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# Implicit Learning in Amnesic Subjects: A Comparison with a Large Group of Normal Control Subjects*

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## ABSTRACT

We assessed 136 normal control subjects and between 12 and 16 amnesic subjects on three tests of indirect memory. The three tests were a perceptual priming test (fragmented pictures), an auditory priming test to determine preference for novel or previously heard melodies (Korean melodies), and a motor skill learning test (mirror tracing). We have established normative data for these tasks and demonstrated that amnesic subjects tend to be poorer than controls in general but show a similar pattern of learning over time.

The past two decades have seen a rapid growth in studies of preserved learning and memory in people with amnesia. These preserved abilities have been demonstrated using "indirect" tests of memory (Hasher & Johnson, 1987). "Indirect" tests are those that can be performed without conscious or deliberate recourse to the learning episode. Examples range from motor skill learning to perceptual priming and mathematical rule learning. (See Richardson-Klavehn & Bjork, 1988, Schacter, 1987 and Tulving & Schacter, 1990 for comprehensive reviews.)

Amnesic subjects may perform well above chance and even within the normal range on "indirect" tests of memory. "Direct" tests, on the other hand, include conventional memory tests such as free recall, cued recall, and forced choice recognition. In order to perform well on these tests, it is necessary to recall the learning episode. Consequently, amnesic subjects typically perform very poorly on such tasks.

The theories put forward to explain this pattern of preserved and impaired performance shown by people with amnesia fall into two main groups: those that suggest a unitary preserved memory system and those that argue for a fractionated system. The unitary system approach suggests that "direct" tests of memory tap the system of memory that is impaired in amnesia and that "indirect" tests tap the system that is preserved. Graf and Schacter (1985) describe the preserved system as "implicit" memory and the impaired system as "explicit" memory.

In contrast to the concept of one single system for preserved learning in amnesia, are the theories that propose the involvement of a number of different systems (e.g., Witherspoon & Moscovitch, 1989). Schacter, Cooper, and Delaney (1990), for example, suggest a perceptual representation system that governs performance on those "indirect" tests of memory involving perceptual priming. Included here would be the perceptual identification of fragmented pictures (Warrington & Weiskrantz, 1968). The system underlying perceptual priming is thought to be

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functionally distinct from the system(s) governing performance on other indirect tests such as pursuit rotor, mirror tracing, and other motor skill tasks.

Despite reports of relatively normal performance on indirect tests of memory by amnesic subjects, some reports are anecdotal and others have compared amnesic subjects to a small group of age-matched controls. As far as we know, no normative data have been collected on a relatively large group of control subjects from the young and middle-age range. Consequently, it is often difficult to know how "normal" is the performance of amnesic subjects on tests of implicit preserved learning.

The present study was designed to answer the question "How do amnesic subjects compare with normal control subjects on 'indirect' tests of memory?".

To answer this question we assessed 136 normal control subjects aged 20 to 55 years from five European countries and 16 amnesic subjects. Because of potential language difficulties, we used only nonverbal tests. The three tests we selected were (a) fragmented pictures (Warrington & Weiskrantz, 1968; Green, 1989; Snodgrass, Smith, Feenan, & Corwin, 1987), (b) Korean Melodies (Johnson, Kim, & Risse, 1985) and (c) mirror tracing (Starch, 1910).

## METHOD

### Fragmented Pictures

Fragmented pictures are pictures that are degraded from a greater to a lesser degree, ranging from whole to very incomplete versions of the picture (see Figure 1). The initial findings of Warrington and Weiskrantz (1968) showed that amnesic subjects showed savings, that is, recognised the pictures earlier in the sequence when these were re-presented a second time despite no episodic memory of having seen the stimuli earlier. Green (1989) found that amnesic subjects showed savings from prior presentation of a whole picture as well as from the fragmented sequences. In the present study, we included both a whole picture condition and a fragmented picture sequence condition to see whether there are different patterns of facilitation among amnesic subjects.

Three sets of items were prepared. Each set consisted of seven line-drawings and each line-drawing comprised eight fragments (taken from Snodgrass et al., 1987), ranging from a whole picture to a very degraded picture (see Figure 1 for an example).

### Korean Melodies

In the Korean melodies task, Johnson et al. (1985) found that both normal controls and amnesic subjects showed a reliable preference for previously presented melodies over novel melodies on an indirect memory test. Performance of the amnesic and control subjects did not differ with regard to preference. In contrast, the amnesic subjects' performance on a direct test (a recognition task) was significantly impaired relative to the normal controls.

In the present study, we wished to determine whether our amnesic subjects showed a similar pattern to that observed by Johnson et al. (1985). We were able to obtain copies of the melodies used by Johnson et al. (1985). They constructed two sets of melodies from segments of Korean music. Each of the two sets contains 12 melodies lasting between 5 and 6 seconds in duration. Each set (A and B) contains 6 targets and 6 foils.

### Mirror-Tracing Task

Mirror tracing is a motor skill task in which subjects are required to trace a pattern (in this case, a star) with a light pen. The star cannot be seen directly by the subject, it can only be viewed through a mirror (see Figure 2). Woodworth and Schlosberg (1954) report that this familiar laboratory experiment yields a large practice effect; they were referring to non-brain-injured subjects. Improvement over time also has been reported in amnesic subjects. Cushman and Caplan (1987), for example, described a 62-year-old woman who developed a marked declarative memory deficit following a stroke in the anterior regions of the left hemisphere. On a mirror-tracing task, however, she improved over a 4-day period and, by the final set of trials, her speed was close to that of a normal control subject. In the present study, we wished to compare the performance of amnesic subjects with a larger group of normal control subjects.

The material for this task was constructed at the Neurological Therapy Centre in Düsseldorf (see Figure 2 for an illustration). Each subject is required to trace the star with a special pen. Time and errors are recorded. The subject cannot directly see the star because of the screen which blocks the view. The star is viewed in the mirror.

