < x < 700)
- imaginability (300 < x < 700)

We decided to utilise the BNC (<http://www.itri.brighton.ac.uk/~Adam.Kilgarriff/bnc-readme.html#lemmatised> using lemma.al (124 KB)) for word frequency measures as this is more recent than that listed in

the MRC psycholinguistic database interface (Kucera & Francis, 1967).

We selected words with a BNC frequency of 1000 – 5000 (corpus = 100 000 000) as this matches the Kucera and Francis proportion of 10 – 50 words out of a corpus of 1 000 000.

Care was given to generate wordlists of equal values in the above criteria.

Furthermore

all lists had a total of 40 syllables each meaning that lists did not differ in reading/rehearsing time.

List A	List B	List C	List D	List E
Romance	Academy	Fisherman	Biology	Possession
Outbreak	Prosperity	Invention	Encounter	Uniform
Champion	Bacteria	Harvest	Caravan	Witness
Emergence	Harbour	Edition	Woodland	Triangle
Composer	Builder	Segment	Dismissal	Portion
Principal	Instinct	Discovery	Ambulance	Detective
Orchestra	Commander	Citizen	Clothing	Knitting
Whisky	Exposure	Diamond	Hardware	Sunshine
Cathedral	Assault	Laughter	Friendship	Opening
Pollution	Journal	Mineral	Profile	Protest
Dividend	Ownership	Apartment	Medicine	Episode

Comfort	Peasant	Engineer	Personnel	Removal
Convention	Arrival	Junction	Resistance	Childhood
Opponent	Formation	Lecture	Inquiry	Expedition
Disaster	Servant	Ceiling	Channel	Humanity

Verbal Interference: from ‘The Guinness book of Amazing Nature (1998)’: Guinness Publishing Ltd.

Passage 1

RIVERS

Although they contain only a fraction of the world’s water – 1% as compared to the 97.2% contained in oceans – rivers are the main force behind changing landscapes. From its source near a watershed, or from a spring, a stream seeks the steepest and shortest course downwards. Swollen by tributaries, rainfall and ground water, it becomes a river and its power increases, enabling it to erode the landscape as it works its way to the sea. When a river reaches low-lying ground, its pace slackens; meandering along valley floors, it deposits large amounts of sediment which create flood plains, levees and even islands.

The Amazon

The greatest river complex in the world, the Amazon is also the world’s longest river. From its source among the snow-covered Andes of southern Peru, the river forms the Apurimac, which joins other streams to become the Ene, the Tambo and the Ucayali and the Marañon, the river is called the Amazon for its final 3,700-km journey to the Atlantic Ocean. In total, the river is 6,750 km long. The Nile, which stretches from Burundi to the Mediterranean, was 6,670 km long before the loss of some meanders when Lake Nasser formed behind the Aswan Dam. The Amazon’s flow is 60 times greater than that of the Nile, and it drains 7,045,000 km² of land – nearly twice that of any other river. It has 15,000 tributaries, 10 of which are over 1,600 km in length. The Amazon also supports the largest tropical rainforest in the world.

The ‘father of waters’

As the central river artery of the USA, the Mississippi has become one of the busiest commercial waterways in the world. From its source in northern Minnesota, the river flows south, receiving the waters of the Missouri and the Ohio in its middle reaches, until it empties into the Gulf of Mexico – a distance of 6,020 km, which makes it the third longest river in the world. The Mississippi basin contains 31 US states and two Canadian provinces. When the great river enters its alluvial plain, it winds in enormous curves, forming ox-bow lakes, levees and huge banks of sediment.

Land between the two rivers

The Euphrates is the greatest river of south-western Asia. Together with the Tigris, it originally encompassed the ancient ‘Land Between the Two Rivers’, the location of humans’ earliest recorded urban civilisations. From its source in the mountains of Erzurum in Anatolia, the Euphrates flows south-east until it joins the Tigris and becomes a muddy waterway known as the Shatt al Arab, which extends through a vast delta into the Persian Gulf. During the heavy rains in spring, the combined discharge of the two rivers is some 4,960 m³/sec and their waters can carry as much as 3 million tonnes of eroded material downhill from the highlands in a single day. The majority of this sediment is deposited on the plains of Mesopotamia where it forms rich fertile soil.

Mother Volga

Lying entirely within the Russian Federation, the Volga’s catchment area is the largest in Europe. From its source in the Valdai Hills, the main river flows south-east through steppe and forest, gathering up the waters of its main tributaries, the Oka, Belaya, Vyatka and Kama on its way. As it approaches the Caspian Sea, it divides into a delta comprised of about 275 tributaries. Navigable for nearly its entire length, the Volga has played an important role in Russia’s history: in the 9th century Viking invaders sailed down the Volga into the heart of Russia, establishing trade routes which still exist to this day. The river, known in Russian folklore as ‘Mother Volga’, remains Russia’s most important waterway, and is connected to Moscow and St Petersburg by canals.

Frozen giant

The Ob'-Irtysh (Ob') is the world's seventh longest river. Running along the Siberian slopes of the Altai Mountains, it stretches for some 5,409 km and drains a basin of around 2,990,000 km². The Ob' absorbs massive amounts of seasonal snow and rain. Its entire length is frozen by November, the upper reaches remaining so for 150 days. Up to 80 km wide in places, it is the widest river in the world which regularly freezes over.

The world's largest delta

The Ganges-Brahmaputra delta – formed where two great rivers, the Ganges and the Brahmaputra, join and flow through Bangladesh and West Bengal – covers an area of 75,000 km². Bangladesh is a land of rivers which flood regularly, leaving rich deposits of alluvium. The area is home to over 100 million people whose lives are enhanced by the region's fertility.

Delta in danger

Surrounded by arid rocky desert, the river Nile and its vast delta have supported most of Egypt's agriculture and 99% of its population since the Ancient Egyptians first planted their crops in soils enriched by deposits carried downriver in the annual flood from the African interior. But the site of such a magnificent early civilisation is now in decline: some 150 years ago, 2 million hectares of farmland supported 5 million people; today 2.8 million hectares of farmland must support a population of 60 million. The construction of the Aswan High Dam nearly 30 years ago prevented the Nile's annual flooding, and any silt that now reaches the delta is washed away by the Mediterranean currents faster than it can be replenished. The delta is further imperilled by an increased salinity of the soil, brought about by intensified farming and the use of fertilizers.

Mud pie

The Mississippi delta has been formed by millions of years of sedimentation which spills out in a huge cone over the floor of the Gulf of Mexico. Each year the river adds some 495 million tonnes of sediment to the delta which is advancing its shoreline seawards by nearly 10 km every 100 years. The low flat alluvial plain between Memphis and New Orleans used to be extremely vulnerable to flooding and as a result a network of levees now regulates the flow of water. The man-made river control structures are modifying the natural landscape. The original delta area of south-central Louisiana is no longer receiving sediment from the Mississippi, and as a result subsidence is causing loss of land.