### Subjects

*Control Subjects*

One hundred and thirty-six subjects from nine centres in five European countries were selected. All were between the ages of 20 and 55 years. None had any history of neurological disease.

Fig.

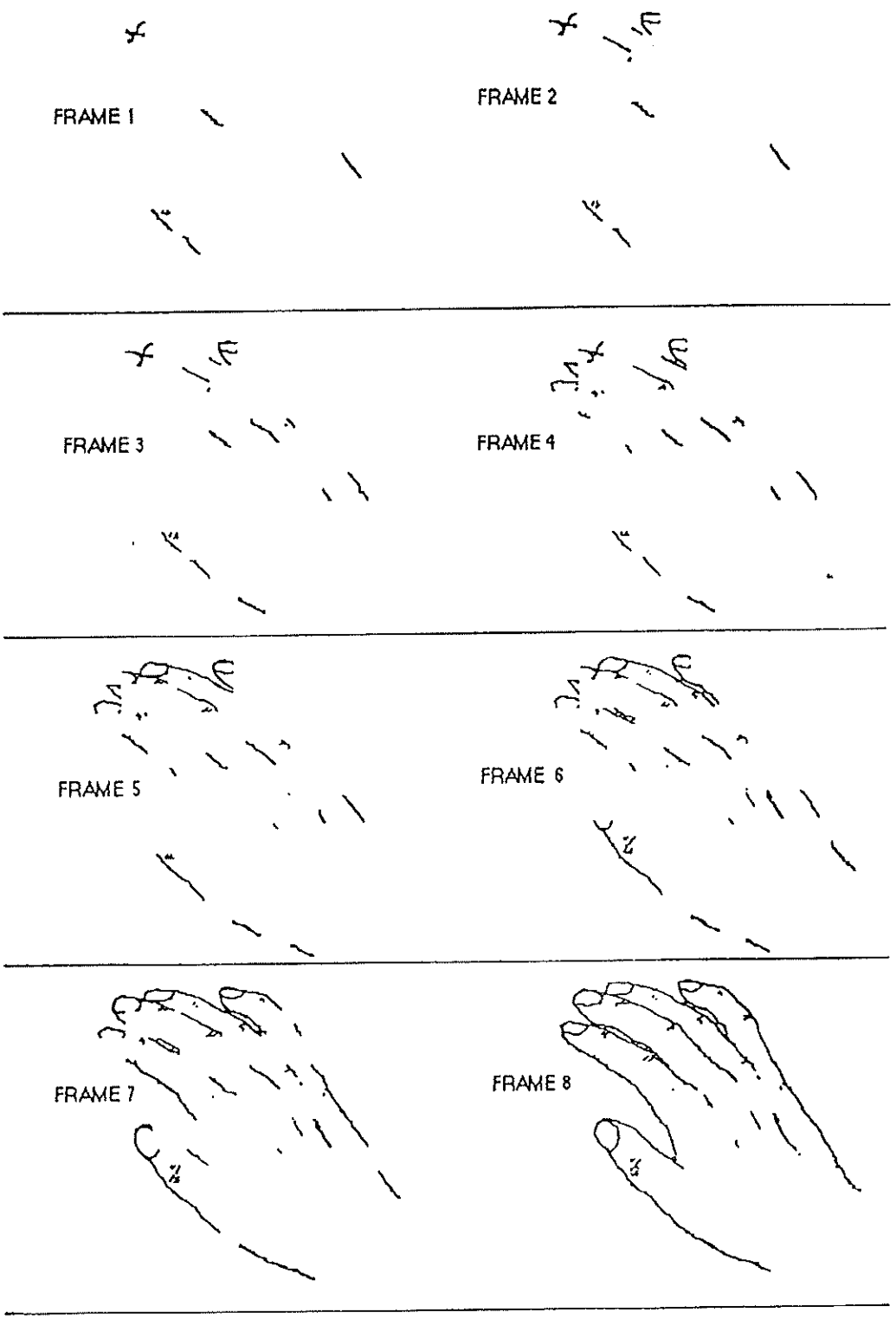


Fig. 1. Example of stimuli: One series of fragmented pictures.

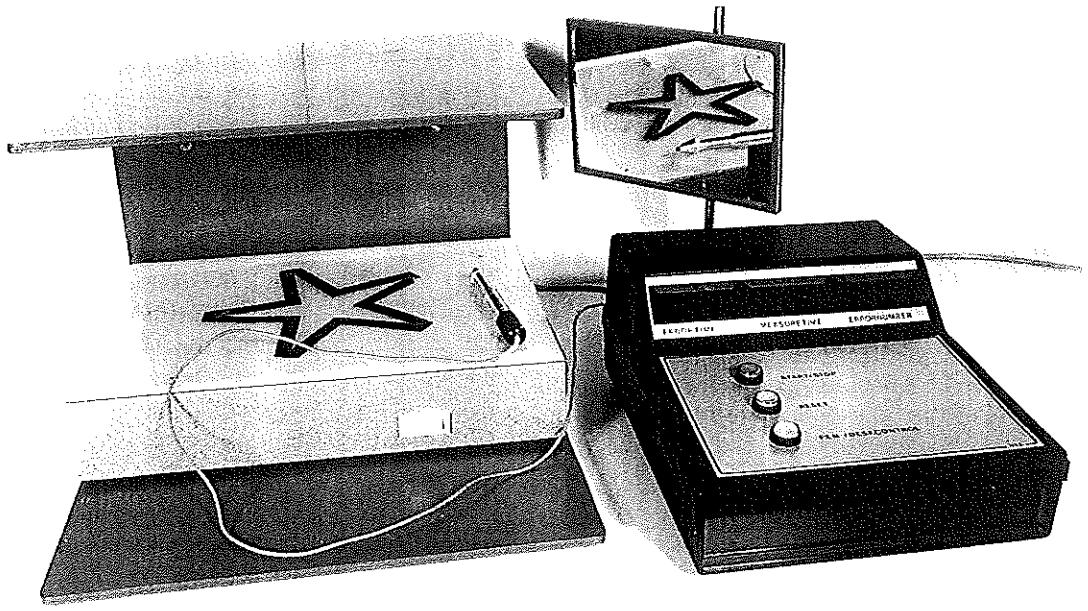

Fig. 2. The equipment for the mirror-tracing task.

*Amnesic Subjects*

There were 16 subjects with an age range of 24 to 75 years. Diagnoses included Korsakoff's syndrome, cerebral vascular accident, encephalitis, anoxia, and head injury. There were missing data from 2 subjects on the fragmented pictures task and from 4 subjects on the mirror-tracing task. Our operational definition of amnesia was a screening score of 5 or less on the Rivermead Behavioural Memory Test (Wilson, Cockburn, & Baddeley, 1985) because the cut-off point for memory impairment is 6. Normal control subjects score at least 10 of a maximum of 12 points.

Amensic subjects were also required to fulfil the following criteria: (a) a normal immediate memory span as assessed by forward digit span; (b) a normal visual span as assessed by the forward tapping task on the Wechsler Memory Scale - Revised (Wechsler, 1981); (c) a score in the normal range on the Ravens Standard Progressive Matrices (Raven, 1960); (d) normal performance on the Gottschaldt embedded figures test (Gottschaldt, 1928); (e) no evidence of naming deficits when assessed by a frequently used naming test for the country and (f) no major motor or sensory deficits.

Table 1 presents basic demographic and data for the amnesic and control groups.

## Procedure

*Fragmented Pictures*

Following a brief practice, each subject was tested under two experimental conditions and one baseline condition. Experimental Condition 1 consisted of the presentation of seven sequences of Gollin Figures at study and the re-presentation of the same seven sequences at test. Experimental Condition 2 comprised the presentation of seven intact pictures at study and the Gollin Figures version of those seven intact pictures at test. Condition 3, the baseline condition, consisted of seven sequences of Gollin Figures at test, with no corresponding pictures having been presented at study. All subjects performed all conditions within the same testing session. The presentation of whole pictures and fragmented picture sequences was randomised and interleaved. The presentation of each fragmented sequence involved the consecutive presentation of picture fragments until the object was identified, at which point the presentation of the series stopped. During the sequences, subjects were encouraged to guess what the object might be.

Testing took place after approximately 1 hr. Subjects were told that they would see sequences of visually degraded objects on index cards, and that each sequence would begin with a few lines and gradually build up to a complete picture. Their task was to try to identify the object as early as possible in the sequence. Once again, they were encouraged to guess. Subjects were then presented with all 21 sequences of fragmented pictures seven of which had been previously presented in the same form during the study phase, seven of which had been previously presented as intact pictures during the study phase, and seven of

Table 1. Demographic Characteristics of Amnesic Subjects and Control Subjects.

| | | *Amnesic Subjects* | *Control Subjects* |
|---|---|---|---|
| Mean age(SD) | | 45.9 (12.5) | 35.9 (10.0) |
| Sex | Male/Female | 10/6 | 69/67 |
| Country | Belgium | 5 | 10 |
| | Denmark | 0 | 6 |
| | Germany | 7 | 71 |
| | Italy | 2 | 20 |
| | United Kingdom | 2 | 29 |
| | Total | 16 | 136 |
| Type of Injury | Anoxia | 5 | |
| | Aneurysm | 4 | |
| | Head Injury | 3 | |
| | Korsakoffs | 2 | |
| | Thalamic Infarct | 1 | |
| | Encephalitis | 1 | |

which were new (i.e., they had not been presented previously).

Each sequence was scored 1-7, determined by the number of fragmented pictures required for identification, with 1 being the most fragmented and 7 being the least fragmented, that is, the final degraded picture before the whole picture.

*Korean Melodies*

Each subject performed an indirect and a direct version of the melody learning task. The indirect tests always preceded the direct tests. For the indirect test, six melodies were presented at study and the same six were re-presented along with six foils at test. For the direct test of memory, the item set not used in the indirect test was used. Again, six melodies were presented in the study phase and the same six were represented at test along with six foils.

The study and test phases of the indirect test of memory were conducted completely independently of the study and test phases of the direct test of memory. There was a 1-hr filled-delay separating the end of the indirect test and the start of the direct test.

*Study Phase* (for Indirect Test of Memory only). Each subject was presented with short Korean melodies one at a time from a tape recorder. Two of the melodies were presented 10 times each; two of the melodies were presented five times each, and two of the melodies were presented once each. Thus, there were 32 presentations of melodies in total, and the order of presentation was randomised. After each melody was heard, there was a pause of approximately 5 s during which time subjects indicated whether a melody sounded "Far Eastern" or "Western." Subjects were told that they did not require any knowledge of music in order to make this decision, and that the decision was meant to be a subjective one--there was no objectively correct answer.

*Test Phase* (for Indirect Test of Memory only). After a delay of either 1 min or 5 min, the test phase for the indirect test began. Subjects received one of two delays, both of which were intended to exceed the temporal limits of short-term memory. The purpose was to identify any potentially existing differences in forgetting rates among people with amnesia. Subjects were presented with melodies one at a time, and their task was simply to decide how much they liked or disliked each melody. They were to indicate their decision during a short pause (approximately 5 s) after each presentation by pointing to one of five points on a rating scale. The 5-point scale ranged from "like a lot" to "no opinion" to "dislike a lot." During this phase, no reference was made to the prior occurrence of a study phase.

*Measure of retention.* Retention of melodies was indicated by a preference for the previously presented melodies over the new melodies.