China's river deltas

Three of China's greatest rivers, the Yangtze, Zhujiang and Hunag Ho (or Yellow River), have all formed vast deltas, each one rich in arable land, natural resources and heavily populated. The Yangtze's delta supports a population of 73 million, 14 cities and produces abundant crops of grain, cotton, hemp and tea. Flowing for some 4,700 km from the Kunlun Mountains to the sea, the Hung Ho carries with it vast quantities of yellow silt which forms the delta that has become one of China's most fertile regions. Beneath its mud flats lie enormous reserves of petroleum and natural gas. Situated in the sub-tropical zone, the Zhujiang delta's mild climate and plentiful rainfall enable crops like rice and sugarcane to flourish. Utilizing the delta's extensive network of rivers, ships carry on a thriving trade with Hong Kong, Macao and islands in the South China Sea.

Swampy Orinoco

Over the entire 2,000-km course of the Orinoco River there is not a single dam, so it floods annually and prodigiously. The river begins to widen at the town of Barrancus, about 80 km north-east of Ciudad Guyana, and the delta receives all the silt from the river. The delta itself is really a mangrove jungle that stretches hundreds of kilometres across. It is 60% water and those who live there construct log houses which stand on stilts 5 m above the river. Many of these communities are inaccessible except by small boat. The indigenous Warao Indians call the Orinoco 'a place to paddle' and managed to escape subordination by 18th century European slave traders by disappearing into the difficult waters of the delta. Natural oil has been discovered under this watery landscape.

Passage 2

ENDURANCE

The amazing ability of some animals to endure extreme temperatures, survive great journeys or bear weights many times greater than their own is due to the adaptations their predecessors have made. These physical modifications, which have developed over generations, equip animals perfectly to endure the difficult environments in which they have to live. Staying airborne for four years, for example, is a simple matter for the common swift, thanks to a physical makeup which enables it to eat,

drink, sleep and mate on the wing. Camels and polar bears both have special means to cope with scorching heat and freezing cold.

Weightlifters

Some of the most remarkable load-bearers of the animal kingdom are some of its smallest members. Ants have two sets of jaws: one for chewing and one for carrying. Many species forage alone and have to carry prey over seven times their own body weight. One species, which measures only 3 mm long, has been observed dragging a prey 10 mm in length, such as locusts, to its nest. This would be equivalent to humans carrying a small car in their teeth over a distance of 8 km. The trap door spiders of North America and Japan can endure weights up to 40 times their own while defending their burrows from intruders. But perhaps the strongest of all are the rhinoceros beetles, which can carry up to 100 times their own body weight.

Highs and lows

Jumping spiders have been found at altitudes of 6,500 m on Mount Everest, but it is birds that endure the highest altitude of any animal. In December 1967, a pilot spotted 30 whooper swans on their way from Iceland to Northern Ireland flying at an altitude, confirmed by radar, of over 8,230 m. The highest flying bird on Earth, however, is the Ruppell's vulture which can soar at altitudes of 11,000 m. In November 1973, one of these birds, identified from feathers retrieved afterwards, collided with an aircraft at 11,277m over the Ivory Coast. At the other extreme, tusk shells – marine molluscs with a tapering shell which houses a foot for digging – are found in ocean waters at depths of up to 4,000 m, often buried in the sea-bed. The deepest living fish, the brotulid, has been found in the Puerto Rican Trench in the Atlantic Ocean at depths of an incredible 8,300 m.

Hot and hardy

Camels inhabit scorching desert regions in Africa and Asia where they can survive without water for up to 17 days. These phenomenally hardy animals can lose 25% of their body weight through dehydration without suffering any ill effects. The single hump of the Arabian camel, or dromedary, and the double hump of the Bactrian camel store fat which can keep the camel alive when food is not available and can be converted into water. Their broad feet enable camels to walk easily on soft sand and double eyelashes and sealable nostrils protect their eyes and nose during sandstorms. They can survive on the thorny desert plants which other animals could not endure. These remarkable adaptations have made camels extremely useful as desert pack animals. When water is made available after a long journey, camels can drink 100 litres within a matter of minutes to replenish their body supply.

Cold and hungry

The polar bear survives in icy Arctic conditions thanks to its remarkable coat and a 10-cm layer of insulating fat. Each of the coat's hairs is a clear hollow tube which directs heat from the sun to the skin. The coat is white to provide the polar bear with perfect camouflage on the drifting ice sheets of Canada, Greenland, Norway, Russia and Alaska. Underneath the white fur, however, lies a thick black skin which absorbs the sun's rays. The bear's head is small to minimise heat loss, but the long snout contains large membranes that warm and moisten the freezing dry air before it reaches the lungs. The bear's large feet are covered in fur to stop it slipping on the ice. After the ice has melted in the summer the polar bear lives for some eight months without food. Gorging on seals from April to July, the impregnated females can increase their body fat by 50% or more. They build up a thick layer of fat around the thighs and rump which will provide additional calories when food is scarce. The massive polar bear – weighing up to 750 kg and standing 1.5 m at the shoulder – is a strong swimmer, living up to its scientific name *Ursus maritimus* or 'sea bear'. It often swims over 150 km from land or ice, searching for its main prey: seals.

Great journeys

Migrating birds travel long and difficult journeys, often in search of food not available in one region. Ducks, geese, swans and swifts migrate across Europe, while the golden plover flies the 3,900 km from Alaska to Canada each year.

Animals domesticated for their endurance

Since the first wolves were domesticated thousands of years ago, humans have used dogs for their endurance as well as for companionship. Some of the hardiest breeds are the Alaskan Malamute and the Siberian Husky. Both are intelligent, making them easy to train, and have thick coats to protect them from severe cold. Malamutes have even been used in the Antarctic. Their large size and great strength make them ideal for pulling sledges over snow and ice.

Mules – the offspring of a male ass and a female horse – are also used for their strength. Standing about 150 cm tall, these animals have a thick head and a sturdy muscular build. First used as beasts of burden in Asia Minor 3,000 years ago, mules are still valued today for their ability to cope with rough and steep terrain.

The Arabian horse is valued not for its carrying capacity, but for speed and stamina. It was first bred for these specific qualities in the 7th century AD and has formed the blueprint for horse-breeding to the present day.