*Study Phase* (for Direct Test of Memory only). The study phase for the recognition task followed a delay of 1 hr. This was identical to the study phase for the indirect test (see *study phase*).

*Test Phase* (for Direct Test of Memory only). After a delay of 1 min or 5 min (the same delay as that used for the indirect test), the test phase for the direct memory test began. Subjects were presented with melodies one at a time. Following each presentation, subjects determined whether or not that melody was presented

during the study phase. They indicated this decision during a short pause (approximately 5 s again) by pointing to a card with the choices written on it: "heard before" / "did not hear before". After this decision was made, the subject gave a confidence rating on a 3-point scale: "Very sure", "Pretty sure", "Guessing".

*Measure of retention.* Retention of melodies was indicated by the subject's correct recognition of previously presented melodies and correct rejection of melodies not previously presented. The scores were also weighted for confidence. For example, a correct recognition and a confidence rating of "Very sure" was weighted more heavily than a correct recognition and a confidence rating of "Pretty sure." Thus, the score ranged from 1 to 6, where 1 corresponded to an incorrect response rated as "Very sure" and 6 to a correct response rated as "Very sure."

*Mirror-Tracing*

We used a photoelectric recording that enabled us to measure the time taken to trace a start as well as the number and duration of errors. The device consisted of a light pen, light desk, mirror, sight-protection screen, and control desk and plastic sheet containing a 5-pointed star (see Figure 2). Slight pressure of the light pen on the target caused the clock to start. An error was defined as the light pen leaving the black edge of the target zone. The error was terminated when the pen re-entered the black zone.

There was one practice trial followed by 22 scored trials. The first 10 scored trials were the initial learning trials. Following a 30-min delay, there were 10 further trials (the relearning trials). After a second delay of about 2 min, during which time the star was repositioned, the final two trials were completed. For the practice trial and the learning trials, the 'target' was positioned on the lightdesk with one point of the start at the top (away from subject) and two points at the bottom nearer to the subject. The starting point was furthest away from the subject. The experimenter demonstrated the task and emphasised that: (1) the subject should view his/her hand and pen in the mirror and should not attempt to look directly at the hand or the pen; (2) the subject should trace the star clockwise as quickly as possible and make as few errors as possible; and (3) if the pen left the path of the target, the subject should re-enter at the point s/he left the target zone.

All subjects were given one practice trial which was not scored. This was followed by a reminder from the experimenter about task requirements. Then, the relearning trials began. The trials were identical to the earlier trials except that the practice trial was omitted.

For the final two trials, in order to test for generalisation of skill, the star was repositioned by rotating it 180° so that now there were two points at the top and one at the bottom. The starting point was the top of the right hand point.

*Statistical Tests*

In view of the skewed distributions obtained from many of the measures, particularly among the amnesic subjects, we adopted nonparametric statistical tests throughout. Two-tailed comparisons were made with significance level (alpha) set to 0.05.

## RESULTS

### Fragmented Pictures

As can be seen from Table 2, amnesic subjects were significantly poorer than control subjects at identification of the fragmented sequences in each condition. Nevertheless, they found Condition 1 (fragmented picture sequences at both study and test) significantly easier than Condition 2 (whole picture at study with fragmented sequences at test). This, in turn, was superior to Condition 3 where there was no prior exposure. Control subjects showed the same pattern, with Condition 1 superior to Condition 2 which, in turn, was superior to Condition 3.

Figure 3 shows centile distributions for the three conditions separately for the amnesic and control subjects. It can be seen that there is comparatively little overlap between the two groups in the two conditions where the pictures had been seen previously.

In order to partial out differences in the baseline performance (i.e., performance on the condition without prior exposure) of amnesic subjects and controls, a derived score was obtained using a formula developed by Green (1992) that takes into account the fact that different starting points permit different amounts to be learned. These results, which can be seen in Table 3, provide confirmation that both amnesic and control subjects showed significantly stronger priming from prior exposure to the fragmented pictures than from prior exposure to the whole picture. In both conditions, the control subjects showed significantly greater gains, relative to their baseline, than did the amnesic subjects.

Table 2. Median Scores* (Maximum 7) of Amnesic Subjects and Control Subjects on Three Conditions of the Fragmented Pictures Task.

| | *Condition 1* (Fragmented picture sequences presented at study and re-presented after a delay) | *Condition 2* (Whole picture presented at study and fragmented picture sequences after a delay) | *Condition 3* (No prior exposure. Fragmented sequences presented once only) | |
|---|---|---|---|---|
| | Median | Median | Median | *p* values† |
| Amnesic Subjects | 4.86 | 5.43 | 5.86 | 1 v 2 = .033<br>1 v 3 = .002<br>2 v 3 = .016 |
| Control Subjects | 2.43 | 3.71 | 4.86 | 1 v 2 = .001<br>1 v 3 = .001<br>2 v 3 = .001 |
| Amnesic versus Control Subjects‡ | $p < .01$ | $p < .01$ | $p < .01$ | |

* Score = the number of fragmented pictures required for identification with 1 = most degraded and 7 = least degraded; † Wilcoxon Matched-Pairs Signed-Ranks test; ‡ Mann-Whitney U test

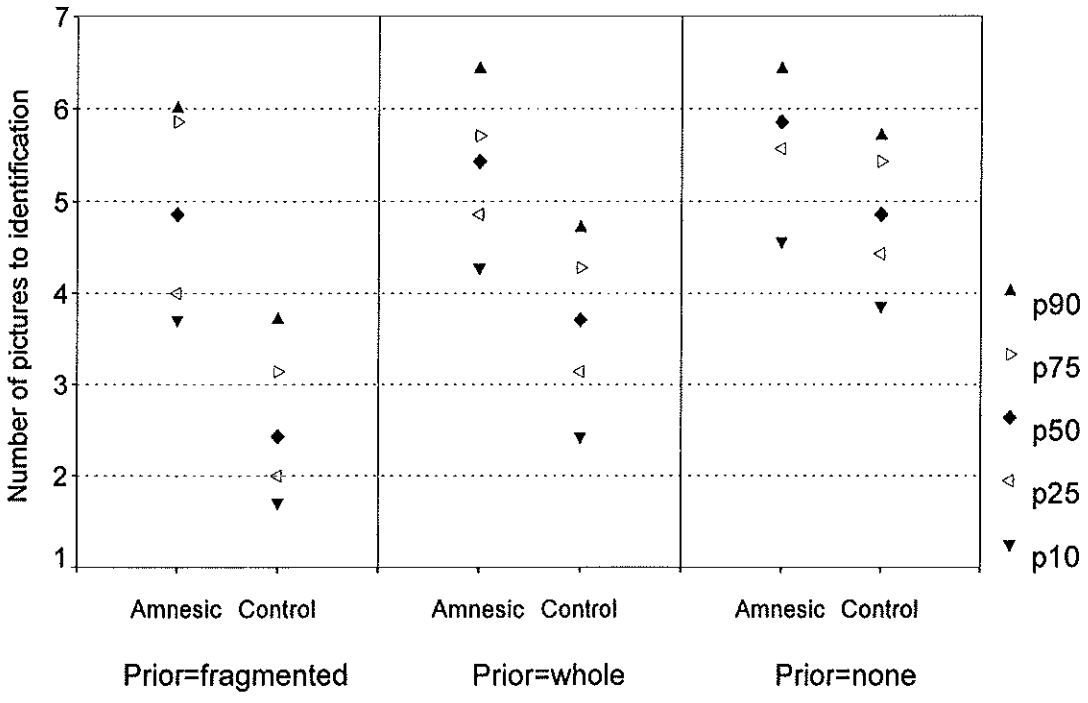


Fig. 3. Percentile distribution of amnesic and control subjects on fragmented pictures under three conditions (see text for explanation).

Table 3. Derived Scores (Maximum 100) of Amnesic and Control Subjects on Fragmented Picture Condition over Baseline Compared with Whole Picture Condition over Baseline.

| | Fragmented Pictures | Whole Pictures | |
|---|---|---|---|
| | Median | Median | *p* values† |
| Amnesic Subjects | 14 | 9 | .028 |
| Control Subjects | 61 | 27 | .000 |
| *p* values‡ | .000 | .000 | |

† Wilcoxon Matched-Pairs Signed-Ranks test; ‡Mann-Whitney U test.

### Korean Melodies

We successfully replicated the findings of Johnson et al. (1985) in that (a) there was no difference between amnesic subjects and controls on the preference ratings and both groups showed the expected preference for 'old' melodies over 'new' ones (indirect learning) and (b) there was a significant difference between the two groups on the recognition trial (direct learning), although only for 'new' melodies (see Table 4).

Figure 4 shows the centile point distributions for the preference and recognition tasks for the amnesic and control subjects. It can be seen that there is an almost complete overlap between the two groups in the preference conditions.

### Mirror Tracing

The number of subjects for whom data were available on this task was 110 controls and 12 amnesic subjects because not every researcher was able to complete testing with every subject due to time constraints. The median times for the amnesics were longer than for the controls at every trial and they also made more errors, defined as the light pen leaving the edge of the target zone . These results can be seen in Figures 5 and 6.

The pattern of learning over time, however, was similar, with both groups showing a significant decrease in the time taken to complete the mirror-tracing task between trials 1 and 10, 1 and 20, 1 and 21, and 1 and 22. These results are summarised in Table 5, and Figure 7 shows the corresponding percentile point distribution points for trials 1, 10, 20, 21, and 22.

All but one of the amnesic subjects showed evidence of (a) learning over trials (Table 6 shows the difference between trial 1 and trial 20), and (b) generalisation when the star was rotated. Seven of the 12 improved during the 30-min delay between trials 10 and 11. The percentage of change over trials can be seen in Table 6.

Table 4. Differences between Amnesic Subjects and Control Subjects on the Preference* and Recognition Conditions (Number Correct) of the Korean Melodies Task.

| | Preference | | | Recognition | | |
|---|---|---|---|---|---|---|
| | Old | New | | Old | New | |
| | Median | Median | *p* values† | Median | Median | *p* values† |
| Amnesic Subjects | 3.59 | 3.00 | .051 | 4.50 | 4.05 | n.s. |
| Control Subjects | 3.67 | 3.17 | < .001 | 4.83 | 4.92 | n.s. |
| Amnesic versus Control Subjects‡ | n.s. | n.s. | | n.s. | < .001 | |

* Preference = subjects rate on a scale of 1-5 how much they like the one they have already heard; † Wilcoxon Matched-Pairs Signed-Ranks test; ‡ Mann-Whitney U test