High altitude

Plant life is scarce at high altitudes due to low temperatures and barren soil. In the northern Andes in Colombia and Ecuador, alpine meadows called *paramo* contain grass and herbaceous plants. Some of these plants, called frailefones, can grow 4-6 m. In the southern *paramo*, rough grasses, cushion and rosette plants, shrubs and cacti survive. The Alps support a range of hardy plants called pulsatillas. The key to the survival of these plants is their thick, long, woody rootstocks that penetrate deep into the sparse soil and gravel. The plants open their leaves for a short period of activity during the early spring thaw, producing enough food to see them through the winter. Once the flowers are pollinated, they produce fuzzy seeds with tufts of hair to carry them in the wind.

Hardy lichens

The Earth's polar regions are some of the most barren of all, where only 10 mm of rain falls each year and the soil is always frozen. Only in the six months of summer sunlight, when snow meltwater is available, can the flora of these regions emerge. In the Arctic, temperatures rise above freezing for only one month a year. But this is enough for 1,000 species of ferns and flowers, 950 species of fungi, 300 liverworts and around 2,000 algae to flourish. Perhaps the hardiest of all the Arctic's plants are the lichens. These tiny plants can survive on barren rocks, nourished by the occasional bird dropping. In the Antarctic, around 400 species of lichen survive, along with snow algae which colour the coastal landscape red, green and yellow.

Fertile deserts

Desert plants have to face scorching sun and lack of water. In the Arabian Desert plants spring into action at the first sight of rain – seeds, buried for months in the dry gravel soil, germinate and send up shoots within hours. Mustard, pea, daisy, caper, iris and milk-weed plants turn the normally barren plains green with their hastily produced shoots and blooms. Along with these seasonal plants, hardy shrubs survive, yielding fragrant frankincense and myrrh. The desert carrion flower of southern Africa has no leaves, just spine-tipped stems which store rainwater and protect the plant from grazing animals. At the tips of these stems the plant produces odd star-shaped flowers. Patterned in yellow and red to imitate rotting flesh, the flowers give off a foul stench like carrion to attract flies which pollinate the flowers, enabling the plant to reproduce.

Spiky cacti

Succulents are the true specialists of arid regions. The most amazing of all is the miracle plant which can live for 1,000 years. Also called the 'living fossil', this plant, found in the deserts along the southern shore of South Africa, consists of two huge leaves which grow out flat to the sand in opposite directions from a low woody stem. These leaves can be up to 3 m long and over 1 m wide. The plant gains water from sea fogs, driven inland by winds from the Atlantic – these same winds disperse the plant's seeds across the hot desert sands. There are a total of 1,650 known cactus species. Many of these can be found in the arid deserts of Mexico, including Button cacti which live on drops of moisture from beneath the desert rocks, and protect themselves from hungry animals by looking just like stones. One cactus which inhabits the totally arid Atacama Desert in Chile never receives any rain, only the damp mist from the Pacific.

Action beneath the surface

Using extremely long roots to get to any available water is a survival strategy common to the most resilient of desert plants. In the sandy Arabian Desert, the long, deep roots of sedge plants are so substantial that locals use them for firewood. The banana plant has an underground stem that sustains it safely through the dry season. This stem sends out a sturdy shoot that consists of thick leaf stalks, arranged one inside the other, and ends on an oblong leaf blade. When the rain comes, this shoot finds the water and a flower stem emerges from its centre.

Taken from: *The Guinness book of amazing nature, 1998, Guinness publishing ltd. Pp153-154*

Passage 3

PREDATORS

Hawk-eyed

When it comes to sharp eyes, few predators can rival hawks. The hawk family birds include buzzards, eagles and kites. Hunting by day, these fast and agile birds of prey scan their surroundings from the air, sometimes taking a leisurely warm-up flight before scouring the ground for the tiniest movement. Once it has locked on to its target, a hawk may swoop suddenly or track its prey until the victim tires and the predator strikes, grabbing the prey in its sharp talons and ripping it apart with its powerful beak.

Hawks are so fast they can even snatch up rattlesnakes. Small mammals, birds and insects also fall victim to hawk air-strikes. These sharp-eyes raptors are found on all six continents where they nest either in trees or on marshland or cliffs. Some roam far and wide to find food, flying up to 500 km a day to scan the landscape. One species, the bat hawk, provides the ultimate testament to the incredible accuracy of hawk vision: it hunts only at twilight, locating and catching all its food within just half an hour.

Fastest land mammal

The cheetah is a stalker. It hunts alone in the morning or late afternoon, avoiding the intense midday heat of its African and Middle Eastern habitat. Its excellent eye-sight enables it to spot prey – usually an antelope – at great distances. Then it waits, moving into position undetected by its victim before breaking cover and running its prey down with explosive speed. Incredible agility enables the cheetah to change direction with the prey. Its sharp, non-retractable claws grip the ground and its strong slender legs take it to speeds of over 100 km/h over short distances. Once it has caught its victim, the cheetah clamps its teeth onto its prey's throat to stop it struggling. Thanks to the arrangement of its teeth, the cheetah breathe while it subdues its victim in its throat-hold until the struggle is over.

Silent night killers

Incredible night-vision is what makes owls such effective nocturnal killers. Their large eyes are positioned at the front of their head, maximizing perspective sight and enabling them to swoop with pinpoint accuracy on birds, small mammals and insects. Perching silently, an owl can scan its surroundings without changing position and alerting potential prey, thanks to highly adapted neck muscles which allow its head to swivel almost all the way round – through 270 degrees. The shape of the head channels sound into the ears, which are positioned asymmetrically to locate the source of every sound perfectly. Even when the owl launches itself into the air to swoop on a victim, it makes almost no sound. This is because its flight feathers have a velvet-like covering which muffles the sound of the owl's wing-beat.

Team-work

Wolf packs hunt as a team. In the hostile habitats of the far north, grey, or timber, wolves work in packs of up to 25. Stalking downwind of their victim, the wolves suddenly give chase, bringing down animals much larger than themselves, like bison, caribou, elk and moose. The pursuit can last several kilometres and often ends in a fearsome struggle. To weaken the victim quickly, the wolves target the areas that will cause the fastest loss of blood – while the alpha wolf grips the animal's nose, the others rip at the flanks and throat. Once the animal has been felled and killed, the wolves tear open the belly and eat the protein- and fat-rich entrails. Wolf attacks can take place on ice, open ground or amongst vegetation. The pack is such a dedicated hunting unit that most prey stand little chance of survival. The largest wolf prey, moose, sometimes defend themselves by simply standing their ground against the pack. But if they eventually run, they are always chased and often killed despite their size.

Mongoose snake-killers

The mongoose is one of the fastest and most agile of all predators. This brave fighter, found in Africa, Asia and southern Europe, can grow to a metre in length and has short legs, a pointed nose, small ears and a long furry tail. It lives in burrows and feeds on birds, small mammals and reptiles, such as lizards. But it is against venomous snakes that this predator reveals its truly amazing ferocity. The mongoose jumps at the snake's head and, before its victim has time to bite, clamps its small teeth into the snake's skull and cracks the bone. Mongooses attack snakes so fearlessly that, traditionally, they were thought to be immune to snake venom. In fact this is not so; it is just their incredible speed and agility that makes these small mammals effective snake-killers.

Deadly designs

There are approximately 400 known species of carnivorous, or insectivorous, plants. While they vary greatly, all digest the prey that they trap by a process of chemical breakdown that is comparable with animal digestion. This ability to digest nitrogen-rich animal proteins means that they are often able to survive in hostile environments. Such plants do not feed exclusively on prey, however. As with other plants, they also create food by photosynthesis, the synthesis of organic compounds from carbon dioxide and water using light energy absorbed by chlorophyll. Most carnivorous plants are

small, often less than 30 cm tall, and the majority have green leaves and colourful flowers. The smallest of all tend to be those species that thrive in mossy regions surrounding bogs.

Trap-setters

Bladderworts are one of the few carnivorous plants to catch their victims under water. They have small pear-shaped leaves that feature a trapdoor, or valve. The chamber, or bladder, inside this trap is maintained by water tension, which flattens and curves the chamber's walls inwards. Tiny organisms, such as protozoans, crustaceans, worms and newly-hatched fish, become trapped on the bladderwort's leaves. The water then sucks the prey through the trap-door, which opens and closes in a split second. It is still not clear whether the prey is then digested by enzymes produced by the plant or by bacterial action, but the end product is harnessed to feed and nourish the plant.

After swallowing an organism, it takes about 30 minutes for the bladderwort to discharge the water and reset the trap. On dry land, bladderworts capture insects using sticky glands on the leaf surface. The leaf rolls up to trap and digest the prey, before unrolling again when digestion is complete.

Sticky tentacles

The Sundew family of plants are widely distributed in tropical and temperate regions. They are bedecked with nodding, five-petalled pink and white flowers. The roundish, reddish leaves measure less than 2.5 cm in diameter and are covered with gland-tipped hairs. These exude a sticky nectar that attracts insects. The insects are trapped by the plant's flexible tentacles on the upper part of the leaves. The leaves fold and the prey is then digested by enzymes secreted by the tentacles before the leaf reopens again. Sundews lure midges, gnats, mosquitoes and other tiny insects. The digestion process can take up to a week.

Venus fly-trap

The Venus fly-trap is found primarily along the coastal plains of North and South Carolina in the USA. A member of the sundew family, it grows on the edges of ponds and wet depressions. The blade of each leaf has two lobes that are hinged to one another like jaws. These jaws have nectar glands and bright-red digestive glands. Insects become trapped on the spine-like teeth along the margins. On the middle lobe of each leaf, there are three pressure-sensitive hairs which, when touched, send a chemical message that triggers the jaws to close. The insect, having landed in search of nectar, then becomes engulfed and is digested over several days. The leaf, which tends to be between 8 and 15 cm long, can only complete three or four trappings before it dies.

Drowning in nectar

Pitcher plants capture prey by a variety of means. Some have tubular leaves that resemble a trumpet or an urn. They have stiff, downward-pointing hairs around the entrance and smooth, greased surfaces beyond. Insects are attracted to the entrance by nectar-secreting glands that may then extend inside the trumpet. As the insect follows the nectar path, it falls deeper inside and, because of the smooth surface, is incapable of retracing its steps. Eventually, it falls into a liquid pool at the bottom of the leaf where digestion takes place.

Territorial combat

Honeysuckle and ivy are the best known territorial plants. They grow in a diverse range of conditions and invade the territory of other plants, shutting out the light for the plant underneath. Despite, or perhaps because of its intrusive nature, the honeysuckle plant has long been a symbol of love and protection. The scent is meant to encourage erotic dreams. When placed over a door, honeysuckle is meant to keep out fevers and those with ill-intent. Ivy, on the other hand, is associated with death and decay, perhaps because it requires a structure to support it, such as a crumbling wall or a dead tree. Ivy is associated with the gods of wine, Bacchus and Dionysus, and used to be hung outside inns as a sign that good wine was drunk within.

Taken from: *The Guinness book of amazing nature, 1998, Guinness publishing ltd. pp138-141*

Passage 4

SYMBIOSIS

Symbiosis is the intimate association of different species. Many animals collaborate with organisms from different species because such cooperation means mutual survival. Symbiotic relationships can

be amicable and mutually beneficial, as is the arrangement between the cleaner fish in its host, or they can be more sinister, as in the enslavement of some ants by their fellows.

Ant Slavery

A small number of ant species are known to pillage, plunder and enslave other ants. Found in the northern temperate zone, there are four genera known to be slave-makers. Their victims tend to be eggs or larvae snatched from defending workers trying to save their colony. Most of the spoils are eaten, but those that are not are given work that would normally have been done by workers of the invading species. The enslaved ants' workload increases all the time, and in some cases, the slave-owners become wholly dependent on their slaves to the extent that they cannot even feed themselves. Ant slavery can lead to changes in the social structures of colonies- workers from colonies that may disappear altogether as slaves are brought in. It has been observed that some ants, when reduced to slavery, can kill their own queen causing the demise of the colony.

Cleaner fish

Certain animals groom or clean others, helping to remove parasites. These lifestyles are mutually beneficial; hosts benefit by having parasites removed, while groomers get a ready source of food. Over 40 species of fish are known to be cleaners, as well as several crab and shrimp species. A wrasse is a small brown fish which cleans a number of other species, including the opaleye, blacksmith, black sea bass and sunfish. When they are being cleaned, they adopt a motionless position, sometimes remaining perfectly still upside down, as the wrasse cleans. The cleaner is granted immunity from attack, even when it cleans inside the mouth of a large predatory fish.

Marine fraudsters

Some non-cleaner fish have exploited the immunity that cleaners seem to enjoy. For example, several cleaner fish have elaborate dances and display sequences which they use to advertise their services. One such cleaner, the Labridae, moves its posterior up and down as a signal to a passing fish that it might need cleaning. The blenny fish has learnt to imitate the size, shape and colour of this fish, and has even copied its dancing techniques in its efforts to attract a fish who wishes to be cleaned. But the blenny is really a fraud: a fin-eater, its true motive is to capture and kill the fish.

Marine hitchhikers

Several animals use others as a form of transportation. Hitching a ride on another creature is often a useful way of expanding the territory a species can occupy. Hitchhikers have also been known to rely on the movements of hosts to generate water currents from which food can be gleaned. Barnacles are well known for hitchhiking. They usually attach to non-living hard surfaces, such as driftwood, but they are also known to attach to animals such as whales. One species, which has transverse ridges, in the valves of its shell, actually grows in to the host's upper skin, literally screwing itself into the whale, resulting in visible scars on the host animal. Others choose large eels, ship's hulls, turtles, manatees, lobsters, sunfish, sea-snakes and even the teeth of sperm whales as their hosts. Barnacles are highly adapted to the hitchhiking life, possessing specialised funnels to gather in water from which they extract food.