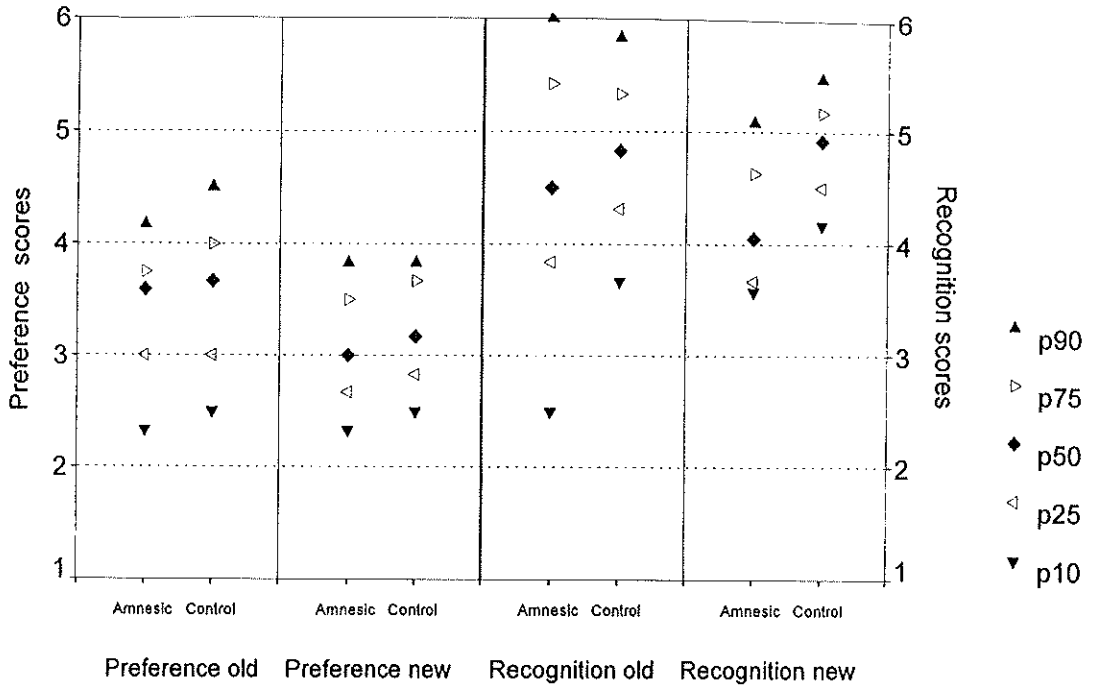


Fig. 4. Percentile distribution of amnesic and control subjects on Korean Melodies under indirect (preference) and direct (recognition) conditions.

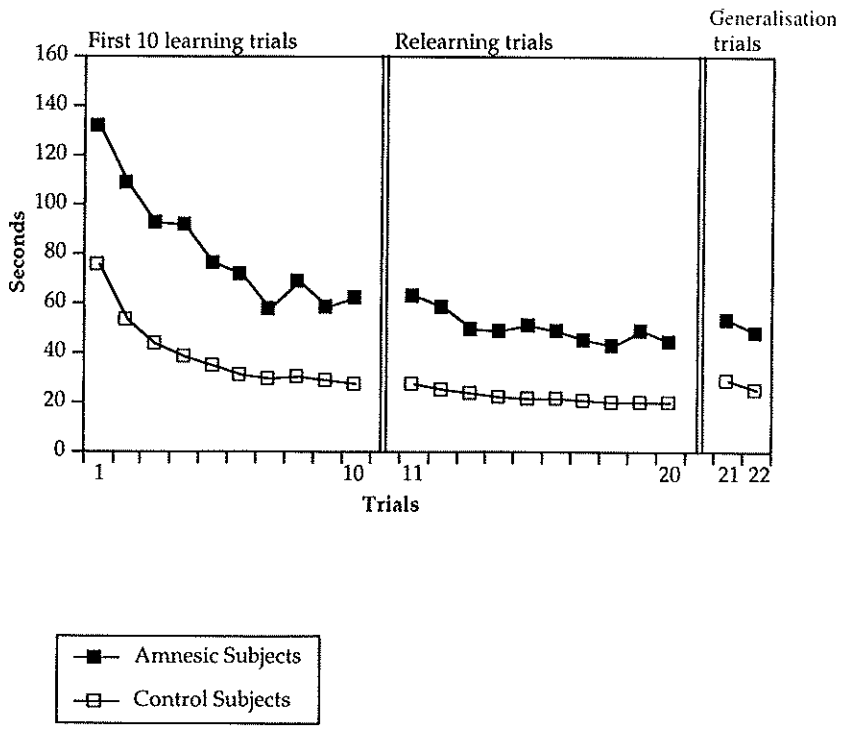


Fig. 5. Mean time (seconds) for amnesic subjects and control subjects on each trial of mirror-tracing task.

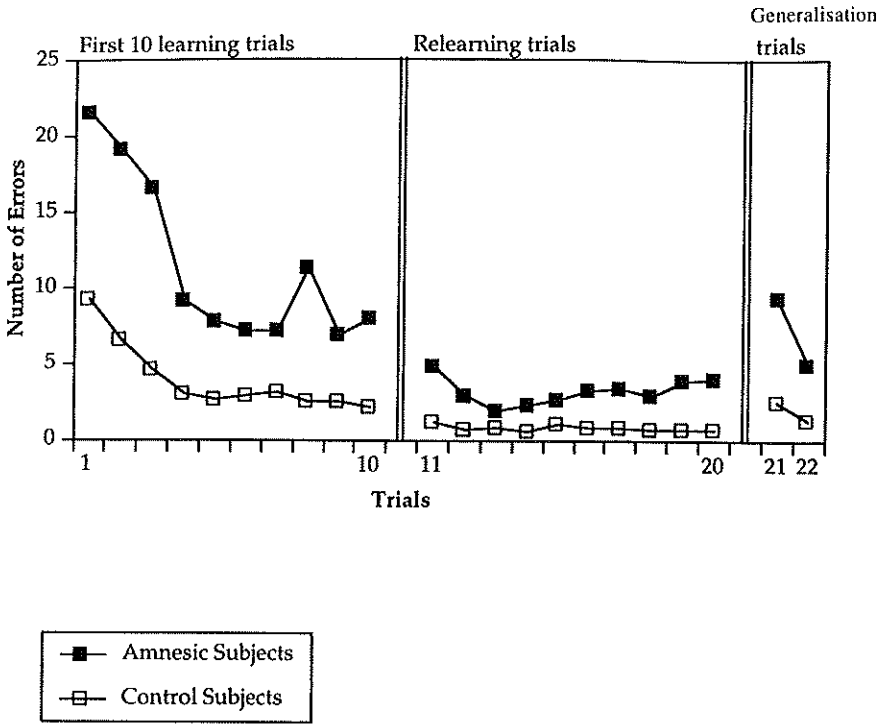


Fig. 6. Number of errors for amnesic subjects and control subjects on each trial of mirror-tracing task.