Suction powered

The remora genus is perhaps the best known of hitchhiking fish. It has a powerful suction disc at the top of its head which it attaches to other large fish, sharks, whales and turtles. Several remoras can be found on a single host. The suction disc is under the direct control of the remora, so it can easily break free of its host. Remoras often hitch a ride to the hosts feeding ground, and then break free to share in a meal to which they have been conveniently transported. Humans have utilised remoras' special skills by tying a fishing line around a live remora's tail to catch turtles and other marine life. Remoras do have some beneficial uses as they often take part in grooming, thereby ridding their host of unwanted parasites.

Close companions

Symbiosis between birds and mammals is one of the most familiar and enduring symbols of species interdependence, and no other bird highlights this better than the oxpecker. The two species, the red-billed and the yellow-billed oxpecker, live on the bodies of large mammals in the African savannah. These mammals include rhinos, hippos, giraffes, cattle and antelope. The birds grip tightly with strong claws to the hides of their hosts, eating parasites such as ticks and flies. The bird-mammal symbiosis works well most of the time, but the working relationship between the two does occasionally breakdown- the mammals can get irritated by the persistent pecking of the birds, while the oxpeckers have been known to worry at skin wounds and peck the flesh of their hosts. On occasion, the oxpeckers roost overnight on their host in order to avoid the trouble of finding a new mammal to peck in the morning.

Communication

Almost all animals communicate, though their reasons for doing so vary enormously. They may be establishing and maintaining hierarchies within a group, expressing feelings of hunger or guiding each other to food or nesting places. Communication can take many forms, such as visual displays, sound production or the release of chemicals. Sound signals can be used when animals are out of sight of each other to warn of an approaching danger. The messages conveyed by facial signals can vary widely between species: a chimpanzee displays insecurity and fear when it bares its teeth whereas a tiger is issuing a threat.

Sounds of the deep

Whales, porpoises and dolphins belong to the order of mammals called Cetacea. All have complex vocal communication systems. Dolphins live in groups, or 'schools', which may include up to 300 animals. Members of the group communicate with each other by means of pulsing high and low-pitched sounds. The low-pitched sounds include barks, whistles, screams and moans and are audible to humans. The high-pitched sounds, which use sound wave frequencies that are inaudible to humans, are used for navigation. Whales and porpoises use a similar communication system to dolphins. The finback whales produce a long, drawn out sound which is thought to enable them to communicate with each other over distances of 850km.

Sign language

The use of sign language is one of the main differences between humans and animals. Some animals are advanced enough to be able to use one sound to warn of the approach of a snake, another for a lion. But no animal can use language as humans can: to communicate an abstract concept. Attempts to teach human language to animals, particularly chimpanzees, have met with little success as chimps cannot form the range of sounds necessary. However, recent attempts to teach sign language to these most intelligent of mammals have proved more successful: one female chimp called Washoe has learned to use some 150 signs and understand over 300. But does the chimp know the meaning of the words or is it just responding to a stimulus for which it has previously been rewarded? There is evidence which suggests that chimpanzees are capable of communicating with each other by using concepts, not just noises. The trainer of a chimp called Lucy received the following request from her: "Roger tickle Lucy". The trainer replied: "No, Lucy tickle Roger". After a little pause the chimp tickled the trainer.

Electric code

All creatures generate electricity, but usually at very low levels. Species such as electric eels and knifefish produce electricity at higher levels than average creatures. The knifefish, so called because it is shaped like a knife blade, uses low voltage to detect its prey- a useful talent in the murky waters of the Amazon. From recent research it seems the knifefish talk to each other by changing frequencies, stopping and starting electricity production very rapidly- rather like morse code. Similarly, electric eels can communicate their presence to other eels through electric pulses. Males make the loudest and most frequent emissions, while female respond with shorter bursts. This allows males to correctly identify females.

Birdsong anthems

About half the world's birds are able to use their vocal cords to produce the sounds by which they communicate. The main reasons for sound production are to enable a male bird to attract a mate, to establish and maintain its territory and to warn of danger. Each species has its own calls, ensuring that within a large group of birds only members of its own species will be contacted. The nightingale's song is one of the most complex: it not only varies in pitch, volume and structure, but can change form day to day.

Squid semaphore

Some animals communicate their moods by visual means. In the deepest darkest parts of the ocean live squid whose tentacles glow like strings of fairy lights. The eyes belonging to squid and octopus are as highly developed as some mammals and they use them to observe each other in the murky depths. These molluscs can change colour at will. When angry or sexually aroused, they will pulse with vivid bands of colour. Some octopuses can alter the texture of their skin, raising small bumps or sprouting finger-like projections.

Language of wolves

Animals that live in complex societies will often develop sophisticated sign-systems to help them survive in harmony. Wolves amongst the most socially complex of carnivorous mammals, have several means of conveying messages. Amongst the strongest and fiercest of the dogs, they have a special status language which can determine rank without the need for pack infighting. This involves a series of facial expressions, tail positions and other gestures that convey which is the top dog. Wolves also use effective communication prior to hunting. Before setting out on the hunt, wolf packs may engage in a series of gestures, including circling around each other, rubbing noses, wagging tails and

vocalising. These movements and howls may be the wolves' way of deciding where to hunt, what strategy to use or which route to take.

Defensive postures

Mammals that feel threatened by predators can make themselves seem larger, louder or more frightening. A wolf's fur will rise all the way along its arched back, while an elephant will trumpet, flapping its ears away from its body, like giant flags.

APPENDIX 2 (Pilot instructions)

Pilots 1 & 2 Instructions

"In this experiment we want you to do the same memory tasks 3 times. I will explain what you have to do, and then we will have a practice run, before we begin properly.

Imagine these diners are all people sitting at a table in a restaurant, ordering lunch. Some of them are vegetarians. I will point out the vegetarians to you, and your job is to remember where they are sitting. After I point them out, I will take the board away and ask you to move around the table to a different chair. I will then give you some circles and you will have to put them on to a piece of blank paper to show where the vegetarians were sitting. You do not have to remember the order in which I pointed to them, just the position of where they were sitting.

I will then remove the paper and give you something to read for five minutes. Please read it out aloud, at your own speed. When the five minutes reading is over, I will show you around the table to another chair, and give you a new set of circles. Once again you must put the circles in the positions where you think the vegetarians were sitting. So you will have to recall the positions of the same set of vegetarians twice: immediately after I show them to you, and then again after you have done the reading aloud.

After a short break, we will do the same thing again but for two new groups of people around a table. The groups will be different sizes, and the number of vegetarians you will have to recall will be different for each group. In some cases you will have more vegetarians, and in some cases you will have less. But always, you will be given the right number of circles to place and you will recall their positions immediately after I show them to you, and then again after you have done the reading aloud for five minutes.

Any questions?"

Once the trials have begun the following are phrases to be used as instructions:

"I will now point to the vegetarians. Are you ready? Please remember these positions."

Presentation.

"Please sit here?"

Participant is shown the next seat position, and the direction he/she should take around the table.

Participant is handed the sticky counters.

"Now place the circles in the positions I showed you."

Answer sheet removed. Participant is handed the folder of passages, opened to the correct page (see counterbalancing).

"Please read the passage aloud, at your own speed"

Five minutes by stopwatch.

"Ok, please sit here?"

Participant is shown next seat position as before and handed more counters.

"Please recall the positions of the vegetarians."

Sheet removed and participant is given a short break before the next trial.

APPENDIX 3

**PILOT 1 Data Entry Sheet
(with counterbalancing)**

	ID	Mb	Chair P	Chair IM	Error score	VRI	Chair DR	Error Score
Ss1		13	1	3		1	4	
		15	2	4		2	3	
		17	3	1		3	2	
Ss2		15	2	1		1	4	
		13	4	2		3	3	
		17	1	3		2	2	
Ss3		13	3	2		2	1	
		17	1	4		1	2	
		15	4	1		3	3	
Ss4		17	4	3		2	2	
		13	3	1		3	4	
		15	2	4		1	1	
Ss5		15	1	3		3	4	
		17	2	4		1	3	
		13	3	1		2	2	
Ss6		17	2	1		3	4	
		15	4	2		2	3	
		13	1	3		1	2	

APPENDIX 3
PILOT 2 Data Entry Sheet
(with counterbalancing)

	ID	Test	Chair P	Chair IR	Error score	VRI	Chair DR	Error Score
Ss1		A	1	3		1	4	
		B	2	4		2	3	
		C	3	1		3	2	
		D	4	2		4	1	
Ss2		B	2	1		2	4	
		A	4	2		4	2	
		D	1	3		1	3	
		C	3	4		3	1	
Ss3		C	3	2		2	2	
		D	1	4		1	4	
		A	4	1		3	3	
		B	2	3		4	1	
Ss4		D	4	1		3	2	
		C	3	3		4	4	
		A	2	4		2	1	
		B	1	2		1	3	
Ss5		A	1	3		3	4	
		C	2	4		1	3	
		B	3	1		4	2	
		D	4	2		2	1	
Ss6		C	2	1		4	4	
		B	4	2		3	3	
		D	1	3		2	2	
		A	3	4		1	1	

Notes: A = 1st 9-diners test, B = 2nd 9-diners test, C = 1st 17-diners test, D = 2nd 17-diners test.

APPENDIX 4

Percentage retentions in pilot 1 (spatial).

Participant	13-diners	15-diners	17-diners
1	100	100	100
2	100	60	120*
3	133*	150*	85.71
4	66.67	100	100
5	80	80	100
6	75	100	100

% retention = number of correct responses DR expressed as a percentage of correct responses IR.

Percentage retentions in pilot 2 (spatial).

Ss	9-diner (1)	(2)	17-diner (1)	(2)
1	100	25	120	66.67
2	100	75	100	100
3	66.67	75	100	71.43
4	100	100	100	85.71
5	150	150	100	85.71
6	50	0	100	75

% retention = number of correct responses DR, expressed as a percentage of correct responses IR

APPENDIX 5 (Main study – instructions).

RI in Temporal Lobectomy patients & Controls

PROCEDURE AND INSTRUCTIONS

All Italic and Bold writing is what we should roughly be saying to the participant.

Ask the participant to sit down.

Once he/she has made him/herself comfortable, explain what you'll be asking them to do during the experiment.

You will be asked to perform a number of short memory and attention tasks during the study.

Before each task you will be informed of all the details and procedures. The experiment should last no more than 1.5 hours and you will be given plenty of opportunity to rest as and when you need to.

Are you ready to begin the first part of this experiment?

VERBAL MAIN TASK – WORD LISTS

In this part of the experiment you'll be presented with a word list via speakers in this lab. I would like you to attend well to this list as you will be asked to try and recall as many of the words immediately after the last word has been presented. You can recall these words in any order.

TRIAL 1

Do ***NOT*** say anything more about the trial and experiment at this point!!!

ALL OTHER TRIALS

See Interference task instructions below

→ Play the relevant List (WMA file)

→ Immediate recall

Could you please try and recall as many words from the previous word list please?

<D> 5 minute delay period

→ Delayed recall

Could you please try and recall as many words from the previous word list once more please?

VISUOSPATIAL MAIN TASK – DINNER TABLE

Get main board and counters

In this part of the experiment you'll be presented with a seating plan for a dinner party of 9 people [point to main board]. ***There are 4 vegetarians at the table and I will point out their positions round the table to you. Immediately after showing you these 4 positions I will ask you to sit on another chair and indicate on a blank board the positions of the vegetarians by placing these counters on the board (in any order). Let's do a quick practise trial.***

I'll now point to 2 vegetarians. [POINT TO COUNTER 2 and 7]. ***Then I take away this board. Could you please sit here now*** [point to chair 3]. ***Here are 2 counters. Could you please indicate where the vegetarians are sitting?*** (make sure they understand that they have to recall the original positions irrespective of their new position at the table). Make sure they understand the task 100% before commencing the real trial (i.e. do more practise trials if required).

The main task will be identical to this practise trial, the only difference being that you will have to remember the positions of 4 vegetarians .

TRIAL 1

Do ***NOT*** say anything more at this point!!!

ALL OTHER TRIALS

See Interference task instructions below

Are you ready to begin?

I will now point out the positions of the vegetarians around this table. Please concentrate.

→ Point to the 4 relevant positions

→ Remove Main Board

→ Ask participant to sit on next relevant chair

→ Immediate recall

Could you please try and indicate where the vegetarians are sitting?

→ Remove IM board

<D> 5 minute delay period

→ Ask participant to sit on next relevant chair

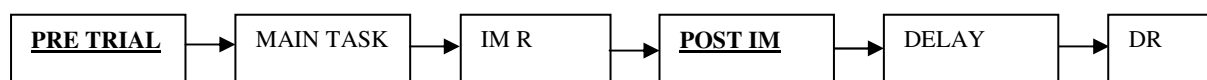
→ Delayed recall

Could you please try and indicate where the vegetarians are sitting once more (hence the last seating arrangement you were presented with)

INTERFERENCE TASKS

PRE TRIAL: The Interference task instructions given before the main task is begun

POST IM: The instructions given after immediate recall, i.e. just before the interference task begins (as a reminder for participants)



MINIMAL INTERFERENCE

PRE Trial

Trial 1

NO mention of delay following IM

Trial 5

Once you have recalled the words/vegetarians you will be asked to rest in the lab for 5 minutes.