### Dissociations among Amnesic Subjects

Using a cut-off point of two standard deviations below the mean for the control subjects, amnesic subjects showed differing patterns of performance on the three implicit memory tests. Some exhibited normal (or relatively normal) performance on one task, some on two, and some on three. These dissociations, which are shown in

Table 5. Mirror-Tracing Task: Median Time in Seconds for Amnesic Subjects and Control Subjects.

| | Median Time Trial 1 | Median Time Trial 10 | | Median Time Trial 20 | | Median Time Trial 21 | Median Time Trial 22 | Difference† |
|---|---|---|---|---|---|---|---|---|
| Amnesic Subjects | 131.9 | 61.7 | 30 min delay | 44.3 | 2 min delay and reorientation of stimulus (generalisation) | 53.0 | 47.7 | 1 v 10 = .005<br>1 v 20 = .004<br>1 v 21 = .041<br>1 v 22 = .002 |
| Control Subjects | 75.4 | 26.8 | | 19.7 | | 28.3 | 24.8 | < .001 for all comparisons |
| Amnesic versus Control Subjects‡ | < .001 | < .001 | | < .001 | | < .001 | < .001 | |

† Wilcoxon Matched-Pairs Signed-Ranks test; ‡ Mann-Whitney U test.

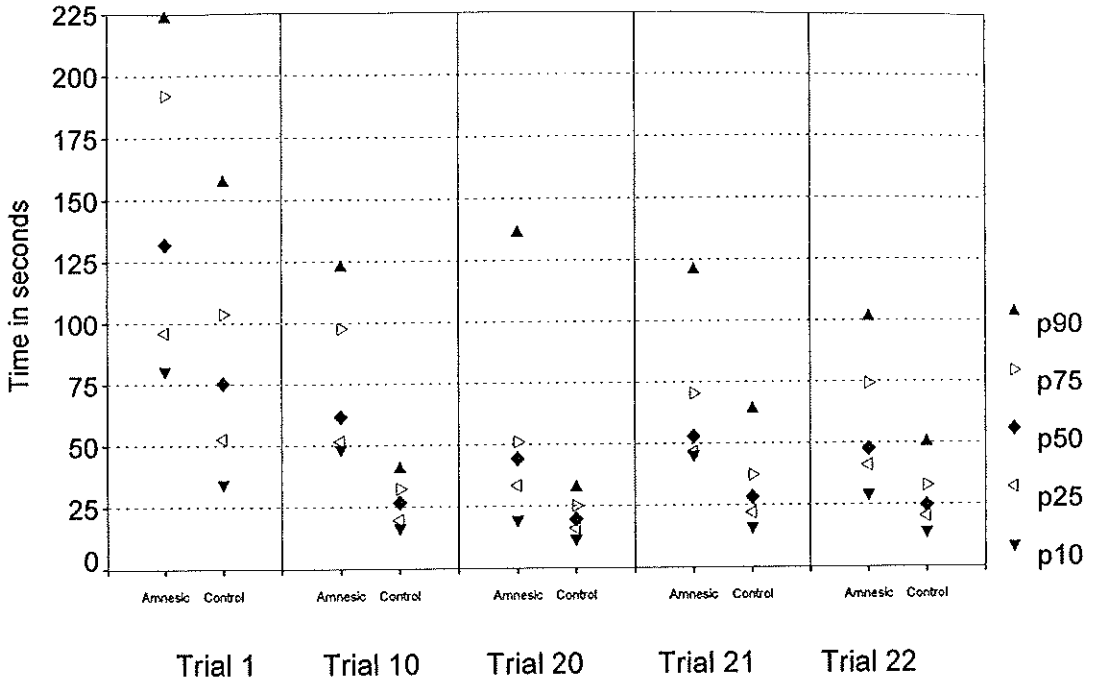


Fig. 7. Percentile distribution of amnesic and control subjects on mirror tracing trials 1, 10, 20, 21, and 22.

Table 6. Mirror-Tracing Task: Percentage Change (to nearest whole number) for each Amnesic Subject in Comparison to the Mean Percentage Change for Control Subjects.

| | | | Total Learning Change from Trial 1 - Trial 20 | Generalisation Trial 1 - Trial 21 | Forgetting Trial 10 -11 |
|---|---|---|---|---|---|
| Mean for Control Subjects | | | 77 | 63 | 7 |
| Amnesic Subjects | *Sex* | *Age* (years) | | | |
| 1 | Male | 75 | 16 | -125 | 81 |
| 2 | Male | 61 | 70 | 51 | +45 (improved) |
| 3 | Male | 50 | 80 | 77 | 2 |
| 4 | Male | 49 | 73 | 69 | +21 (improved) |
| 5 | Male | 48 | 71 | 67 | +20 (improved) |
| 6 | Male | 46 | 29 | 32 | 13 |
| 7 | Male | 34 | -29 | -15 | +10 (improved) |
| 8 | Male | 32 | 81 | 51 | +33 (improved) |
| 9 | Male | 26 | 67 | 59 | 22 |
| 10 | Female | 52 | 58 | 42 | 31 |
| 11 | Female | 48 | 57 | 49 | +22 (improved) |
| 12 | Female | 43 | 86 | 75 | +15 (improved) |

Table 7, suggest that implicit learning is not dependent on a unitary preserved memory system but can be fractionated.

## DISCUSSION

We report on the performance of a group of control subjects and a group of amnesic subjects on three tests of indirect learning. We wanted to establish normal performance on these tasks in order to determine whether amnesic subjects perform normally on these tasks, as is widely believed.