POST IM

Trial 1 and 5

Could you please just rest here for a few minutes until I have set up the next task. I'll dim the light a little.

→ 5 min

→ DELAYED RECALL of MAIN TASK

ARTICULATORY SUPPRESSION

PRE Trial

→ Open 20s AS WMA file for practise trial

Once you have recalled the words/vegetarians you will be asked to shadow a person saying 'doe' on the computer. You will hear the person saying 'doe' for a period of 20 seconds, followed by 40 seconds of silence and another 20 seconds of 'doe'. This sequence will go on for a few minutes. Please shadow the person you will hear via these speakers whenever she says 'doe' and be silent when she is silent. [Play the 20s AS WMA file and show them what they have to do, then get them to try it for a few seconds – make sure they know that there will be silent phases and that they have to start shadowing again once the sound starts]. [Make sure the person fully understands this task]. **Don't worry if you miss the first 'doe's as this is not a reaction task. Simply rest until you hear the person say 'doe'** (hence we don't want the participants to be attending to the speakers, waiting for the first doe as this will add an attention factor to the task).

→ Set up the E-Run file 'AS' prior to MAIN TASK

→ Begin relevant **MAIN TASK**

POST IM

Please shadow the person saying 'doe' while she says 'doe' and rest when she is silent.

→ Begin the 'AS' task on E-prime

→ 5 min

→ DELAYED RECALL of MAIN TASK

TAPPING TASK

PRE Trial

→ Open the 20s tapping WMA sound file

Once you have recalled the words/vegetarians you will be asked to tap this board in a triangular formation [show participant the tapping board] to a given tapping speed presented to you via the loudspeakers. You will hear a constant tapping sound for a period of 20 seconds, followed by 40 seconds of silence and another 20 seconds of tapping. This sequence will go on for a few minutes. Please tap whenever you hear the tapping through the loudspeakers and rest when no tapping sound is present. Let's try this. [Play the 20s tapping WMA file and show them what they have to do, then get them to try it for a few seconds – make sure they know that there will be silent phases and that they have to start tapping again once the tapping sound starts]. [Make sure the person fully understands this task – give an example if required]. **Don't worry if you miss the first taps as this is not a reaction task. Simply rest until you hear the tapping sound** (hence we don't want the participants to be attending to the speakers, waiting for the first taps as this will add an attention factor to the task).

→ Set up the E-Run file 'tapping' prior to MAIN TASK

→ Begin relevant

MAIN TASK

POST IM

Please tap the board in a triangular formation at the same speed as the tapping you will hear and rest during the silent periods.

→ Begin the 'tapping' task on E-prime

→ 5 min

→ DELAYED RECALL of MAIN TASK

MAP SEARCH

Get relevant map (i.e. 1 or 2)

The A4 sheets with the search items are labelled 1-6. start with 1 (2,3,4,5,6) for the first map trial and 6 (5,4,3,2,1) for the second map search.

PRE Trial

Once you have recalled the words/vegetarians you will be asked to search for symbols on a map of a fictional town [show participant map]. I will give you a map and an A4 sheet indicating the symbol you should look for on the map. There will be a large number of this symbol. You will be given a pen and asked to circle all of these symbols on the map. Once you have found all symbols please ask for the next map and symbol by TAPPING the table. You will then be given the next map and an A4 sheet with a new symbol, which you will be asked to search for. Should you finish the second search please request a further map by tapping on the table.

Please be thorough when doing the task and try and find all symbols you are asked to find.

→ Set up the E-Run file 'tapping' prior to MAIN TASK

→ Begin relevant **MAIN TASK**

POST IM

Please circle all of the items shown here (point to A4 sheet) on the map. Tap the table when you have finished and you will be given a new map and search item.

→ 5 min

→ DELAYED RECALL of MAIN TASK

READING

Get relevant information sheets (i.e. A or B)

PRE Trial

Once you have recalled the words/vegetarians you will be asked to read aloud a passage of text for a few minutes. Please note that you will not be required to recall any of the information provided in the passage during this experiment. We would simply like you to read this passage.

→ Begin relevant **MAIN TASK**

POST IM

Please now read aloud the following passage of text.

→ 5 min

→ DELAYED RECALL of MAIN TASK

APPENDIX 5 (Main study – Questionnaire)

Questionnaire

Participant initial: _____

(1) Can you tell me a bit about the assessment we just did? What did you have to do?

(2) There were 2 main things you had to remember in this experiment – the position of diners at a round table and words.

a) Please rate the difficulty of each task:

Position of diners:

Very hard hard average easy very easy

b) Words:

Very hard hard average easy very easy

(3) You had to recall the positions of diners/words twice each – immediately and after a delay of 5 minutes.

a) Did you find it easier/harder to recall the diner positions after the delay than immediately after presentation?

b) Did you find it easier/harder to recall the lists after the delay than immediately after presentation?

(4) Please rate the comparable difficulty of the position of diner and word list memory task:

- (a) The 2 tasks were equal in terms of difficulty
- (b) The diner task was harder than the word list task
- (c) The diner task was easier than the word list task

(5) Use of strategy:

(a) Did you use any particular strategy to remember the positions of diners?

Yes/No

If yes, please describe your strategy in detail:

(b) Did you use any particular strategy to remember the words?

Yes/No

If yes, please describe your strategy in detail:

(6) Rehearsal:

(a) Did you try to rehearse the positions of diners in your head during the 5 minute delays?

Yes/No

If yes please explain how you did this.

If yes please indicate the times during which you rehearsed the position of diners:

- (1) when I didn't have to do anything
- (2) When I had to do the tap on the table
- (3) When I had to find objects on the map
- (4) When I had to read

(b) Did you try to rehearse the words in your head during the 5 minute delays?

Yes/No

If yes please explain how you did this.

If yes please indicate the times during which you rehearsed the position of diners:

- (1) when I didn't have to do anything
- (2) When I had to mirror the tape
- (3) When I had to find objects on the map
- (4) When I had to read

7) During the 5 minute intervals you had to do various tasks:

Please rate these in terms of difficulty:

1 very easy, 2 easy, 3 average, 4 hard, 5 very hard

(8) You didn't have to do anything during the 5 minute intervals at the start and at the very end. What did you do during this period?

(9) Did you expect the experimenter to ask you about the first word list after he/she entered the lab again or did this come as a surprise? (please circle one)

expected it

was surprised

Do you have any further comments?