As a group, amnesic subjects are poorer than control subjects on the initial identification of fragmented pictures and on the amount of savings shown when the fragmented sequences are re-shown after a delay. Nevertheless, amnesic subjects do show savings in that they score significantly better at identification of pictures that they have been shown previously than of pictures without prior exposure. Despite the overall improvement, not every amnesic subject performed normally in comparison to a non-brain-injury control group, with only 9/16 (56%) performing within 2 SD of the mean score of the normal control group. The most likely reason for the difference is that the fragmented pictures task is not "process pure," that is, subjects are probably using both implicit and explicit memory which puts the amnesic subjects at a disadvantage in comparison to the control subjects.

This is less likely to happen with the Korean melodies preference task, which is probably a purer test of implicit memory in that it is difficult to recall explicitly the individual melodies. Indeed, the amnesic subjects were similar to controls on this test and there was no significance between the two groups, although both groups showed significant implicit learning in preferring the "old" melodies to the "new." Our results were very similar to those obtained by Johnson et al. (1985), so we can consider ours to be a successful replication of the original experiment.

On the mirror-tracing task we found that 9 out of 12 (75%) amnesic subjects performed within

Table 7. Pattern of Performance of 16 Amnesic Subjects on Three Implicit Memory Tasks.

| S | Sex | Age (years) | Diagnosis | Fragmented Pictures (Savings Measures) | Korean Melodies (Preference) | Mirror-Tracing (Time) |
|---|---|---|---|---|---|---|
| 1 | Male | 75 | Thalamic infarction | ✗ | ✓ | ✗ |
| 2 | Male | 61 | Hypoxia | ✓ | ✓ | ✓ |
| 3 | Male | 50 | Hypoxia | ✓ | ✓ | ✓ |
| 4 | Male | 49 | Hypoxia | ✗ | ✗ | ✓ |
| 5 | Male | 48 | Korsakoffs | ✓ | ✓ | ✗/✓ |
| 6 | Male | 46 | Hypoxia | ✗ | ✗ | ✗ |
| 7 | Male | 34 | Head Injury | ✗ | ✓ | ✗ |
| 8 | Male | 32 | Head Injury | ✓ | ✓ | ✓ |
| 9 | Male | 26 | Aneurysm | ✓ | ✓ | ✓ |
| 10 | Female | 52 | Head Injury | ✓ | ✗ | ✗/✓ |
| 11 | Female | 48 | Hypoxia | ✓ | ✓ | ✓ |
| 12 | Female | 43 | Korsakoffs | ✗ | ✗ | ✓ |
| 13 | Female | 53 | Aneurysm | ✓ | ✗ | NT |
| 14 | Female | 41 | Encephalitis | ✓ | ✓ | NT |
| 15 | Female | 60 | Aneurysm | ✗ | ✓ | NT |
| 16 | Female | 29 | Aneurysm | ✗ | ✓ | NT |

*Note.* ✓ = normal performance (within 2 SDs of control mean); ✗/✓ = borderline performance (close to 2 SDs of control mean); ✗ = impaired performance (well outside 2 SDs of control mean; NT = not tested.

the normal range, although two of these performed just on the cut-off point of 2 SD. This task, too, is likely to be more "process pure." One difference noticed here was the tendency of amnesic subjects to improve after the 30-min delay, perhaps because of a build-up of inhibition over the first 10 trials that proceeded with very little delay between each trial. So, once again, amnesic subjects as a group, show relatively normal learning over time but, in general, perform slower throughout.

We can conclude that, for all three indirect memory tasks, amnesic subjects tend to perform more poorly than control subjects although they show a relatively normal pattern of learning. Although we made every effort to include subjects with no general intellectual impairments and a pure amnesic syndrome, we have to accept that these subjects are neurologically impaired and have sustained brain damage, so it is not surprising to find many of them perform at lower levels than do their neurologically intact peers.

We suggest that these results can be used clinically if people have access to the same materials. Our control group appears to be representative of 20- to 55-year-old subjects. No marked age or sex differences appear across this age range. The tasks seem to be appropriate for people of different European cultural backgrounds because all tasks are nonverbal. Furthermore, we anticipate no problems in administering the tasks to people of non-European origin given that (a) the drawings used in the fragmented pictures task are of common and familiar objects, (b) the Korean melodies are simply short snatches of melody that could be administered to people of non-Western cultures by asking them to decide whether the melody is Eastern or Western or local to the area or not local, and (c) the mirror-tracing task simply requires a visuomotor response to a familiar geometric shape.

Although, at first sight, the amnesic group appears small, it can be argued that 16 (or even 12) people with a pure amnesic syndrome is a reasonable cohort and few studies report numbers of this size. We ensured, as far as possible, that no amnesic subjects had additional cognitive deficits. Given that these subjects were representative of referrals to clinical neuropsychologists working in the different countries, our clinical group is likely to be representative of amnesic people in general. Nevertheless, we would hope that others would replicate and confirm our findings. In particular, it would be helpful to determine if these findings hold up with a group of memory-impaired patients who exhibit more widespread cognitive impairments such as those seen following traumatic brain injury or other diffuse brain damage.

The dissociation among amnesic subjects is interesting and difficult to interpret. Why do some patients find one implicit task relatively easy and another difficult? Examining the results from Table 7, we can see that 11 amnesic subjects scored within 2 SDs of controls on Korean melodies, 9 on fragmented pictures, and 7 on mirror tracing. There does not appear to be a relationship with diagnosis, age, or sex. Nor can these results be explained by naming deficit because good naming skills was one of the inclusion criteria. It is possible that, if one were to look at the extent and severity of each patient's lesion, this would throw light on the matter. To do this, one would need good imaging techniques and those with access to these techniques would, perhaps, undertake such an investigation.

Finally, returning to the two theoretical views of implicit memory, that is, whether it is a unitary system or a fractionated system, our results tend to suggest a fractionated system, because we found dissociations between all three tasks in our amnesic subjects. We hope to see other studies which replicate and extend our findings in order to address this issue.

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