APPENDIX 6 (Main study counterbalancing)

		Stim 1	Stim 1 ID	Chair P	Chair IR	Int 1	Int ID	Chair DR
C1	1	V	1			NI	/	
C1	1	S	1	1	2	NI	/	3
C1	1	V	3			AS	/	
C1	1	S	3	3	4	AS	/	1
C1	1	V	2			V	1	
C1	1	S	2	4	3	V	2	2
C1	1	V	5			S	1	
C1	1	S	5	2	1	S	2	4
C1	1	V	4			NI	/	
C1	1	S	4	1	2	NI	/	3
C2	2	S	1	1	2	NI	/	3
C2	2	V	1			NI	/	
C2	2	S	3	3	4	AS	/	1
C2	2	V	3			AS	/	
C2	2	S	2	4	3	S	1	2
C2	2	V	2			S	2	
C2	2	S	5	2	1	V	1	4
C2	2	V	5			V	2	
C2	2	S	4	1	2	NI	/	3
C2	2	V	4			NI	/	
C3	3	V	2			NI	/	
C3	3	S	2	2	3	NI	/	1
C3	3	V	1			V	1	
C3	3	S	1	4	1	V	2	3
C3	3	V	5			AS	/	
C3	3	S	5	3	4	AS	/	2
C3	3	V	4			S	1	
C3	3	S	4	1	2	S	2	4
C3	3	V	3			NI	/	
C3	3	S	3	2	3	NI	/	1
C4	4	S	2	2	3	NI	/	1
C4	4	V	2			NI	/	
C4	4	S	1	4	1	V	1	3
C4	4	V	1			V	2	
C4	4	S	5	3	4	S	1	2
C4	4	V	5			S	2	
C4	4	S	4	1	2	AS	/	4
C4	4	V	4			AS	/	
C4	4	S	3	2	3	NI	/	1
C4	4	V	3			NI	/	
C5	5	V	3			NI	/	
C5	5	S	3	3	4	NI	/	2
C5	5	V	4			S	1	

C5	5	S	4	2	4	S	2	3
C5	5	V	1			AS	/	
C5	5	S	1	1	3	AS	/	2
C5	5	V	2			V	1	
C5	5	S	2	4	2	V	2	1
C5	5	V	5			NI	/	
C5	5	S	5	3	4	NI	/	2
C6	6	S	3	3	4	NI	/	2
C6	6	V	3			NI	/	
C6	6	S	4	2	4	S	1	3
C6	6	V	4			S	2	
C6	6	S	1	1	3	V	1	2
C6	6	V	1			V	2	
C6	6	S	2	4	2	AS	/	1
C6	6	V	2			AS	/	
C6	6	S	5	3	4	NI	/	2
C6	6	V	5			NI	/	
C7	7	S	4	4	2	NI	/	3
C7	7	V	4			NI	/	
C7	7	S	5	1	3	AS	/	4
C7	7	V	5			AS	/	
C7	7	S	3	2	4	V	2	1
C7	7	V	3			V	1	
C7	7	S	1	3	1	S	2	2
C7	7	V	1			S	1	
C7	7	S	2	4	2	NI	/	3
C7	7	V	2			NI	/	
C8	8	V	4			NI	/	
C8	8	S	4	4	2	NI	/	3
C8	8	V	5			AS	/	
C8	8	S	5	1	3	AS	/	4
C8	8	V	3			S	2	
C8	8	S	3	2	4	S	1	1
C8	8	V	1			V	2	
C8	8	S	1	3	1	V	1	2
C8	8	V	2			NI	/	
C8	8	S	2	4	2	NI	/	3
C9	9	S	5	1	4	NI	/	2
C9	9	V	5			NI	/	
C9	9	S	2	4	3	V	2	1
C9	9	V	2			V	1	
C9	9	S	4	2	1	AS	/	3
C9	9	V	4			AS	/	
C9	9	S	3	3	2	S	2	4
C9	9	V	3			S	1	
C9	9	S	1	1	4	NI	/	2
C9	9	V	1			NI	/	

C10	10	V	5			NI	/	
C10	10	S	5	1	4	NI	/	2
C10	10	V	2			V	2	
C10	10	S	2	4	3	V	1	1
C10	10	V	4			S	2	
C10	10	S	4	2	1	S	1	3
C10	10	V	3			AS	/	
C10	10	S	3	3	2	AS	/	4
C10	10	V	1			NI	/	
C10	10	S	1	1	4	NI	/	2
C11	11	S	1	2	3	NI	/	4
C11	11	V	1			NI	/	
C11	11	S	4	3	2	S	2	1
C11	11	V	4			S	1	
C11	11	S	2	4	1	AS	/	2
C11	11	V	2			AS	/	
C11	11	S	3	1	4	V	2	3
C11	11	V	3			V	1	
C11	11	S	5	2	3	NI	/	4
C11	11	V	5			NI	/	
C12	12	V	1			NI	/	
C12	12	S	1	2	3	NI	/	4
C12	12	V	4			S	2	
C12	12	S	4	3	2	S	1	1
C12	12	V	2			V	2	
C12	12	S	2	4	1	V	1	2
C12	12	V	3			AS	/	
C12	12	S	3	1	4	AS	/	3
C12	12	V	5			NI	/	
C12	12	S	5	2	3	NI	/	4
C13	13	V	1			NI	/	
C13	13	S	1	1	2	NI	/	3
C13	13	V	3			AS	/	
C13	13	S	3	3	4	AS	/	1
C13	13	V	2			V	1	
C13	13	S	2	4	3	V	2	2
C13	13	V	5			S	1	
C13	13	S	5	2	1	S	2	4
C13	13	V	4			NI	/	
C13	13	S	4	1	2	NI	/	3
C14	14	S	1	1	2	NI	/	3
C14	14	V	1			NI	/	
C14	14	S	3	3	4	AS	/	1
C14	14	V	3			AS	/	
C14	14	S	2	4	3	S	1	2
C14	14	V	2			S	2	
C14	14	S	5	2	1	V	1	4
C14	14	V	5			V	2	

C14	14	S	4	1	2	NI	/	3
C14	14	V	4			NI	/	

APPENDIX 7 (Main study – rehearsal summaries)

Nine-diners test: rehearsal during spatial trials

	MI1	MI2	Tapping	Reading	Mapsearch	All
Rehearsed	4	9	4	3	2	2
N	7*	14	14	14	14	14

Table shows number of participants who reported rehearsing during interference conditions.

*Only 50% of participants began the experiment with a spatial trial, therefore N=7.

Rehearsal during verbal trials

	MI1	MI2	AS	Reading	Mapsearch	All
Rehearsed	5	12	7	4	6	2
N	7*	14	14	14	14	14

Table shows number of participants who reported rehearsing during interference conditions.

*Only 50% of participants began the experiment with a verbal trial, therefore N=7.

